Assessment of the Impacts of Selected Extreme Climatic Events on the Marine Fisheries along Kerala and Tamil Nadu Coast

by

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THESIS

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DECLARATION

I, Punya, P. (2014 – 20 – 105) hereby declare that this thesis entitled **"Assessment of the Impacts of Selected Extreme Climatic Events on the Marine Fisheries along Kerala and Tamil Nadu Coast"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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SYMBOLS AND ABBREVATIONS

AR5	Fifth Assessment Report
CF_N	Month wise 10 year average catfish landings
CHL_N	Month wise 10 year average Chlorophyll concentration
Chl-*a*	Chlorophyll-*a* concentration
CKS_N	Month wise 10 year average croker landings
CMFRI	Central Marine Fisheries Research Institute
CPUE	Catch per Unit Effort
CRB_N	Month wise 10 year average crab catch
DCM	Degree Cooling Month
DHM	Degree Heating Month
DMI	Dipole Mode Index
EEZs	Exclusive Economic Zones
EOF	Empirical Orthogonal Function
ESRL	Earth System Research Laboratory
ESSO	Earth system science organization
FAO	Food and Agriculture Organization
FRP	Fibre-reinforced plastic
GCOS	Global Climate Observing System
GIS	Geographical Information System
GODAS	Global Ocean Data Assimilation System
IM_N	Month wise 10 year average Indian mackerel landing
IMD	India Meteorological Department
IMF	International Monetary Fund
INCOIS	Indian National Centre for Ocean Information Services
INR	Indian Rupees
IOD	Indian Ocean Dipole
IPCC	Intergovermental Panel on Climate Change
JPL	Jet Propulsion Laboratory
LTA	Local Temperature Anomalies
LTA_M_N	Month wise 10 year average Local temperature anomaly
MDTN	Multi day trawl net

MEI	Multivariate El Niño/Southern Oscillation index
MGN	Mechanized gillnet
MHL	Mechanized hook and lines
MODIS	Moderate Resolution Imaging Spectroradiometer
MOTHS	Mechanized other gears
MPS	Mechanized purse seine
MRS	Mechanized ring seine
MTN	Mechanized trawl net
N_NM_CPUE	Month wise 10 year average catch per unit effort of Non motorized craft
N_OBBN_CPUE	Month wise 10 year average catch per unit effort of Outboard boat seine
N_OBBS_CPUE	Month wise 10 year average catch per unit effort of Outboard bag seine
N_OBGN_CPUE	Month wise 10 year average catch per unit effort of Outboard gill net
N_OBHL_CPUE	Month wise 10 year average catch per unit effort of Outboard hook and line
N_OBRS_CPUE	Month wise 10 year average catch per unit effort of Outboard ring seine
N_OBSS_CPUE	Month wise 10 year average catch per unit effort of Outboard shore seine
N_OBTN_CPUE	Month wise 10 year average catch per unit effort of Outboard trawl net
NetCDF	network Common Data Form
NM	Non-motorizedcraft
NMFDC	National Marine Fisheries Data Centre
NOAA	National Oceanic and Atmospheric Administration
OBBN	Outboard bag net
OBBS	Outboard boat seine
OBDOL	Outboard dol net
OBGN	Outboard gill net
OBHL	Outboard hook and lines
OBOTHS	Outboard other gears
OBPS	Outboard purse seine
OBRS	Outboard ring seine
OBSS	Outboard shore seine
OBTN	Outboard trawl net
OC-CCI	Ocean Colour Climate Change Initiative

OGD	Open Government Data
OLR	Outgoing long wave radiation
OS_N	Month wise 10 year average oil sardine landing
OSCAR	Ocean Surface Current Analysis Real-time
OTS_N	Month wise 10 year average other sardine landing
PCA	Principal Component Analysis
PDNA	Post-Disaster Needs Assessment
PO.DAAC	Physical Oceanography Distributed Active Archive Centre
PP_N	Month wise 10 year average Penaeid prawn landing
PRIMER	Plymouth Routines In Multivariate Ecological Research
PSD	Physical Science Division
RF_N	Month wise 10 year average Rainfall
SALT_N	Month wise 10 year average sea surface salinity
SC_N	Month wise 10 year average scad landing
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SIF	South India Flood
SIMPER	Similarity Percentages
SLP	Sea level pressure
SODA	Simple Ocean Data Assimilation Ocean/Sea ice Reanalysis
SP_N	Month wise 10 year average silver pomfret landings
SSHA	Sea Surface Height Anomaly
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
SST_N	Month wise 10 year average Sea Surface Temperature
STL_N	Month wise 10 year average *Stolephorous* landing
SVB_N	Month wise 10 year average silverbellies landing
THR_N	Month wise 10 year average *Thryssa* landing
TN	Tamil Nadu
TOT_N	Month wise 10 year average Total catch
TSS	Total Suspended Solids
VSCS	Very severe cyclonic storm
WG-SP	Working Group on Surface Pressure
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

The Fifth Assessment Report (AR5) of the Intergovermental Panel on Climate Change (IPCC) has stated that human influence on climate is evident and the increased emissions from anthropogenic activities are exacerbating the impacts of climate change on human populations and ecosystems (IPCC, 2014). One of the major impacts is the increase in the frequency and intensity of extreme events across the globe (IPCC, 2012).

An extreme event is generally defined as the occurrence of a weather or climate variable above or below a threshold value near the upper or lower ends of the range of observed values of the variable (IPCC, 2012). In some cases, a weather or climate event may not qualify as an extreme in a strict statistical sense but can lead to extreme conditions with high impact on physical, ecological and social aspects and these are also deemed as extreme event (Seneviratne *et al.*, 2012; WMO, 2016). As per World Meteorological Organization, 8835 natural disasters were reported globally during the period 1970 to 2012 and these have led to a loss of 1.94 million lives and caused economic damages of US$ 2.4 trillion (WMO, 2014). During this period 2681 disasters were reported in Asia and 45% were due to floods and these caused about 60% of the total economic loss of US$789.8 billion. Direct links between increasing greenhouse gas levels and the growing intensity of precipitation has been observed (Pall *et al.*, 2011; Min *et al.*, 2011).

One of the most common extreme events which affect the marine ecosystems and the coastal fishing communities is the tropical cyclone. A cyclone is also known as hurricane or typhoon and is an intense circular storm or whirl in the atmosphere that originates over warm tropical oceans. It is characterized by low atmospheric pressure, high winds (>119 km hr^{-1}) and heavy rains. Based on the maximum sustained wind speed (i.e., the Saffir–Simpson scale), tropical cyclones are categorized into tropical depressions, storms and category 1 to category 5 cyclones. The coastal zone is expected to be home to nearly 75% of the Asian population by 2025 (Dutta *et al.*, 2004) indicating the increased vulnerability of the coastal population and the fishing sector.

In India, cyclones are more common along the east coast and much less on the west coast. Floods have also impacted the Indian sub-continent and resulted in human causalities and cause damages to infrastructure. In the present decade, the South India 2015 flood along the east coast and the floods in 2018 in Kerala are two extreme events which caused widespread damage.

Significant increasing trends in the frequency and magnitude of extreme rainfall events have been observed in the country (Goswami *et al*., 2006; Singh and Patwardhan, 2012) and risks associated with these are also expected to increase in the forthcoming decades (Goswami *et al*., 2006). An analysis by Guhathakurta *et al.* (2011) has indicated that the frequency of heavy rainfall events are decreasing in major parts of central and north India but they are increasing in peninsular, east and north east India. From the analysis of 104 years data (1901-2004) Rajeevan *et al.* (2008) have indicated the coherent relationship between Indian Ocean SST and extreme rainfall events. In central India, a threefold increase in extreme rainfall events has been observed based on the analysis of the events which had occurred during the period 1950-2015 (Roxy *et al*., 2017).

It has been stated that extreme events have more severe impacts on sectors which are closely related to climate including those related to water and food security (IPCC, 2012). The IPCC report indicates that there have been considerable increase in economic losses to the communities affected by the event and these are also predicted to increase in future. The nature and intensity of impact and losses varies with the event and location with large spatial variability, but in general these have been found to be increasing globally.

The extreme events can change the physical and biological characteristic of the coastal waters. These can alter the fishery resource availability which in turn can affect the fishery landings. Movement of fishes away from locations which are affected by abiotic stress has also been observed along the coast (Kim *et al.*, 2007, Damatac and Santos, 2016). Such changes in the ecosystem can affect the people who depend on these resources.

Marine fisheries are one of most important sector of the Indian economy. Spread across the east and west coasts there are 3288 marine fishing villages where fishermen earn their livelihood by venturing into the coastal waters and harvesting the natural resources. Fisheries sector contributes around 1% to national GDP (Gross Domestic Product) and 5.23% to Agriculture GDP (NFDB, 2019). Fish and fish products have presently emerged as the largest group in agricultural exports from India and it constitute 20% of the national agriculture exports (NFDB, 2019). The census conducted by CMFRI in 2010 indicated that there were about 4.0 million marine fishers along the coastline of India, indicating an increase of 14% over the previous half a decade (Rao *et al.*, 2016). There are different types of fishing crafts and gears operated in each state and the CMFRI has a detailed census report of the number of fishermen and the fishing units of each state. In India, natural disasters like cyclone, floods and other extreme events are known to affect the fishing community for the past several decades (Shanmugavelu *et al.*, 1979; Rao and Datta, 1982; Ellithathyya *et al.*, 1997; Shiledar *et al.*, 2013).

The assessments made by CMFRI have indicated that there are more than 1200 species which contribute to the fishery along the Indian coast (Sathianandan *et al.*, 2016). Similarly the alpha, beta and gamma diversity of the species in different zones of Kerala for the period 1970 to 2005 has indicated that there is rich diversity of fished taxa along the Kerala coast (Zacharia *et al.*, 2011). Sathianandan *et al.* (2012) have tried to analyse the impacts of tsunami on the species diversity of fixed taxa along the Tamil Nadu coast. Impact of El Nino on the tuna has been indicated by Kumar *et al*. (2014) who have found high tuna landings during weak El Nino and La Nina period. Though there are annual assessments of the fishery of each maritime state, detailed analysis of the catch variation immediately after an extreme event has not been made. FAO has remarked that with better understanding of the functioning of the ecosystem, it will be possible to reduce the hardships of the fishing community through proper policies (Kurien, 2015).

Along the Tamil Nadu coast the number of cyclones has increased drastically since 1961 (Fig 1.1). There was just one cyclone during the decade 1961-1970 and after this in the succeeding two decades there were no cyclone at all. However, during 1991-2000 there were five cyclones which got reduced to three during 2001-2010. In the running decade (2011-20), within eight years (2011-18) there have been nine cyclones which give a frequency of 1.12 per year which was only 0.1 per year in five decades back. The lowest pressure recorded and the wind speed during these events is presented in Fig 1.2. It can be seen that the cyclone with highest wind speed was in 1964.

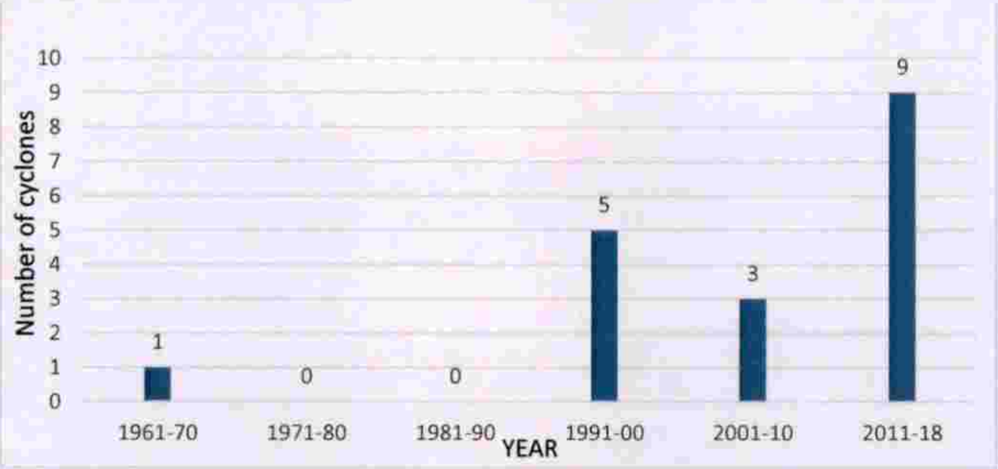

Fig 1.1 Number of cyclones along Tamil Nadu coast during the period 1960 to 2018

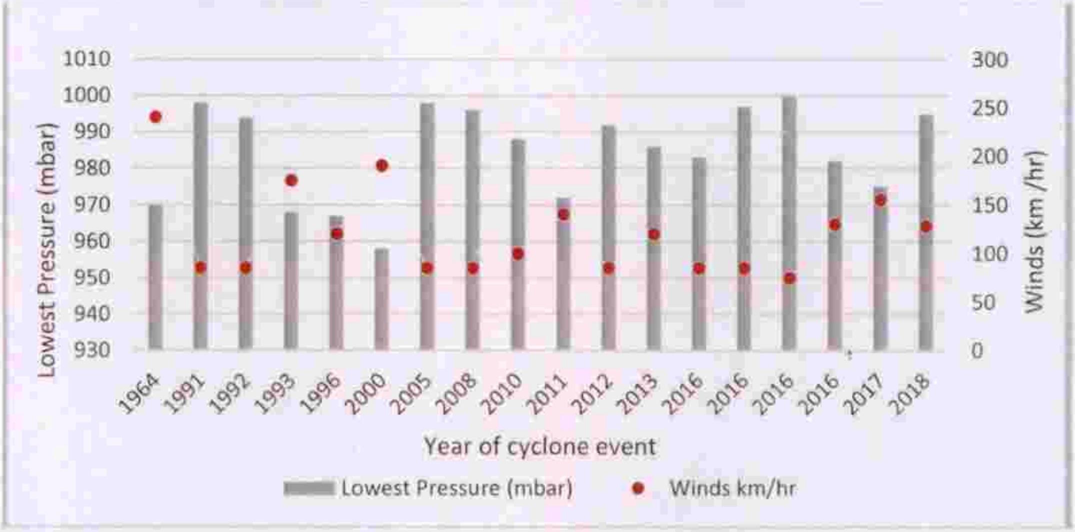

Fig 1.2 Lowest pressure and wind speed recorded during different cyclones which hit the Tamil Nadu coast during the period 1960 to 2018

Tamil Nadu experienced heavy rains during the month of November and December, 2015 which led to flooding of coastal districts. Two years after that Tamil Nadu and Kerala in the southern part of the country were impacted by the cyclone Ockhi. Cyclone Ockhi originated as a low pressure area on 28th November, 2017 in the south-west Bay of Bengal (Fig 1.3). Then rapidly intensified into a cyclonic storm and claiming the lives of about 350 people along southern Tamil Nadu and Kerala between 30 November and 3 December 2017. Ockhi became a very severe cyclonic storm (VSCS) over the Lakshadweep islands where it curved and moved in a north easterly direction and dissipating into a depression. Slowly it reduced to a low pressure system as it reached southern coast of Gujarat on 6th December 2017.

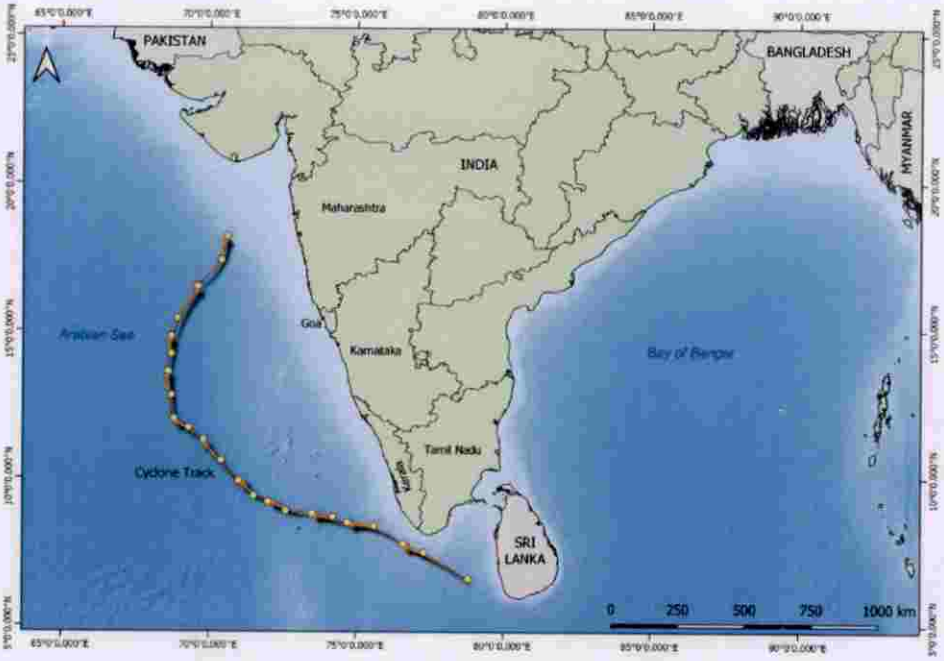

Fig 1.3 – The Path of cyclone Ockhi-2017

BOX 1 DETAILS OF PUBLIC PROPERTY DAMAGE AND OTHER LOSSES DUE TO SOUTH INDIA FLOOD 2015

- The Chief Minister of state reported that a total of 470 lives have been lost in the state of Tamil Nadu during the North East monsoon.
- Over 18 lakh (1.8 million) people were displaced because of the flooding event.
- About 30.42 lakh (3.042 million) families had suffered total or partial damage to their dwellings; 3,82,768 lakh hectares of crops had been lost due to flooding, including over 3.47 lakh hectares of agricultural crops and 35,471 hectares of horticultural crops; roughly 98,000 livestock animals and poultry had died.
- It is reported that more than 100,000 structures were damaged as a result of the floods.
- Almost 30% of Chennai households each faced losses between Rs.2 lakh and Rs.20 lakh.
- Aon Benfield, an UK reinsurance broker has claimed that the floods in Chennai can cost Indian economy a whopping Rs.20,034 crores, making it the eighth most expensive natural disaster in the world during 2015.

(Narasimham *et al.*, 2016)

- As per the information provided by the State Government of Tamil Nadu, the Chennai city particularly, was worst affected. Approximately 470 people were killed, 12,000 heards of cattle were lost and lakhs of people were displaced in the State. Besides, around 4.92 lakh houses got destroyed/ damaged in addition to heavy loss of public property. The crop area that got damaged was also extensive measuring up to, 3.83 lakh hectares.
- The total number of 3,59,171 huts were damaged in the State since 23rd November, 2015 out of which 2,23,610 huts were fully destroyed and 1,35,561 huts were partly damaged. In addition, 65 pucca houses were severely damaged and 13,601 were partly damaged in the State.
- The number of submerged houses has been assessed to be 26,90,660 in Chennai, Cuddalore, Thiruvallur, Kancheepuram and other affected districts.

(Rajya Sabha Report, 2016)

Table 1.1 Details of losses incurred due to cyclone Ockhi in Tamil Nadu, Kerala and Lakshadweep (Rajya Sabha Report, 2018)

Items	Tamil Nadu	Kerala	Lakshadweep
Human lives lost	30	75	Nil
Livestock lost	7654	Nil	1691
No. of missing fishermen	203	141	Nil
Houses damaged	Hut damaged- 6262 Pucca/kutcha houses partly damaged-101	Fully-221, Severely-3253	Fully -87 Partially -935
Infrastructure Damage	Mechanized boats partially-640 Mechanized boats fully- 60 (FRP)Vallams fully-3407	Boats-fully damaged/lost-384	Boats-fully damaged /lost-12 Boats partially damaged-25
	Damage to 75.046 km State Highways, 98.93 km National Highways, 417.18 km Rural/Urban Roads	Loss of road- 41 km	
	103 Government buildings damaged		Government building – 340
	Transformers-95 Electricity Board Poles-15,858	Damage to Pumps – 180 Damage to Supply Tanks –430	
	38 Breaches in tanks and 31 Breaches in channels/canals Fallen Trees -25,526		Other trees-5514 Coconut trees–32747
Total crop area affected (in hectares)	6625	7817.43	

Though the physical damage and human fatalities due to these events have been recorded (Box 1; Table 1.1). A detailed study on the impact of Ockhi 2017 and South India floods-2015 on the marine fishery has not been done. Considering the importance of marine fisheries and the vulnerability of fishers to extreme events like flood and cyclones, this study entitled- **"Assessment of the Impacts of Selected Extreme Climatic Events on the Marine Fisheries along Kerala & Tamil Nadu Coast"** has been carried out with the following objectives;

1. To evaluate the changes in landings of marine fishery resources following an extreme event
2. To analyse the major changes in environmental variables during extreme event episodes
3. To assess the impacts of extreme events on the livelihood of marine fishers

Kerala is a state which has not witnessed cyclones or other natural disasters as other states along the east coast. The sudden outburst of Ockhi during December 2017 along the southwest coast was totally unexpected. The coastal communities had to refrain from fishing for several days. In this study detailed information on how Ockhi affected the fishery, the fishery resources and the livelihood of fishers was analysed. Also the similar impacts on the fishery along Tamil Nadu coast during South India floods 2015 were analysed. Though the Kerala Floods happened during 2018, in the present study the impact of Kerala floods on marine fisheries could not be covered since the data was not completely available.

The results of impact on fishery (catch, effort, and catch per unit effort), the variation on marine resource assemblage in different gears between pre and post extreme event followed by impacts on revenue and man days due to loss in fishing days during flood / cyclone is presented in different sections. Apart from this the variation in selected environmental variables during the extreme event was also analysed. This was compared with past fifteen year's average (2003-2017) and the correlation between the environmental variables and selected species variation and fisheries were analysed. Impacts were plotted on GIS platform for better understanding of variation in catch and revenue.

The results of this study would be helpful to develop strategies to support fishers to mitigate the impacts of similar extreme events and increase the preparedness of local administration.

CHAPTER 2

REVIEW OF LITERATURE

Natural disasters like flood, cyclones and droughts have affected mankind since ancient times and have taken heavy toll of the population in the impacted area. One of the most destructive floods of the 20th century in Asia is the China floods of 1931 which claimed the lives of an estimated 1 to 4 million people. Similarly the cyclone which hit the Indian coast on October 7, 1737 and November 26, 1839 known as the Calcutta cyclone and India cyclone had an estimated death toll of 3,00,000 people. Apart from floods and cyclones there have been droughts/famines, heat waves, tsunamis and several other types of natural disasters. Analysis of the frequency and magnitude of such events has shown that there is an increase in such events in several parts of the world (Webster *et al.*, 2005; WMO, 2014; McPhillips *et al.*, 2018; Bhatia *et al.*, 2019) and these have been attributed to climate change especially warming of the earth. Webster *et al.* (2005) examined the number of tropical cyclones, cyclone days and tropical cyclone intensity during the period 1970-2004 and observed wide variation between the different oceanic regions.

A review of the research done on impacts on marine resources and fishery, ocean – atmospheric parameters and economic impacts due to fishery changes following extreme events is presented below

2.1 Impacts of extreme events on coastal and marine resources

Extreme events can disturb the ecosystem which can disrupt their physical nature and lead to changes in ecosystems including the community and population structure of the faunal assemblages of the areas (Scheffer *et al.*, 2001, Rizzo *et al.*, 2018).

Phytoplankton : Cyclone induced phytoplankton blooms where identified with the advent of satellite ocean color remote sensing from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectroradiometer (MODIS) (Lin *et al.*, 2003; Peierls *et al.*, 2003; Babin *et al.*, 2004; Walker *et al.*, 2005; Miller *et al.*, 2006; Shi and Wang, 2007; Liu *et al.*, 2009; Wang *et al.*, 2011). Babin *et al.* (2004) analysed the changes associated with the passage of 13 hurricanes through the Sargasso Sea region of North Atlantic during the period 1998 to 2001 and found that surface chlorophyll as inferred from remotely sensed ocean colour was found to increase and this was found to last for 2 to 3 weeks before it returned to the pre-hurricane level (Babin *et al.*, 2004). Lin (2012) have observed that not all cyclone produce phytoplankton blooms. Off the eleven typhoon which passed the Western North Pacific subtropical ocean, only two lead to phytoplankton blooms where the Chlorophyll-*a* concentration increased from ≦0.1 mg m^{-3} to 0.4–0.8 mg m^{-3}.

Zooplankton : Hurricane Isabel which made landfall on 18^{th} September 2003 along North Carolina led to few biological changes in Chesapeake Bay including high abundance of the calanoid copepod *Eurytemora affinis* in spring 2004, and increased recruitment of Atlantic croaker (Roman *et al*., 2005). After the tropical cyclone Tiffany along the Australian coast in January 1998 changes in SST and salinity due to local heating and evaporation was observed. Changes in phytoplankton community with increase in micro-phytoplankton abundance and biomass and primary production on the shelf waters was observed. Along with this the diversity of copepod-dominated mesozooplankton community declined and a less diverse community consisting of copepods near shore shallow habitats. In the fish larvae collections larvae of fishes which are usually rare or absent in these assemblages and these variations have been attributed to the change in water mass transport (McKinnon *et al*., 2003).

Benthos: Thistle (1981) has reviewed the changes taking place in soft bottom benthic communities due to natural physical changes and has reported that most species are affected by the disturbance and recovery usually depends on the life history strategies. Posey *et al.* (1996) found that approximately one third of common surface dwelling especially polychaetes, juvenile bivalves and epifauna exhibited a significant decline in abundance after the storms but there were no significant changes in the abundance of the deep burrowing animals.

Crustaceans: Lobsters have been found to be affected by the ecological changes especially lowering of salinity and they have been found to take short term migrations and move to deeper waters (Cooper *et al*., 1975; Ennis, 1984). Drastic reduction in salinities has been known to result mortality of lobsters as observed by washing ashore of dead lobsters (Prince, 1897). Jury *et al*. (1995) found that storms can induce movements of lobsters and subsequent transient shifts in the demographics of the lobster population and these can also lead to increased catch in some areas. One of the earliest records on impacts of storm related changes in the ecosystem and on fish fauna is that by Robins (1957) who observed that the increased sediments resulting from the turbulence had caused erosion of gill filaments and the storms also hindered shoreward migration of fishes in Florida.

Turtles: The tropical cyclone Kathy which hit the Northern Australia region in 1984 affected several marine resources; it stranded about 500+ green turtles (*Chelonia mydas*), sharks, rays, fish and at least 27 dugongs on the supra-tidal mud flats inshore from the coast (Marsh, 1989). The south-eastern coast of the United States is nesting ground of world's largest loggerhead sea turtle (*Caretta caretta)* and nesting aggregations were studied by satellite tagging during the period 1988 to 1992 (Dodd and Byles, 2003). It was found that tropical storms and cyclones affected the swimming behaviour of few female loggerhead turtles (*Caretta caretta*) along the US coast (Dodd and Byles, 2003).

Seabirds: In 1958, a tropical storm, Hurricane Helene, swept through Newfoundland and brought with it large numbers of Laughing Gulls (*Larus atricilla*) and Black Skimmers (*Rynchops nigra*), neither of which had been recorded previously in the region (Tuck, 1968). Another sea bird which has been found to be impacted by hurricane is the Atlantic Petrel (*Pterodroma incerta*) which is endemic to Gough and Tristan da Cunha islands (Hass *et al.*, 2012). This species has a vulnerable global status (Birdlife International 2004) and is one of the least known seabirds (Cuthbert, 2004). Bugoni *et al.* (2007) have reported a massive displacement of about 354 petrals which were starving and weak in southern Brazil, after Hurricane Catarina. Based on records of carcasses salvaged between 1893 and 2003 along the Florida coast after a cyclone, Hass *et al.* (2012) have indicated that increasing tropical cyclone induced by climate change increases the extinction risk of the endangered tropical seabird, the black-capped petrel *Pterodroma hasitata*.

Sea snakes: Along the Orchis Island of Taiwan, Sea snakes–sea kraits (*Laticauda* spp.) which usually are abundant in the littoral zones were found to disappear with the lowering of barometric pressure prior to typhoon Morakot, which impacted the island severely during 7–9 August 2009 (Liu *et al.*, 2010).

Fishes: Hydrostatic pressure variations have been known to affect marine animals and research related to this has been reviewed Knight-Jones and Morgan, 1966; Flugel, 1972; Naylor and Atkinson, 1972. And some workers have focused on the impacts on fishes (Gordon, 1970; Gibson, 1982). Tidal freshwater habitats are known to be affected and after the hurricane Katrina (2005) along USA coast, these changes were found to lead to a nekton community containing brackish/migrant species, many of which are characterized by pelagic and benthic life history strategies. The original community revived in 2007 (Piazza and

Peyre, 2009). Following changes in abiotic factors of the coastal waters after three consecutive cyclones in 1999 in North Carolina, there was found to be displacement of fauna and an increase in fish diseases (Paerl *et al.*, 2001).

Seagrass and mangroves: Hurricanes were seen to cause severe damage to the sea grass beds of Florida by the severe wind of Tropical Hurricane Donna in the year 1961 (Thomas *et al.*, 1961). Storms are also known to affect mortality indirectly by destroying the sea grass beds on which dugongs feed (Heinsohn and Spain, 1974, Kenyon and Poiner, 1987). This was found to increase the mangrove litterfall (Davis *et al.*, 2004). Studies have shown that hurricanes with wind speeds in excess of 200 km hr^{-1} can cause massive destruction to mangroves (Craighead and Gilbert, 1962; Roth, 1992; Smith *et al.*, 1994). The passage of Hurricane Charley through the Charlotte Harbour region caused extensive damage to the mangrove shoreline habitats which are nursery grounds of commercially important fishes like the sawfish and Simpfendorfer *et al.* (2005) have indicated that the destruction of mangrove habitat can affect these resources.

Fisheries: After the Hurricane Harve there was an increase in the CPUE of red drum at a rate of 0.81fish hr^{-1}, from 0.67fish hr^{-1} in 2016 and close to the 10-year average. Similarly, spotted sea trout were caught at a rate of 0.41fish hr^{-1}, from 0.22fish hr^{-1} in 2016 and this was higher than the 10-year average. This observation implies that these species are actually more abundant in Aransas Bay following an extreme event. (Pettis, 2018)

Paerl *et al.* (2001) have indicated that there will be more changes in the bio-geochemical cycles and tropic variations in the coastal and estuarine habitats due to predicted increase in number of extreme events in the coming years. Evaluating the ecological impacts especially the changes in physical and chemical properties (salinity, water residence time, transparency, stratification and dissolved oxygen), phytoplankton primary production and phytoplankton community composition in the Atlantic and Gulf coast due to cyclones of various intensities during the mid 1990s. Paerl *et al.* (2006) have indicated that there should be strategies for development of water quality management following such natural disasters. Roxy *et al.* (2017) have opined that there is hope in mitigating the destructive impacts of extreme events as there is predictability of these events by two to three weeks using the variations in ocean parameters.

2.2. Impact of extreme events on environmental parameters

Temperature: Hurricanes (cyclones) and the changes they make in the upper ocean characteristics have been studied since the last century (Leipper, 1967; Brooks, 1983; Sanford *et al*., 1987; Shay and Elsberry, 1987; Shay *et al*., 1989, 1998; Jacob *et al*., 2000). Lowering of temperature in the ocean surface in the path of cyclones has been observed and the reasons have been attributed to several upper ocean processes including entrainment and upwelling (Price, 1981; Price *et al*., 1994; Jacob *et al*., 2000; Prasad and Hogan, 2007; Chang *et al*., 2008) and the levels of SST variation has been linked to velocity of the storm (Black, 1983). The mixed layer has been found to deepen several meters and cool the near –surface waters of the path of the cyclone (Hazelworth, 1968; Dickey and Simpson, 1983; Stramma *et al*., 1986; Sanford *et al*., 1987). On the other hand, downward mixing of heat has been found to warm the upper thermocline and sometimes currents which persist for several days are also formed (Shay and Elsberry, 1987; Shay *et al*., 1989, 1992, 1998; Zedler *et al*., 2002). Pei *et al.* (2015) have studied the impacts of the typhoon Rammasun (May 6–13, 2008) in the north west Pacific and observed that there is a deepening of surface mixed layer, a strong latent heat loss and also an intense upwelling in the centre of typhoon leading to lowering of temperature.

Nutrients: Inorganic nitrogen and phosphorus concentrations were found to increase briefly elevated during the flooding (Peierls *et al*., 2003). Significant increase in nutrients in the upper ocean with the passage of hurricane has been reported (Liu *et al*., 2009). When this influx of nutrients especially increases in nitrate concentration is within a cold core eddy, the favourable conditions have been found to lead to phytoplankton blooms and such change has been observed in Gulf of Mexico after Hurricane Katrina's passage in August 2005. Hanshaw *et al.* (2008) have found that cyclone-induced chlorophyll-*a* increase has minimal impact on the integrated biomass budget. A detailed study by Wang *et al*. (2011) concludes that tropical cyclone is an important mechanism to pump nutrients into the upper euphotic zone which can lead to significant phytoplankton blooms and increase of the ocean's primary production. More recently Foltz *et al*. (2015) using an integrated and comprehensive approach for analysing the impacts of tropical cyclones during the period 1998 to 2011 found that the accumulated cyclone energy explained about 22% of the interannual chl *a* variance during the hurricane season (June–November) in the western subtropical North Atlantic Ocean and that tropical cyclone contribute significantly to interannual variations in primary productivity of this region. Avila-Alonso *et al*. (2019) have observed variations in chlorophyll-*a* in the EEZ of Cuba after passing of hurricanes during the period 1998 to 2016.

Turbidity: Storms especially cyclones have been found to increase the turbidity of inshore waters and reduce the dissolved oxygen levels in the water due to decomposition of detritus and other organic matter (Tabb and Jones, 1962; Saloman and Naughton, 1977). Physical disturbance due to tidal, wind and wave action can also change the ecology of inshore waters (Saloman and Naughton, 1977; Yeo and Risk, 1979; Lowery, 1992).

Salinity: Floods and storm surges can also lower the salinities especially if there are heavy rains associated with the natural disaster (Saloman and Naughton, 1977; Knott and Martore, 1991). One major investigation in North Carolina where three cyclones (Dennis, Floyd and Irene) had inundated the coastal region with up to 1 m of rainfall causing severe flooding showed that lowered the salinity and the organic carbon levels entering from a major tributary of a river showed 2-fold increase. Following these changes there a series of cascading impacts including vertical stratification, bottom water hypoxia and increase in algal biomass (Paerl *et al*., 2001).

National – Ocean atmospheric variations

In India Premkumar *et al*. (2000) observed a lowering of SST by 3° in the Arabian Sea and later Naik *et al*. (2008) have also studied the impacts of a tropical cyclone on biogeochemistry of the central Arabian Sea. After the Orissa super cyclone in October 1999, large amount of organic matter was brought in by the rivers and this has been attributed to the increase in chlorophyll in the river outlet areas (Kundu *et al*., 2001; Nayak *et al*., 2001). They also indicate that the Fisheries Department has reported high fish catch in Chilka lake area after the cyclone. In the Arabian Sea also high concentrations of chlorophyll has been observed immediately after the cyclone on May 2001 (Subrahmanyam *et al*., 2002). Vinayachandran and Mathew (2003) have indicated that the phytoplankton bloom in Bay of Bengal intensifies after a cyclone. Using a three dimensional models a net decrease of the SST of 6–7°C was simulated when the severe cyclonic storm moved over the coastal ocean (Rao *et al*., 2004). Rao *et al*., (2006) have reported that in addition to lowering of SST by about 2°, the tropical cyclone leads to a sea surface depression of 0.1m, increases the chlorophyll-*a* by 1.5 mg/m^3 and primary productivity. They have also indicated that this increase in productivity would support the pelagic fisheries of Bay of Bengal. Tropical cyclones Hudhud (2014) and Vardah (2016) were found to increase the chlorophyll, nitrate and primary productivity (Girishkumar *et al.*, 2019).

Socio-economics

Globally about 200 million people are directly and indirectly employed in different activities related to fisheries right from harvesting from natural areas to distribution. Another important factor is that women represent about 14 percent of the primary work force (FAO, 2018) and this increases to about fifty present if the secondary sector is also included (Monfort, 2015). Most of these activities are close to the sea and, this population stays close to the sea, making them more vulnerable to extreme events like tropical cyclones, tsunamis, storm surges, droughts and tsunamis. As per FAO (2018), there is high probability that extreme events will become more frequent and thus making fisheries sector more vulnerable. Based on factors like frequency of occurrence, dependence on fishery and capacity to adapt, Badjeck *et al.*, (2013) have stated that fisheries sector of Africa and south-east Asia is more vulnerable to disasters.

The physical destruction by most extreme events in coastal areas is the damage and destruction of fishing and transport boats, the engines and the fishing gears. These also destroy common facilities like harbours and infrastructure for post harvest processing (FAO, 2018). Though extreme events are reported globally, the impacts and economic losses vary from place to place. The International Monetary Fund (IMF) has found that small developing states are disproportionally affected by natural disasters with the annual cost being much greater than in larger countries (Cabezon *et al.*, 2015).

A review of 74 Post-Disaster Needs Assessment (PDNA) conducted in 53 developing countries between 2006 to 2016 shows that agriculture including crops, livestock, fisheries, aquaculture, and forestry absorbed 23 percent of all damage and loss caused by medium- to large-scale natural disasters (FAO, 2018).

Considering the disproportionate impact on the society and the ecosystems, the Fifth Assessment Report (AR5) of the IPCC has highlighted the importance of understanding changes in extreme climate events (IPCC, 2014). However, due to poor database and the difficulty in modelling the physical processes involved extreme events are harder to monitor and predict (Alexander, 2016; Ghil *et al.*, 2011).

Extreme events can impact the coastal communities and their livelihoods (Mirza, 2003; Buck, 2005; Barrientos and Hulme, 2016, Radway *et al.*, 2016; Corbin, 2015). Damage to Infrastructure and loss of fishing gear has been one of the major impacts on coastal fishing communities (Buck, 2005; Cheuvront, 2005; Westlund *et al.*, 2007; Chowdhury *et al.*, 2012; Badjeck *et al.*, 2013). Aspects like relocation and resettlement brought persistent uncertainty to fishermen and threatened to disrupt their community bonds and social networks (Lebel *et al.*, 2006; De Silva and Yamao, 2007). Loss of life has found to affect the surviving family members and also the social systems within the coastal communities (De Silva and Yamao, 2007; Westlund *et al.*, 2007; Badjeck *et al.*, 2013).

The analysis by Belhabib *et al.* (2018) of data during the period 1950 to 2010 from 270 Exclusive Economic Zones (EEZs) covering 17,700 extreme events including 273 extreme events which had impacts on fisheries showed that fish catches have increased after the extreme events, indicating that there is a valuable compensation mechanism to revive from the natural disaster. However, the effects on the coastal communities showed variation, with higher opportunistic fishing by foreign fleets in countries with poor governance and increased rates of unemployment (Belhabib *et al.*, 2018). This study has pointed out the need to assist the coastal communities for increasing their resilience and adaptive capacity. Seara *et al.* (2016) found that the adaptive capacity showed variation between the commercial and for-hire fishermen in relation to Hurricane Sandy.

Bangladesh with a cyclone frequency of 5.48 events per year or once every 9.49 weeks is one of the most disaster prone countries of the world and the frequency is expected to be 7.94 storms per year or once every 6.54 weeks by 2050 (Chowdhury *et al.*, 2012). These events have been found to impact the coastal community and have also led to unemployment after the cyclone. Biswas *et al.* (2019) have observed that though the exposure to extreme events is high, the relative index to national economy due to damage and destructions in the fisheries sector was low.

Women crab farmers of Fiji were found to be affected by the tropical cyclone Winston in 2015 (Thomas *et al.*, 2018). After the cyclone about 52% of the fishers had stopped harvesting crabs because most of them had to attend to the repairs related to their own houses. Moreover there was it was difficult to reach the fishing area since the roads and markets were damaged. Those who collected crabs found them to be less in number and also smaller.

Impact of cyclone on coastal communities has been studied by few researchers in India. Venkataraman and Algaraja (1980) have given a detailed account of the destruction caused by four cyclones in different districts of Andra Pradesh during the period 1976 to 1979 while Makadia *et al*. (1998) have provided information on the impacts of cyclone which hit the coastal villages of Gujarat in 1998. The tsunami which caused considerable loss of lives and damage in Andaman and Nicobar Islands and along the mainland has been more studied extensively. Its damage along Andaman and Nicobar Islands, Tamil Nadu and Kerala (Sathiadhas and Prathap, 2005) has been recorded. More recently Geetha *et al*. (2016) have worked out the economic loss due to cyclone Vardha along Tamil Nadu coast.

South-India flood 2015 and Cyclone Ockhi 2017

Investigations on the south India floods -2015 was carried out by different teams and the reports by Narasimham *et al.* (2016), Rajya Sabha Report (2016), CAG (2016) and NRSC (2016) provide an insight into the causes, damages and intensity of impact on the affected population of Chennai and other districts of Tamil Nadu. The cyclone Ockhi which was least expected along the Kerala, southern parts of Tamil Nadu and Lakshadweep Islands has also been studied and reports on this have covered the fatalities in different fishing villages (Rajya Sabha Report, 2018; OPIOC, 2018, Fousiya and Lone, 2018; Roshan, 2018; FAO-ICSF, 2019).

CHAPTER 3

MATERIALS AND METHODS

The two extreme events selected to assess the impacts were South India Flood-2015 (also called Chennai flood-2015) and cyclone Ockhi in 2017. The different methods followed to meet the objectives of the research theme are described below. The entire work has been on three sections-1) impacts on fishery and the resource assemblages in the affected districts, 2) impacts on the environmental variables and 3) the socio economic impacts due to loss in fishing days. In this chapter the details of the data collected and analysed and the statistical packages /software used for various sections are presented.

3.1 Fishery Data

The fishery data including the catch, number of units operated (effort) and actual fishing hours was sourced from National Marine Fisheries Data Centre (NMFDC) of Central Marine Fisheries Research Institute (CMFRI), Kochi, India. The fishery data is collected by the multistage stratified random sampling design (Srinath *et al*., 2005). In this method developed by CMFRI, trained observers collect data for 16 to 18 days every month on landings of different resources, the number of fishing days and the units operated per month from the landing centres all along the Indian coast in specific forms and this is raised to derive the estimate for the month. The data for the period 2007 to 2018 was extracted for all districts of Tamil Nadu and Kerala and it was used for the further analysis. Fishing crafts are mainly divided into mechanized, motorized and non-motorized (NM) and different gears are operated from these.

Table 3.1 Types of gears operated in the mechanised and motorised fisheries sectors

Mechanised Sector	Motorised Sector
Multi day trawl net (MDTN)	Outboard bag net (OBBN)
Mechanized gillnet (MGN)	Outboard boat seine(OBBS)
Mechanized hook and lines (MHL)	Outboard dol net (OBDOL)
Mechanized purse seine (MPS)	Outboard gill net (OBGN)
Mechanized ring seine (MRS)	Outboard hook and lines(OBHL)
Mechanized trawl net (MTN)	Outboard purse seine (OBPS)
	Outboard ring seine(OBRS)
	Outboard shore seine (OBSS)
	Outboard trawl net(OBTN)

Apart from these, other gears are sometimes observed and these are mechanized other gears (MOTHS) and outboard other gears (OBOTHS).

The catch varies depending on the area of operation and type of gear. If the gears operated in the near shore areas like the NM and most out board crafts and gears, resources which are influenced by the coastal waters will be caught and in mechanised crafts which fish in distant waters, the resources will vary. Depending on the depth of operation, the catch will be either pelagic resources which occur in the surface waters (or in column waters) or demersals which inhabit mainly the lower column waters. The latter can be benthic also; living very close to the sea bottom.

The gear mesh determines the size of the resource caught; and usually in the seines which are encircling gears, small pelagic fishes are caught while in hook and line large pelagic fishes like tunas and seerfishes are caught. Trawlers usually catch bottom resources; hence shellfishes (shrimps and cephalopods) and rays, sharks and other benthic fishes dominate.

Resource assemblage of a particular group of resources can be understood from the catch and from the catch per unit effort (CPUE) the abundance of the resource can be inferred. A schematic representation of the approximate depth of operation and area (pelagic/demersal) of different craft–gear operated along Tamil Nadu coast is given in Fig.3.1. The area and depth of operation may vary slightly along the Kerala coast where the continental shelf is more wider than east coast.

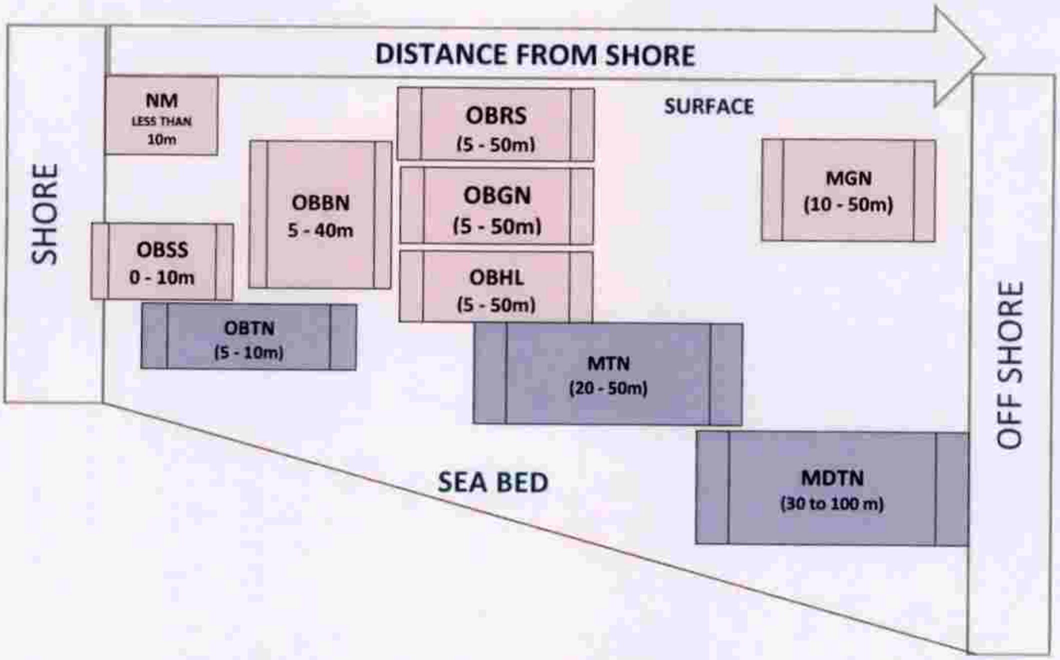

Fig 3.1 Schematic presentation of the depth and area of fishing of different craft-gears along Tamil Nadu coast

(NM=Non-motorised; OBBS=Out Board Boat Seine; OBTN=Out Board Trawl Net; OBBN=Out Board Bag Net; OBRS=Out Board Ring Seine; OBGN=Out Board Gill Net; OBHL=Out Board Hook and Line; OBSS=Out Board shore seine MTN=Mechanised Trawl Net; MGN=Mechanised Gill Net; MDTN=Multi Day Trawl Net)

Catch per Unit Effort (CPUE)

CPUE is an indirect measure of the abundance of fishes. Changes in the CPUE are inferred to signify changes in the abundance of fishes. CPUE is the ratio of total catch and effort.

CPUE = TOTAL CATCH ÷ EFFORT

For studying the impact of 2015 south Indian flood, Chennai, Cuddalore, Kancheepuram, Thanjavur and Thiruvallur districts were selected. The catch, effort (number of units) of these districts were used for the analysis. The period August to October 2015 was taken as Pre-flood, November and December 2015 as Flood and January to March 2016 as Post flood.

To assess the impacts of cyclone Ockhi in 2017, four districts from Kerala *viz.*, Thiruvananthapuram, Kollam, Ernakulam and Alappuzha as well as three districts of Tamil Nadu such as Kanyakumari, Thirunelveli and Tuticorin were selected. In this study, we considered the period from September to November 2017 as pre-cyclone, December as cyclone and January to March 2018 as post-cyclone period.

For analysing the impact on effort, catch and CPUE, the percentage deviation between the pre-flood/cyclone vs flood/cyclone vs post flood /cyclone was calculated and the based increase /decrease of effort and catch, the impacts were categorized into six as given below (Table 3.2). Then the pre-flood/pre-cyclone vs post flood/post cyclone was also compared to see if the impact of flood/cyclone was reduced or retained.

Table.3.2 Criteria used to categorise the impact of extreme event on Catch, effort and CPUE

	Range of Percentage Deviation	Category of Impact	Based on Increase /Decrease
1	< 10 %	Low impact	1. Positive low impact or 2. Negative low impact
2	10 to 50 %	Medium impact	3. Positive medium impact or 4. Negative medium impact
3	> 50 %	High impact	5. Positive high impact or 6. Negative high impact

Software used

The software PRIMER 7.0 (Plymouth Routines In Multivariate Ecological Research) and MS-EXCEL were used in the analysis of fishing datasets.

PRIMER was used for assessing the variation in catch composition. Using SIMPER module, dissimilarity in the Species/Group composition during pre-flood, flood & post-flood periods were analysed. Biomass of the resources was considered for the analysis.

SIMPER (Similarity Percentages)

This test was used to determine the changes in species/Group composition during flood and cyclone. The Bray–Curtis dissimilarity was calculated and the average dissimilarity between all pairs of inter-group samples were computed (pre-flood/pre-cyclone, flood/cyclone and post flood/ post cyclone period). Then, the contribution of each resource to dissimilarity was calculated by dividing the individual contribution from each species by the standard deviation of that species.

3.2 Data used for Assessing the Impact on Environmental Variables

Sea Surface Temperature (SST)

Global ocean Sea Surface Temperature data was downloaded from the Physical Oceanography Distributed Active Archive Centre (PO.DAAC) of NASA JPL (Jet Propulsion Laboratory) (https://podaac.jpl.nasa.gov/). Monthly mean SST data with 4 km spatial resolution derived from MODIS Aqua (MODerate Resolution Imaging Spectro-radiometer) sensor was downloaded for the study period. These data were used to determine the climatological mean and variation in SST during the selected extreme events.

Chlorophyll-a concentration (Chl-a)

The global ocean colour data from 2003-2018 were downloaded from the website Ocean Colour Climate Change Initiative (OC-CCI) (https://www.oceancolour.org/). The monthly climatological chlorophyll data downloaded as NC files with a spatial resolution of 4x4km.

Sea Surface Height Anomaly (SSHA)

SSHA of 1/6° spatial resolution and 5 day temporal resolution for the period 1998 to 2018 was collected from JPL MEaSUREs Gridded Sea Surface Height Anomalies Version 1609 from PO.DAAC (https://podaac.jpl.nasa.gov/). Using the R software, these 5 day files were compiled into monthly data.

Sea Surface Salinity (SSS)

SODA3.4.2 (Simple Ocean Data Assimilation Ocean/Sea ice Reanalysis) Monthly Sea surface salinity data of 0.5° resolution from 2003-2016 were extracted from the SODA3 website (http://www.atmos.umd.edu/~ocean/index.html). Global SSS data from GODAS (Global Ocean Data Assimilation System) was also extracted from the NOAA ESRL Physical ScienceDivision (PSD) website (https://www.esrl.noaa.gov/psd/data/gridded/data.godas.html) for the period 2017-2018.

Ocean Current Data

Ocean current information from SODA3.4.2 was extracted from the SODA3 website (http://www.atmos.umd.edu/~ocean/index.html). The monthly climatological data of 0.5°spatial resolution from 1998-2016 was downloaded as NetCDFv4 files. Ocean surface current data was also downloaded from the OSCAR (Ocean Surface Current Analysis Real-time) satellite sensor of 0.33° spatial resolution and 5 day temporal resolution from the website of PO.DAAC (Physical Oceanography Distributed Active Archive Centre) (https://podaac.jpl.nasa.gov/). The current data are represented as zonal (u) and meridional (v) components. Current speed and direction were derived from u and v components using the formula:

$$\text{Current velocity} = \sqrt{(u^2 + v^2)}$$

$$\text{Current Direction} = 180 + [180 * \arctan^2 (u,v)]/\pi$$

Current velocity and direction were calculated using R programming and the results were plotted as polar diagram using Grapher 14.

Local Temperature Anomaly (LTA)

Local Temperature Anomalies (LTAs) are intended as the coastal upwelling indices by comparing coastal and offshore temperature. The positive LTA values suggest coastal upwelling processes (Shah *et al.*, 2015; Smitha *et al.*, 2008; Naidu *et al.*, 1999). And the equation is:

$$LTA = SST_{off} - SST_{coast}$$

Where, SST_{off} represents sea surface temperature associated with an off-shore station at a distance of 3° with respect to that recorded at a coastal station (denoted using SST_{coast}) within the same latitudinal belt. LTA serves as a proxy to represent oceanographic forcing. LTA values grater than 1°C indicate a strong upwelling in the coastal areas (Shah *et al.*, 2015).

Rainfall Data

All India district wise monthly rainfall data was downloaded from Open Government Data (OGD) Platform-data.gov.in website (https://data.gov.in/). Also, rainfall data of India Meteorological Department (IMD) was collected from the IMD's Annual publication "The Rainfall statistics of India" (Kaur and Purohit, 2012, 2013, 2014, 2015, 2016) (Yadav *et al.*, 2018). 2018 rainfall data is only available for Trivandrum and Ernakulam districts.

MEI (Multivariate ENSO Index)

The bi-monthly Multivariate El Niño/Southern Oscillation (ENSO) index (MEI.v2) is the time series of the leading combined Empirical Orthogonal Function (EOF) of five different variables [sea level pressure (SLP), sea surface temperature (SST), zonal and meridional components of the surface wind, and outgoing long wave radiation (OLR)] over the tropical Pacific basin (30°S-30°N and 100°E-70°W). MEI is a method used to characterize the intensity of an ENSO event. 1998-2018 MEI values downloaded from the ESRL (Earth System Research Laboratory), Physical Science Division of NOAA (National Oceanic and Atmospheric Administration) (https://www.esrl.noaa.gov/psd/enso/mei/).

DMI (Dipole mode Index)

The Dipole Mode Index (DMI) is a measure of the anomalous zonal SST gradient across the equatorial Indian Ocean. It is defined as the difference between SST anomaly in a western (60°E-80°E, 10°S-10°N) and an eastern (90°E-110°E, 10°S-0°S) box. When the DMI is positive then, the phenomenon is refered as the positive IOD (Indian Ocean Dipole) and when it is negative, it is refereed as negative IOD. Data from 1998-2017 collected from Global Climate Observing System (GCOS) Working Group on Surface Pressure (WG-SP) hosted by NOAA ESRL Physical Sciences Division (*https://www.esrl.noaa.gov/psd/gcos_wgsp/*). 2018 DMI data obtained from ESSO (Earth system science organization) - Indian National Centre for Ocean Information Services (INCOIS) (*https://incois.gov.in/portal/IOD*) (Sivareddy, 2015).

Degree heating month (DHM)

Fishes are poikilotherms (animal whose internal temperature varies considerably depending on the external medium temperature) and highly mobile organisms. Fishes can often perceive a temperature change of < 0.5°C (Vivekanandan, 2013). A degree heating month (DHM; expressed as °Cmonth) is equal to 1 month of SST that is 0.5°C greater than the maximum in the monthly climatology. DHM is an index of accumulated thermal stress on marine organisms (Kumagai and Yamano, 2018).

Degree cooling month (DCM)

DCM is an index of accumulated reduced thermal stress (cooling effect). A degree cooling month (DCM; expressed as °C month) is equal to 1 month of SST that is 0.5°C lesser than the maximum in the monthly climatology (Jones *et al.*, 2017).

Software used

The software *viz.* R 3.6.0, QGIS 3.4.1, Python 3.7 and MS-EXCEL were used for the data processing.

Using R software, datasets falling within the area of shore line to 100 m depth contour were extracted. 15 years (2003-2017) datasets were used to find out the climatological (normal) monthly mean values. Anomalies were calculated using the given equation.

Percentage Anomaly = (Actual value-Normal/Normal)*100

Standardized Anomaly = (Actual value-Normal)/Standard Deviation

Pearson's Correlation Test

Pearson's correlation test or parametric correlation test is a measure of the linear correlation between two variables. It was developed by Karl Pearson. Pearson's correlation coefficient is a statistical measure of the strength of a linear relationship between paired data. Correlation coefficient *r* ranges from +1 to -1. +1 indicates a positive correlation, -1 indicates a negative correlation and 0 shows no correlation.

According to Evans (1996), the strength of the correlation could be categorized in to very weak/no correlation ($r \leq 0.19$), weak correlation ($r = 0.2$ to 0.39), moderate correlation ($r = 0.4$ to 0.59), strong correlation ($r = 0.6$ to 0.79), very strong correlation ($r = 0.8$ to 1).

Principle Component Analysis (PCA)

Principal component analysis (PCA) was carried out to select the most influencing environmental parameters. PCA is a statistical procedure that transforms a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. Principle components whose eigen values ≥ 1 are selected for the study. Parameters having highest factor loading in the selected principle component were used for the further analysis (Andrews *et al.*, 2002).

Multiple Linear Regression Model

Linear regression is a linear approach to modeling the relationship between a dependent variable and one or more independent variables. The case of one explanatory variable (independent variable) is called simple linear regression. For more than one explanatory variable, the process is called multiple linear regression. Linear regression is defined by the formula

$$\boxed{y = mx + C}$$

Where,

y = Dependent variable, x = Independent variable, m = Regression coefficient, C = Intercept

Multiple linear regression model was used to find out the relationship between environmental parameters and marine catch in R software. The influence of oceanic parameters on CPUE, Total catch and the landings of major species/ catch rate of selected fishery were found out. Percentage variance explained by these parameters was arranged in a tabular form.

The fishery data for the period 2008-2017 (10 years) was used to calculate the normal (Month wise 10 year average). The CPUE of crafts operated within the 100m depth zone (Motorised and Non motorised crafts) like NM, OBBN, OBBS, OBDOL, OBGN, OBHL, OBPS, OBRS, OBSS, OBTN and their total catch were used for the study. The dominant fishes in the district coastal zones were selected. The selected resources are oil sardine, Indian mackerel, *Thryssa*, *Stolephorous*, other sardines, silverbellies, silver pomfret, rays, croakers, scads, squids, pigface breams, barracudas, penaeid prawns, crabs, mullet and catfishes. The 6-month data before and after the extreme event episode were selected and compared to normal in order to discover the changes in marine fisheries and environmental parameters during and after the selected extreme events. The data were plotted as line graph.

3.3. Analysis for assessing socio-economic impact

The accurate calculation of profit is an important aspect to assess the financial success of a fishing activity. The financial term 'profit' can be defined many ways based on different modes of fishing. In the present context, the term 'Net Profit' is used to represent the income gained in Indian Rupees (INR) after deducting all expenditures incurred associated with the fishing activity.

Gross Revenue = Quantum of Selling * Market Prize

Net Profit = Gross Revenue - Operating Cost

During the days of cyclone and flood, majority of the fishermen could not go for fishing and allied activities mainly due to the bad weather conditions over sea. Loss in fishing days led to reduction in marine fish landings, which in turn resulted in revenue loss to fishermen (Johnson and Narayanakumar, 2016). In addition, craft and gear damages are common in cyclonic events. With this backdrop, the loss in revenue and catch were estimated based on the operating cost, gross revenue, net profit and crew size data collected from CMFRI. Loss in catch is the product of average catch and loss in fishing days. Economic loss was calculated by estimating number of loss in fishing days and fishing income per day. Loss in man days is the product of crew size and loss in fishing days. The economic loss was mapped using QGIS software. During SIF-2015, there was no loss in fishing days. Therefore, the economic loss is not calculated for flood.

RESULTS

CHAPTER 4

Impact of South India Flood on Marine Fisheries of Tamil Nadu

4.1 Impact of South India Flood on marine fisheries catch, effort and catch per unit effort of Tamil Nadu

Impact on Catch Effort/unit operations

Chennai district: In Chennai district about 13 different types of craft-gear combinations have contributed to marine fishery. Based on the 2007-2018 average, the maximum number of units operated were OBGN (3933 units) followed by MTN (1309 units) and MDTN (Table 4.1). However, the percentage contribution to the landings was highest by MDT (55%) followed by MGN (17.6%) and MTN (15.8%) (Table 4.1).

Impact of flood on number of units operated: It was observed that during the 2015 flood, the impact on OBBN, MGN, and OBHL were negative and graded as high, with an estimated reduction of 85.8%, 75.8% and 63.9% respectively during the flood period. Though the impact reduced and became low (9.81%), it remained high for OBBN and OBHL (Table 4.2). The impacts on OBGN was medium (10%) during the flood period and remained in the same category with a slightly higher percentage (24%) in the post flood period. Contrary to this the impact was negative and low with 5% reduction in unit operation for MDTN during the flood period which reduced to 52% during the post flood period. Overall the reduction in unit operation in Chennai district during flood period was medium (29.7%) during the flood period and 36% during post flood period.

Cuddalore district : In Cuddalore about 13 craft–gear combinations have been contributing to the fishery during 2007-2018 period and the maximum number of units operated were estimated as OBGN (7565 units) followed by MTN (2225 units) and OBOTH (2039 units). However, the maximum contribution to catch was by MRS (32.7%) followed by MTN (19.6%) and OBGN (19%) (Table 4.1).

Among all districts, Cuddalore district was the most affected with very high negative impacts on the number of units operated by OBHL, OBGN and MDTN with a reduction of 95.2%, 62.9% and 69% respectively. For the first two sectors the impact reduced to 37.4 and 20 % while for MDTN there was no improvement.

TABLE 4.1 – Average catch (in tonnes) and percentage contribution (in parenthesis) of different craft –gear combinations operated in the flood affected districts of Tamil Nadu (Neg = negligible)

DISTRICT	Craft-Gear	MDTN	MGN	MHL	MTN	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBTN
Chennai	Average catch (t)	20986 (55)	6950 (17.6)	5 (neg)	5519 (15.8)	85 (0.2)	1640 (5)	11(0)	1886 (5.3)	397 (1)	10 (neg)	13(neg)	10 (neg)
Cudallore	Craft-Gear	MDTN	MGN	MPS	MRS	MTN	NM	OBBN	OBGN	OBHL	OBPS	OBRS	OBTN
	Average catch	6513 (8.9)	3856 (7.8)	38 (neg)	21537 (32.7)	15460 (19.6)	236 (0.3)	233 (0.3)	11141 (19)	526 (0.7)	42 (0.1)	7274 (10.5)	22 (neg)
Kancheepuram	Craft-Gear	MDTN	MGN	MPS	MTN	NM	OBBN	OBBS	OBGN	OBHL	OBRS	OBSS	OBTN
	Average catch (t)				92 (0.7)	137 (1.8)	2279 (23.6)	147(2.6)	4676 (55.1)	601(7.6)	741 (7.3)	64 (1)	28 (0.3)
Thanjavur	Craft-Gear	MDTN	MRS	MTN	MHL	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBTN
	Average catch (t)	314.9 (1)	169.3 (1)	20868.1 (71)		159.5 (1)			5891. (24)	68.8 (neg)			308.3 (1)
Thiruvallur	Craft-Gear	MDTN	MRS	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBPS	OBRS	OBSS	OBTN
	Average catch			20 (neg)	79 (4)	7 (neg)	1890 (37)	178(4)	59 (1)	78 (2)	3053(50)	8 (neg)	6 (neg)

The impact on MTN was medium with 10% reduction in number of units operated during the flood period which increased to positive impact during the post flood period with 41% more unit operations. Overall for Cuddalore district there was high negative impact with a reduction of 64% units during flood period which improved to medium impact (20.9%) during the post flood period (Table 4.2).

Kancheepuram: In Kancheepuram district there were about 10 different craft–gear combinations during the period 2007-2018 and the maximum was OBGN (13623 units) followed by MTN (2409 units) and OBTN (2340 units). There were no MDTN operational in this district. The maximum contribution to catch was also by OBGN (55%) while OBBN was the second highest (23.6%) (Table 4.1).

The impact of floods was medium negative with a reduction of 30.4% in the OBGN units operated and low impact, 6.4% reduction in the OBHL sector. The situation improved during the post flood period when there was an increase of 25.4% and 6.2% for OBHL and OBGN respectively. Overall, the impact was medium negative with 30.4% reduction in effort during the flood period which improved by an increase of 9.6% increase in effort during the post flood period (Table 4.2).

Thanjavur : In Thanjavur about 10 different combinations of craft and gear have been operational in the marine fisheries sector during the period 2007 to 2018 and the maximum number of effort was by the OBGN (15497 units) sector followed by NM (3360 units) and OBTN (2977 units). Highest Percentage contribution to the total catch of Thanjavur was by MTN (71%) followed by OBGN (24%) (Table 4.1).

In Thanjavur, there was negative impact in the number of units operated only in the MTN sector. Where only a 2% reduction was observed. However, there was an increase by 25.4% in the post flood season. There was a high positive impact in both OBTN and OBGN sectors during the flood period, which continued to be positive for OBTN but reduced drastically for OBGN. Overall there was high positive impact in the number of fishing units operated along the Thanjavur district during the flood period, but there was a reduction during the post flood period (Table 4.2).

Thiruvallur: In Thiruvallur, there were about 9 craft gear combinations mostly outboards units and no Multiday trawlers and Mechanized units. The maximum number of units were OBGN (4628 units) followed by NM (700 units) and OBHL (492 units). However OBRS contributed highest (50%) to the marine fish landing of Thiruvallur followed by OBGN (37%). In Thiruvallur, there was high positive impact for OBHL and OBGN sectors during the flood and post flood period. Overall there was high positive impact in the unit operations of Thiruvallur district (Table 4.1).

Table 4.2 - Variations in effort in comparison with the pre-flood period (Aug-Oct 2015) by different gears in the flood affected districts of Tamil Nadu during the flood (Nov-Dec 2015) and post flood (Jan-March 2016). (N=Negative; P=Positive)

		Flood				Post Flood			
District		Deviation	Percentage deviation	Rank	Impact	Deviation	Percentage deviation	Rank	Impact
Chennai	Total	-1378.67	-20.70	Medium	N	-2401.67	-36.05	Medium	N
	MDTN	34.33	5.07	Low	P	-353.33	-52.22	High	N
	MGN	-79.83	-75.79	High	N	-10.33	-9.81	Low	N
	MTN	-21.67	-1.99	Low	N	-275.67	-25.28	Medium	N
	OBBN	-322.33	-85.88	High	N	-325.00	-86.59	High	N
	OBGN	-333.50	-10.01	Medium	N	-814.67	-24.44	Medium	N
	OBHL	-665.50	-63.99	High	N	-571.00	-54.90	High	N
Cuddalore	Total	-11813.67	-64.08	High	N	-3854.33	-20.91	Medium	N
	MDTN	-578.83	-69.05	High	N	-612.67	-73.08	High	N
	MTN	-131.17	-10.50	Medium	N	517.33	41.43	Medium	P
	OBGN	-8772.50	-62.93	High	N	-2805.33	-20.12	Medium	N
	OBHL	-1537.17	-95.26	High	N	-603.67	-37.41	Medium	N
Kancheepuram	Total	-5954.17	-30.40	Medium	N	1879.67	9.60	Low	P
	OBGN	-4440.83	-29.79	Medium	N	927.67	6.22	Low	P
	OBHL	-217.00	-6.42	Low	N	860.33	25.46	Medium	P
Thanjavur	Total	11560.33	106.11	High	P	-1679.67	-15.42	Medium	N
	MTN	-63.50	-2.99	Low	N	995.33	46.93	Medium	P
	OBGN	10124.17	124.86	High	P	-4803.67	-59.24	High	N
	OBTN	1378.67	252.35	High	P	1845.67	337.83	High	P
Thiruvallur	Total	7127.33	264.40	High	P	2128.00	78.94	High	P
	OBGN	5923.67	363.12	High	P	1282.00	78.59	High	P
	OBHL	1539.00	551.61	High	P	1310.00	469.53	High	P

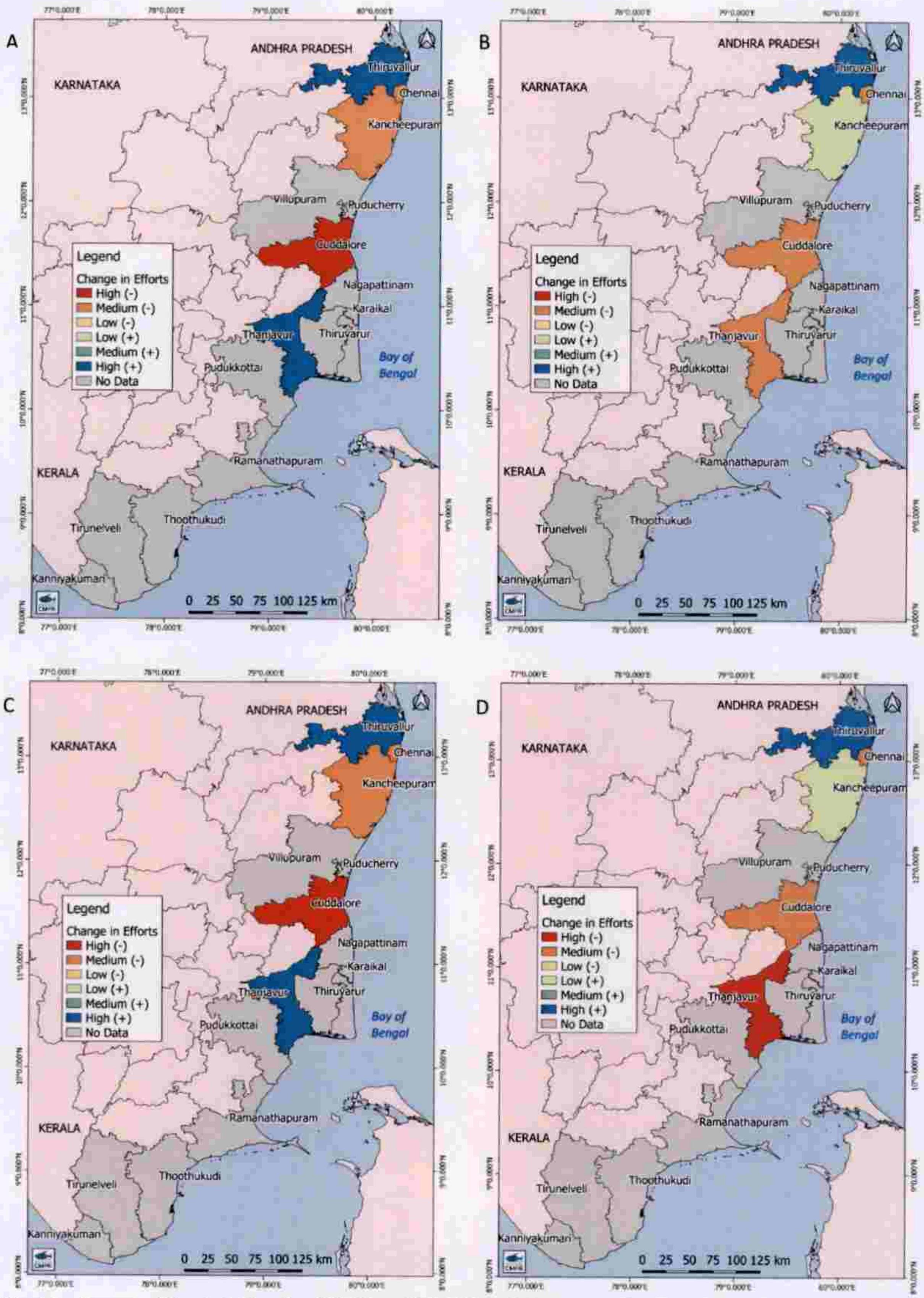

Fig 4.1 - Impact of South Indian flood-2015 on Unit Effort A) Impact on Tamil Nadu total effort during flood period B) Impact TN total effort during post flood period C) Impact on OBGN effort during flood time D) Impact on OBGN effort during post flood period

Impact on Catch:

In Chennai district there was a medium negative impact on the total landings with a reduction of 706 tonnes, ie, a reduction of 16.2% in the flood period. The decrease during the post flood period was much higher; about 3255 tonnes (74.8%) lower than the pre-flood period. Among all the crafts, highest negative impact was seen in OBBN sector (674 units less) with a deduction of 97.6% compared to the pre-flood period and the position remained the same during the post flood period also. Slightly lower reduction but similar situation was observed for OBHL during the flood period (84units less; 84% reduction) and post flood period (78 units less; 81% reduction) (Table 4.3). However, the catch by MTN increased by 170 tonnes about 70.58% more than flood period; but decreased during the post flood period by 91.8 tonnes ie, a reduction by 37%. Similarly, during the flood period, the OBGN catch increased by 36% but decreased by 26.9% in the post flood period.

In Cuddalore district, overall impact was negative. Where the catch was reduced by 3668 tonnes indicate a reduction of 65% in the flood period. However, it improved slightly and the reduction became 23.7% in the post flood period. The catch was reduced for OBHL by about 93.8% and 63% during the flood and post flood period. For OBGN through there was a reduction in catch by 67%, it improved slightly 15.86% during the post flood period (Table 4.3). In the MTN sector also though there a decline of 14.6% during the flood period, the catch improved by 78% with high positive impact during the post flood period.

In Kancheepuram district, the total catch reduced by 67.28% indicating high negative impact which improved to high positive impact during post flood. However, for OBGN the impact was only medium negative which improved and became high positive during post flood. The OBHL fishery remains medium positive with an increase by 38.9% during flood period and 15% increase during post flood (Table 4.3).

Table 4.3 - Variations in catch in comparison with the pre-flood period (Aug-Oct 2015) by different gears in the flood affected districts of Tamil Nadu during the flood (Nov-Dec 2015) and post flood (Jan-March 2016). (N=Negative; P=Positive)

		Flood				Post Flood			
District		Deviation (Tonnes)	Percentage deviation	Rank	Impact	Deviation	Percentage deviation	Rank	Impact
Chennai	Total	-706.34	-16.24	Medium	N	-3255.34	-74.83	High	N
	MDTN	164.71	6.12	Low	P	-2020.90	-75.07	High	N
	MGN	-347.13	-75.03	High	N	-347.70	-75.15	High	N
	MTN	174.14	70.58	High	P	-91.85	-37.23	Medium	N
	OBBN	-674.82	-97.64	High	N	-672.70	-97.33	High	N
	OBGN	57.93	36.18	Medium	P	-43.22	-26.99	Medium	N
	OBHL	-81.49	-84.04	High	N	-78.65	-81.11	High	N
Cuddalore	Total	-3668.25	-65.80	High	N	-1324.34	-23.76	Medium	N
	MDTN	-1059.61	-52.06	High	N	-1523.02	-74.82	High	N
	MTN	-106.64	-14.61	Medium	N	571.89	78.34	High	P
	OBGN	-618.34	-67.28	High	N	145.75	15.86	Medium	P
	OBHL	-99.10	-93.84	High	N	-66.47	-62.94	High	N
Kancheepuram	Total	-998.52	-67.30	High	N	979.30	66.01	High	P
	OBGN	-142.43	-31.79	Medium	N	375.21	83.75	High	P
	OBHL	50.29	38.92	Medium	P	19.57	15.15	Medium	P
Thanjavur	Total	1519.07	87.65	High	P	908.28	52.41	High	P
	MTN	1092.09	74.69	High	P	1033.02	70.65	High	P
	OBGN	427.22	173.01	High	P	-138.40	-56.05	High	N
	OBTN	15.09	238.09	High	P	20.20	318.61	High	P
Thiruvallur	Total	-386.58	-52.82	High	N	-302.35	-41.31	Medium	N
	OBGN	214.26	248.34	High	P	13.14	15.23	Medium	P
	OBHL	31.85	334.39	High	P	41.24	432.88	High	P

In Thanjavur, the total catch improved by 87.65% during the flood period indicating high positive impact, which continued even during the post flood period. The MTN, OBGN and OBTN and catch also improved during the flood period (Table 4.3). Though the catch did not decline in MTN and OBTN gears, there was a drastic decline in OBGN catch making the impact highly negative.

At Thiruvallur the overall impact was a reduction by 52% making the impact highly negative during the flood period, but this improved during the post flood period to medium negative. The catch by OBGN and OBHL gears were positivity impacted during the flood and post flood period (Table 4.3).

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Impact on Catch per Unit Effort (CPUE)

The impacts and the percentage deviation of CPUE from Pre-flood period for different gears operated along the flood affected districts of Tamil Nadu are presented in Table 4.4. The CPUE was negatively impacted during the flood and post flood period for OBBN which were operated along Chennai coast. For MDTN operated along Chennai and Cuddalore the CPUE was positive during the flood period but reduced highly and became negative during the post flood period. The CPUE of MTN operated from Cuddalore and Thanjavur increased during the flood and post flood period. In Chennai, though the CPUE of MTN increased during flood period, it decreased during post flood period. But differed widely during the post flood period in Chennai.In Chennai the CPUE of OBGN increased during the flood and post flood period. The CPUE reduced for OBGN during the flood period but increased subsequently in Kancheepuram and Cuddalore. At Thanjavur and Thiruvallur the CPUE of OBGN did not increase during the post flood period. The CPUE of OBHL decreased and was negatively impacted in Chennai and Cuddalore during the flood and post flood period but was found to increase at Kancheepuram and Thiruvallur. In Thiruvallur, CPUE decreased slightly during post flood period (Table 4.4).

Table 4.4 - Variations in CPUE in comparison with the pre-flood period (Aug-Oct 2015) by different gears in the flood affected districts of Tamil Nadu during the flood (Nov-Dec 2015) and after the flood (Jan-March 2016). (N=Negative; P=Positive)

		Flood				Post Flood			
District	Gear	Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
Chennai	MDTN	20.36	P	0.51	Low	-1816.14	N	-45.64	High
	MGN	-113.01	N	-2.51	Low	-3282.42	N	-73.04	High
	MTN	162.31	P	74.26	High	-43.31	N	-19.81	Medium
	OBBN	-1390.82	N	-74.81	High	-1505.12	N	-80.95	High
	OBGN	25.96	P	55.08	High	1.15	P	2.43	Low
	OBHL	-44.36	N	-51.33	High	-50.95	N	-85.61	High
Kancheepuram	OBGN	-4.80	N	-16.04	Medium	15.04	P	50.23	High
	OBHL	0.48	P	1.70	Low	12.73	P	45.60	Medium
Cuddalore	MDTN	1440.76	P	62.42	High	-796.52	N	-34.51	Medium
	MTN	36.91	P	6.51	Low	92.99	P	16.39	Medium
	OBGN	-10.53	N	-15.00	Medium	11.37	P	16.20	Medium
	OBHL	-39.25	N	-32.27	Medium	-64.87	N	-53.33	High
Thanjavur	MTN	603.36	P	87.46	High	113.53	P	16.46	Medium
	OBGN	-6.21	N	-14.78	Medium	-7.58	N	-18.04	Medium
	OBTN	3.68	P	49.32	Medium	-0.08	N	-1.24	Low
Thiruvallur	OBGN	-9.69	N	-20.42	Medium	-10.73	N	-22.61	Medium
	OBHL	3.82	P	12.27	Medium	-0.81	N	-2.59	Low

Impact of South India flood on the marine species assemblage of commercial fishing grounds of Tamil Nadu

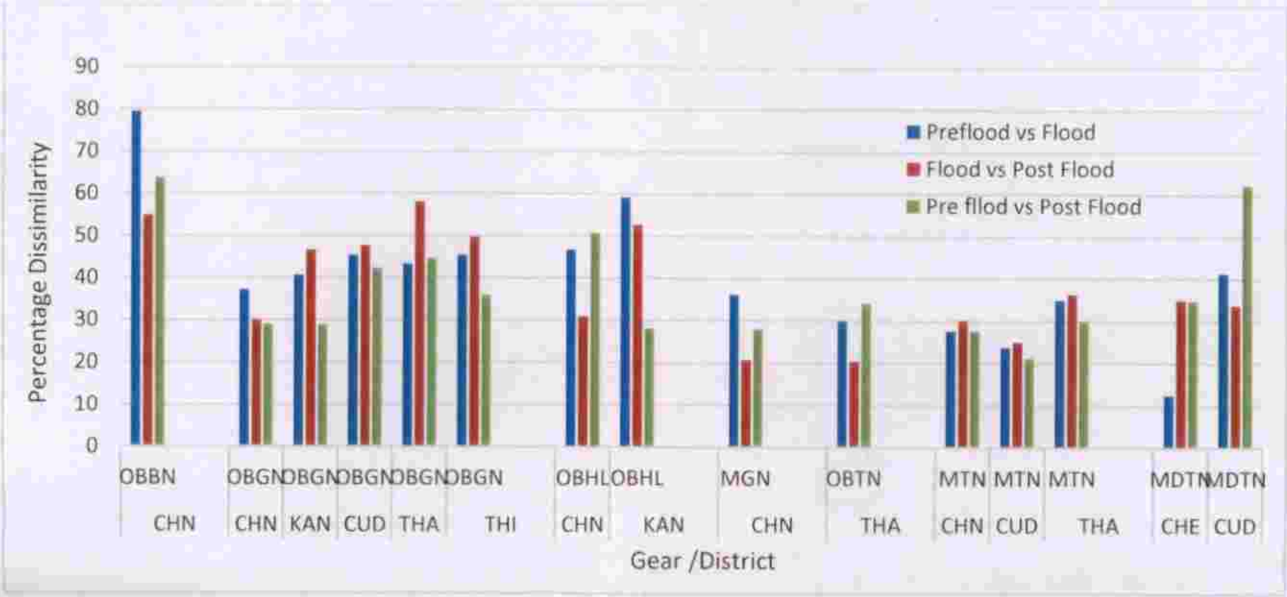

Fig 4.2 - Percentage dissimilarity in the species / group composition of landings by different gears operated in the South India 2015 flood affected districts of Tamil Nadu

Table 4.5 Percentage dissimilarity in the species / group composition of landings by different gears operated in the South India 2015 flood affected districts of Tamil Nadu

		Pre-flood vs Flood	Flood vs Post Flood	Pre-flood vs Post Flood
Chennai	OBBN	79.54	54.85	63.86
Chennai	OBGN	37.18	30.04	29.02
Kancheepuram	OBGN	40.62	46.6	28.87
Cuddalore	OBGN	45.41	47.7	42.38
Thanjavur	OBGN	43.38	58.1	44.74
Thiruvallur	OBGN	45.5	49.84	36.03
Chennai	OBHL	46.76	30.98	50.72
Kancheepuram	OBHL	59.21	52.73	28.21
Chennai	MGN	36.07	20.76	28.09
Thanjavur	OBTN	30.04	20.54	34.18
Chennai	MTN	27.66	30.14	27.66
Cuddalore	MTN	23.86	25.03	21.34
Thanjavur	MTN	34.96	36.35	30.03
Chennai	MDTN	12.49	35.01	34.81
Cuddalore	MDTN	41.26	33.8	62.24

SPECIES ASSEMBLAGE VARIATION

OBBN

High variation in species assemblage as indicated by the catch was in the OBBN operated in the near shore waters off Chennai. The dissimilarity percentage as per SIMPER was highest (79.54%) during the flood period which reduced (54.85%) during the post flood period (Table 4.5 ; Fig 4.2). There was high difference between the pre-flood and post flood fish assemblage (63.86%). The main dissimilarity was due to the decline in contribution by sardine (37.9%) and *Stolephorus* (18.62%). Indian mackerel, *Stolephorus*, and *Thryssa* which are seen in these grounds were absent during the flood period. Lobsters, Other clupeids and other sardines were present only during the flood period (Table 4.8).

OBGN

The variation in resource obtained in the Out board gill nets operated off different districts showed wide variation. In all the districts the variation between the species/groups contributing to catch during the Pre-flood and flood period was *medium* with percentage dissimilarity ranging between 37.18% in Chennai to 45.5 % in Thiruvallur (Table 4.5 ; Fig 4.2). The variation between post flood and flood species/group assemblage was medium raning between 30.04% in Chennai to 49.84% in Thiruvallur. In Thanjavur, the dissimilarly was high (58%). However, the dissimilarity between species/group assemblage reduced at Chennai (29.02%) and Kancheepuram (28.87%). Though the dissimilarity reduced in other districts it was 36.03, 42.38 and 44.74 percentages in Thiruvallur, Cuddalore and Thanjavur respectively.

In Chennai there was an increase in catch of other sardine and penaeid prawns during the flood period this contributed to 18.14% and 4.85% of the dissimilarity. Further the drastic reduction in catch of oil sardine, Indian mackerel, and crabs which had contributed highly in the pre-flood period is also a visible change, contributing to 10.29, 6.89 and 3.29 percentage respectively to the dissimilarity as observed from the SIMPER results. Moreover, fishes like halibut and flying fish were also absent during the flood period. During the post flood period, the catch of other sardines other shads, oil sardine, penaeid prawns, Indian mackerel increased and the former three contributed the most; 17, 14.68 and 9.79 percentage to the dissimilarity in the assemblage of resources caught by the gillnet (Table 4.9a).

In Kancheepuram, there was an increase in cuttlefish landing during the flood period which led to 17.7% contribution to the dissimilarity. Similarly, there was a drastic reduction in landings of other sardines during the flood period which contributed to 15.07% of the variation (Table 4.9a). Reduction in catch of mackerel and absence of oil sardine during the flood period led to 9.73 and 9.27 percentage dissimilarity. During the post flood period sharp increase in Mackerel landing and other sardine landing led to a change in resource assemblage and these two resources contributed 21.2 and 11.87% respectively to the variation. The decline in cuttlefish landing along with increase in carangid landing was responsible for 8.13 and 6.14% dissimilarity.

In Cuddalore there was a drastic reduction in the catch of penaeid prawn, other carangids during the flood period which contributed to 9.14 and 6.61% of the dissimilarity in the species assemblage between pre-flood and flood (Table 4.9a). Moreover there was an increase in catch of Indian mackerel which contributed to 5.03% of dissimilarity in species assemblage during flood period. However there was an increase in catch of catfishes, and rays which contributed to 19.79 and 9.52 % of the difference in assemblage, catch of several species and groups like threadfin breams, crabs, other carangids, mackerel, scads, cuttlefish and soles increased during the post flood period.

In Thanjavur, there was an increase in catch of other carangids, wolf herring, crabs and catfishes during the flood period each contributing to 13.21, 10.14, 6.08 and 6 percentage of the dissimilarity in species assemblage between pre-flood and flood period. There was also complete absence of half beaks and full beaks and leather jackets during the flood period and these contributed 12, 52 and 6.47% of the comparative resource assemblage. In the post flood period, through almost similar resources were there the catch declined the variation in landing of other carangids, *S.commersoni*, threadfins and wolf herring contributed to 12.2, 11.51, 11.41 and 10.34% of the assemblage variation (Table 4.9b).

In Thiruvallur, there was an increase in the catch of Indian mackerel, rays and crabs during the flood period and their percentage contribution to the species assemblage change was 12.23, 10.04 and 6.89 respectively. The decline in catfish landing during the post flood period contributed to 8.36% of the dissimilarity (Table 4.9b).

OBHL

In Chennai, five resources contributed mainly to the average dissimilarity of 46.76 % between Pre-flood and flood assemblage. The complete absence of bill fishes, *K.pelamis*, and other tunnies contributed to 21.41, 12.92 and 10.43% of the dissimilarity and reduced catch of Auxis spp and other carangids contributed to 14.31 and 11.95% dissimilarity (Table 4.10). During the post flood period, occurrence of horse mackerel which was absent in the community during flood period lead to 18.38% dissimilarity. Similarly absence of soles in post flood period, decreased presence of other perches and leather jackets led to 9.72, 9.08 and 8.9 % of dissimilarity.

In Kancheepuram where the dissimilarity of the pre-flood and flood was quite high (59.21), the increase in catch of barracuda was responsible for 19.46% variation. The presence of leather jackets and *Auxis* spp which were absent in pre-flood lead to 11.04 and 10.17% of the dissimilarity while absence of *K. pelamis* in the flood period lead to 10.68% dissimilarity. During the post flood period, the catch of barracudas declined and there was landing of leather jackets which led to 10.89 and 6.75 percentage dissimilarity of the resource assemblage. The landing of snappers, *E. affinis* and other perches which were absent in the pre-flood period contributed to 7.47, 4.77 and 4.67 percentages of the dissimilarity. The average dissimilarity was 52.73 between the resource assemblage of post-flood and flood period (Table 4.10).

MGN

In Chennai in the MGN fishing area there was a reduction in abundance of species /groups contributing to the fishery and the decline in abundance of *Auxis spp*, other tunnies, bill fishes and *K. pelamis* contributed 15.5, 14.07, 13.84 and 13.17 percentage in the dissimilarity (28.92) estimated for the resource assemblage (Table 4.8). During the post flood period the abundance of resources increased especially other carangids, rays and *S. commersoni*, the contributions being 12.15, 11.95 and 10.91 percentage respectively.

MDTN

In the MDTN catches, there was an increase in landing of penaeid prawn indicating its dominance which contributed 9.95% of the dissimilarity. Another difference was there was abundance of mullets during the flood period; these were absent during the pre-flood period and this contributed to 7.58% of the dissimilarity. The increase in other sardines and crabs contributed 6.99 and 6.67% of the dissimilarity. During the post flood period, there was a reduction in catch of most species and the catch of crab, penaeid prawns and other carangids declined and this contributed to 7.66, 7.34 and 6.99 percentage of the dissimilarity observed (Table 4.6).

At Cuddalore, the catch of cuttlefish, squids and octopuses declined and this contributed to 21.84, 17.24 and 11.55% of the dissimilarity in species assemblage observed between pre-flood and flood period (Table 4.6). However, the abundance of crabs increased during the flood period. During the post flood period, there was a further decrease in landings of crabs cuttlefishes and squids which contributed to 20.95, 14.86 and 9.30 percentage dissimilarity which was estimated as 33.8.

Table 4.6 - Results of SIMPER test on resources caught by MDTN in the flood affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed

Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative Percentage
CHENNAI					
Average Dissimilarity : Pre-flood & Flood - 12.49%					
Penaeid prawns	13.32	20.41	1.24	9.95	9.95
Mullets	0	5.39	0.95	7.58	17.52
Other sardines	2.89	7.86	0.87	6.99	24.51
Crabs	13.26	18.01	0.83	6.67	31.19
Snappers	4.92	0.99	0.69	5.52	36.7
Average Dissimilarity : Flood & Post flood - 35.01%					
Crabs	18.01	6.34	2.68	7.66	7.66
Penaeid prawns	20.41	9.22	2.57	7.34	15
Other carangids	14.53	3.87	2.45	6.99	22
Scads	14.52	4.62	2.27	6.5	28.49
Ribbon Fishes	16.08	7.52	1.97	5.62	34.12
Average Dissimilarity : Pre-flood & Flood - 34.81%					
Other carangids	15.86	3.87	2.77	7.97	7.97
Scads	14.24	4.62	2.23	6.4	14.37
Miscellaneous	10.09	3.02	1.63	4.7	19.07
Crabs	13.26	6.34	1.6	4.6	23.67
Other perches	13.09	6.35	1.56	4.48	28.15
E. affinis	6.74	0	1.56	4.48	32.64
CUDDALORE					
Average Dissimilarity : Pre-flood & Flood -41.26%					
Cuttlefish	440.9	154	9.01	21.84	21.84
Squids	353.8	127.3	7.11	17.24	39.07
Octopus	240.8	89	4.77	11.55	50.63
Average Dissimilarity : Flood & Postflood-33.8%					
Crabs	140	31.9	7.08	20.95	20.95
Cuttlefish	154	77.3	5.02	14.86	35.81
Squids	127.3	79.3	3.14	9.3	45.11
Octopus	89	47.9	2.69	7.96	53.07
Average Dissimilarity : Pre-flood & Postflood-62.24%					
Cuttlefish	440.9	77.3	13.43	21.59	21.59
Squids	353.8	79.3	10.14	16.3	37.88
Octopus	240.8	47.9	7.13	11.45	49.34
Threadfin breams	77.8	10.3	2.49	4.01	53.34

Table 4.7- Results of SIMPER test on resources caught by MGN in the flood affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
CHENNAI					
Average Dissimilarity Pre-flood &Flood - 36.07%					
Auxis. spp	9.11	3.46	5.61	15.55	15.55
Other tunnies	9.1	3.98	5.08	14.07	29.62
Bill Fishes	11.42	6.39	4.99	13.84	43.47
K. pelamis	8.21	3.42	4.75	13.17	56.63
Average Dissimilarity Flood & Post flood - 20.76%					
Other carangids	0.93	2.89	2.52	12.15	12.15
Rays	3.2	5.13	2.48	11.95	24.11
S. commersoni	0.68	2.44	2.26	10.91	35.01
Leather-jackets	0.32	1.75	1.85	8.91	43.92
S. guttatus	0	1.39	1.79	8.61	52.53
Average Dissimilarity Pre-flood & Post flood - 28.92%					
Auxis. spp	9.11	4.19	4.36	15.07	15.07
Bill Fishes	11.42	6.88	4.02	13.91	28.98
Other tunnies	9.1	4.75	3.85	13.3	42.28
K. pelamis	8.21	4.18	3.57	12.35	54.63

Table 4.8 - Results of SIMPER test on resources caught by OBBN in the flood affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
CHENNAI					
Average Dissimilarity Pre-flood & Flood - 79.54%					
Oil sardine	24.44	3.29	37.94	47.69	47.69
Stolephorus	10.39	0	18.64	23.44	71.13
Average Dissimilarity Flood & Post flood - 54.85%					
Stolephorus	0	3.33	13.64	24.86	24.86
Other sardines	2.85	0	11.67	21.28	46.14
Other clupeids	1.34	0	5.5	10.03	56.17
Average Dissimilarity Pre-flood & Post flood - 63.86%					
Oil sardine	24.44	3.1	36.02	56.4	56.4
Stolephorus	10.39	3.33	11.92	18.67	75.06

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Table 4.9a - Results of SIMPER test on resources caught by OBGN in the flood affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
CHENNAI					
Average dissimilarity Pre-flood & Flood - 37.18%					
Other sardines	4.39	12.15	6.74	18.14	18.14
Oil sardine	4.39	0	3.81	10.24	28.38
Flying Fishes	3.34	0	2.9	7.8	36.18
Average dissimilarity Flood & Post flood - 36.04%					
Other sardines	12.15	5.91	6.13	17	17
Other shads	0	5.39	5.29	14.68	31.68
Oil sardine	0	3.59	3.53	9.79	41.47
Flying Fishes	0	2.57	2.52	6.99	48.46
Crabs	3.27	1.27	1.97	5.46	53.92
Average dissimilarity Pre-flood & Post flood - 29.02%					
Other shads	0.35	5.39	4.38	15.08	15.08
Crabs	4.76	1.27	3.03	10.43	25.52
Croakers	4.77	1.91	2.48	8.54	34.06
Indian mackerel	5.16	3.42	1.51	5.21	39.27
Catfishes	1.69	0	1.47	5.06	44.32
CUDDALORE					
Average dissimilarity Pre-flood & Flood - 45.41%					
Penaeid prawns	13.39	3.57	4.15	9.14	9.14
Other carangids	10.47	3.36	3	6.61	15.75
Goatfishes	7.2	1.34	2.48	5.45	21.2
Black pomfret	5.65	0	2.38	5.25	26.45
Indian mackerel	5.42	0	2.29	5.03	31.48
Average dissimilarity Flood & Post flood - 47.7%					
Catfishes	1.87	22.38	9.44	19.79	19.79
Rays	0	9.86	4.54	9.52	29.31
Threadfin breams	3.3	12.78	4.36	9.15	38.46
Cuttlefish	0	7.51	3.46	7.24	45.7
Other carangids	3.36	10.14	3.12	6.54	52.24
Average dissimilarity Pre-flood & Postflood-42.38%					
Catfishes	1.07	22.38	6.95	16.41	16.41
Rays	1.43	9.86	2.75	6.49	22.9
Penaeid prawns	13.39	5.63	2.53	5.98	28.87
Oil sardine	7.49	0	2.44	5.77	34.64
S. guttatus	6.36	0	2.08	4.9	39.54
KANCHEEPURAM					
Average dissimilarity Pre-flood & Flood - 40.62%					
Cuttlefish	4.47	16.61	7.19	17.7	17.7
Other sardines	10.34	0	6.12	15.07	32.77
Indian mackerel	8.4	1.73	3.95	9.73	42.49
Oil sardine	6.36	0	3.77	9.27	51.77
Average dissimilarity Flood & Post flood - 46.6%					
Indian mackerel	1.73	20.81	9.88	21.2	21.2
Other sardines	0	10.68	5.53	11.87	33.08
Cuttlefish	16.61	9.3	3.79	8.13	41.21
Other carangids	3.79	9.32	2.86	6.14	47.35
Penaeid prawns	4.98	0	2.58	5.53	52.88
Average dissimilarity Pre-flood & Post flood - 28.87%					
Indian mackerel	8.4	20.81	5.73	19.84	19.84
Oil sardine	6.36	0.82	2.55	8.85	28.69
Cuttlefish	4.47	9.3	2.23	7.71	36.4
Goatfishes	4.39	0	2.03	7.02	43.42
Rays	6.83	3.32	1.62	5.61	49.03

Table 4.9b -

Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THANJAVUR					
Average dissimilarity Pre-flood & Flood - 43.38%					
Other carangids	3.32	12.88	5.73	13.21	13.21
Half Beaks & Full Beaks	9.06	0	5.43	12.52	25.73
Wolf herring	5.54	12.88	4.4	10.14	35.87
Leather-jackets	4.68	0	2.81	6.47	42.34
Crabs	7.24	11.63	2.64	6.08	48.42
Catfishes	2.18	6.52	2.6	6	54.42
Average dissimilarity Flood & Post flood - 58.1%					
Other carangids	12.88	3.1	7.1	12.22	12.22
S. commersoni	12.34	3.13	6.69	11.51	23.74
Threadfins	9.13	0	6.63	11.41	35.15
Wolf herring	12.88	4.61	6.01	10.34	45.48
Crabs	11.63	3.69	5.76	9.92	55.41
Average dissimilarity Pre-flood & Post flood - 44.74%					
Half Beaks & Full Beaks	9.06	0	8.44	18.86	18.86
S. commersoni	8.2	3.13	4.72	10.55	29.42
Threadfins	4.94	0	4.6	10.29	39.71
Croakers	3.85	0	3.59	8.03	47.73
Crabs	7.24	3.69	3.3	7.37	55.11
THIRUVALLUR					
Average dissimilarity Pre-flood & Flood - 45.5%					
Indian mackerel	1.77	7.93	5.56	12.23	12.23
Rays	1.85	6.91	4.57	10.04	22.27
Catfishes	7.04	2.83	3.8	8.36	30.63
Crabs	3.71	7.18	3.13	6.89	37.51
Thryssa	1.72	4.76	2.75	6.04	43.55
Average dissimilarity Flood & Post flood - 49.84%					
Indian mackerel	7.93	2.92	3.91	7.85	7.85
Rays	6.91	2.15	3.71	7.45	15.3
Other sardines	0	4.5	3.51	7.05	22.34
Crabs	7.18	3.43	2.93	5.88	28.22
K. pelamis	0	3.11	2.43	4.87	33.09
Soles	4.08	1.38	2.11	4.24	37.33
Average dissimilarity Pre-flood & Post flood - 36.03%					
Catfishes	7.04	0.94	5.53	15.34	15.34
Other sardines	0	4.5	4.07	11.3	26.64
Goatfishes	1.3	4.71	3.09	8.58	35.21
Leather-jackets	0	2.35	2.13	5.9	41.12
Half Beaks & Full Beaks	0	2.22	2.01	5.58	46.7

Table 4.10 - Results of SIMPER test on resources caught by OBHL in the flood affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
CHENNAI					
Average Dissimilarity Pre-flood & Flood - 46.76%					
Bill Fishes	5.05	0	10.01	21.41	21.41
Auxis. spp	4.68	1.3	6.68	14.3	35.7
K. pelamis	3.05	0	6.04	12.92	48.62
Other carangids	4.84	2.02	5.59	11.95	60.57
Average Dissimilarity Flood & Post flood - 30.98%					
Horse Mackerel	0	1.67	5.7	18.38	18.38
Soles	0.88	0	3.01	9.72	28.1
Other perches	1.47	0.65	2.81	9.08	37.18
Leather-jackets	1.23	0.42	2.76	8.9	46.08
E. affinis	2.1	2.85	2.55	8.24	54.33
Average Dissimilarity Pre-flood & Post flood - 50.72%					
Bill Fishes	5.05	0	9.85	19.42	19.42
Auxis.spp	4.68	0.73	7.7	15.18	34.6
Other carangids	4.84	1.69	6.14	12.1	46.71
K. pelamis	3.05	0	5.94	11.72	58.43
KANCHEEPURAM					
Average Dissimilarity Pre-flood & Flood - 59.21%					
Barracudas	2.68	13.78	11.52	19.46	19.46
Leather-jackets	0	6.3	6.53	11.04	30.49
K. pelamis	6.1	0	6.32	10.68	41.17
Auxis. spp	0	5.81	6.02	10.17	51.35
Average Dissimilarity Flood & Post flood - 52.73%					
Barracudas	13.78	3.62	10.89	20.66	20.66
Snappers	0	6.97	7.47	14.17	34.83
Leather-jackets	6.3	0	6.75	12.8	47.63
E. affinis	0	4.45	4.77	9.05	56.68
Average Dissimilarity Pre-flood & Post flood - 28.21%					
K. pelamis	6.1	0	5.88	20.84	20.84
Threadfin breams	0	3.15	3.04	10.78	31.62
Auxis. spp	0	2.33	2.25	7.97	39.6
Snappers	4.82	6.97	2.08	7.37	46.97
Acanthocybium spp.	2.02	0	1.95	6.91	53.88

4.2 Environmental changes during the months of flood on Tamil Nadu coast

Chennai

Compared to previous months, SST decreased in November and December months (Fig 4.3). Chlorophyll-*a* concentration increased in December (0.39 to 1.19 mgm^3) (Fig 4.4). Rainfall was peak in November (+674.26 mm) (Fig 4.5). In November, LTA was positive (+0.39) and sharply declined in December (Fig 4.6). CPUE of NM and OBGN gears increased in the flood months (Fig 4.18 and 4.20). But the CPUE of OBHL showed a decrease (Fig 4.21). CPUE of OBBN was low in November and increased in December (Fig 4.22). Total catch declined in November (-665 tonnes) (Fig 4.9). The landing of Indian mackerel decreased (Fig 4.12).The other sardines catch significantly increased in the flood period (Fig 4.10).

Cuddalore

Both the SST and Chlorophyll-*a* concentration decreased (Fig 4.3 and 4.4). Salinity declined (32.8 to 31.9 ppt) (Fig 4.7). Current speed considerably increased in December (Fig 4.8). Rainfall was significantly high (+333.27 mm) (Fig 4.5). Total catch (-531 tonnes in November) and OBGN-CPUE was very low (Fig 4.9 and 4.20). But the OBHL CPUE increased (48.89 to 69.75) (Fig 4.21). Indian mackerel and croakers landing increased in the flood months (Fig 4.12, and 4.16).

Kancheepuram

Compared to previous months, SST slightly decreased (Fig 4.3). Chorophyll-*a* concentration rapidly increased in November and there after decreased (Fig 4.4). A record rainfall of 1061 mm occurred in November 2015 (Fig 4.5). Salinity decreased to 30.6 ppt (Fig 4.7). Current velocity was high in November and decreased in December (Fig 4.8). CPUE of OBGN and OBHL gears decreased in November and peaked in December (Fig 4.20 and 4.21). Total catch decreased to 86 tonnes (-535 tonnes) in November (Fig 4.9). The landing of crabs and silver bellies increased in December (Fig 4.11 and 4.13). In post flood months, other sardine catch increased (Fig 4.10).

Thanjavur

Compared to normal and previous months, SST slightly decreased and Chlorophyll concentration increased (Fig 4.3 and 4.4). SLA peaked during flood (Fig 4.8). LTA value was high (Fig 4.6). Rainfall showed an increase during these months (Fig 4.5). Increase in total catch was high in November (+1081 tonnes) and decreased in December (-951 tonnes) (Fig 4.9). CPUE of OBGN decreased (45.4 to 39.3) and OBHL increased (0 to 10.25) in November (Fig 4.20 and 4.21). The landings of catfish, crabs and silver pomfret increased in November (Fig 4.13, 4.14 and 4.17). Catch of croakers increased in December (Fig 4.16).

Thiruvallur

Compared to previous months, SST slightly decreased (Fig 4.3). Rainfall increased sharply during these flood months (Fig 4.5). Total catch increased in December (+394 tonnes) (Fig 4.9). The landings of croakers and catfishes increased (Fig 4.16 and 4.17). Landings of Indian mackerel and crabs increased in December (Fig 4.12 and 4.13). A sharp increase was noticed in the crab and *Thryssa* landings (Fig 4.15). CPUE of NM and OBHL increased in November (Fig 4.18 and 4.21). CPUE of OBGN increased in November and slightly decreased in December (Fig 4.20).

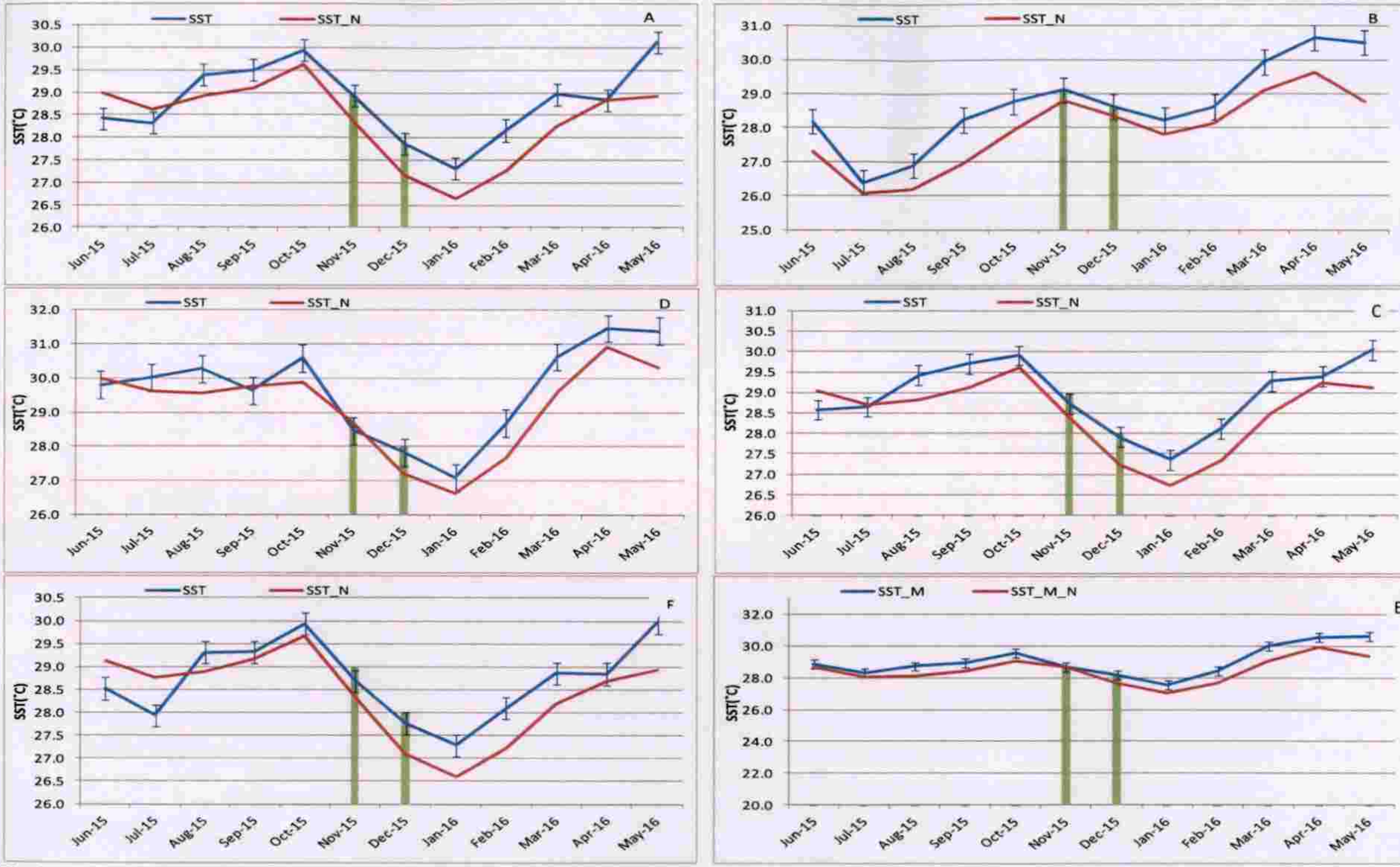

Fig 4.3 - Monthly mean SST (Sea surface temperature) and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; SST_M: Monthly mean SST, SST_M_N: Month wise 10 year average Sea Surface Temperature

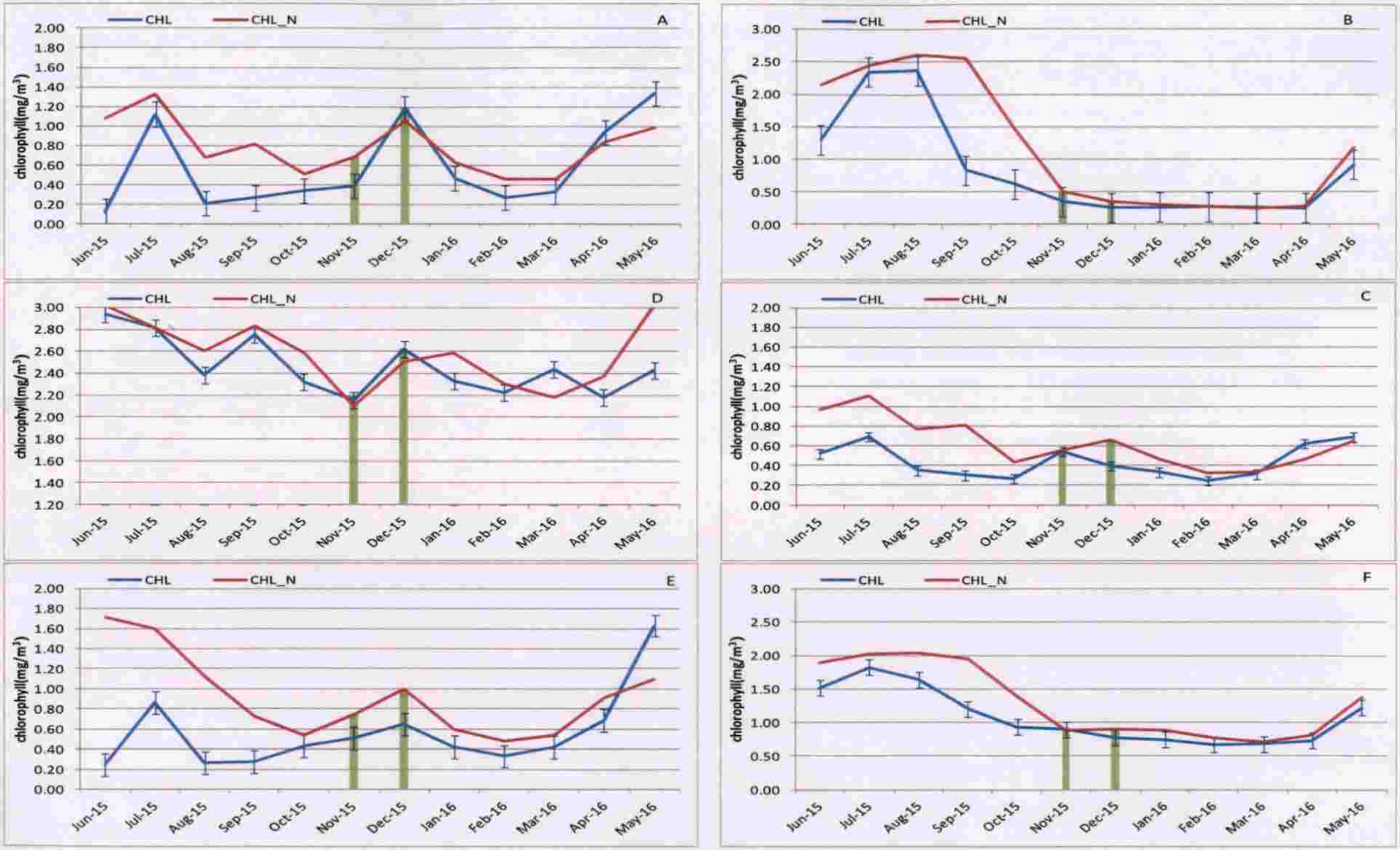

Fig 4.4 - Monthly mean Chlorophyll-*a* concentration and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; CHL: Monthly mean Chlorophyll concentration, CHL_N: Month wise 10 year average Chlorophyll concentration

Fig 4.5 - Monthly Rainfall from and standard error June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; RF: Monthly rainfall, RF_N: Month wise 10 year average Rainfall

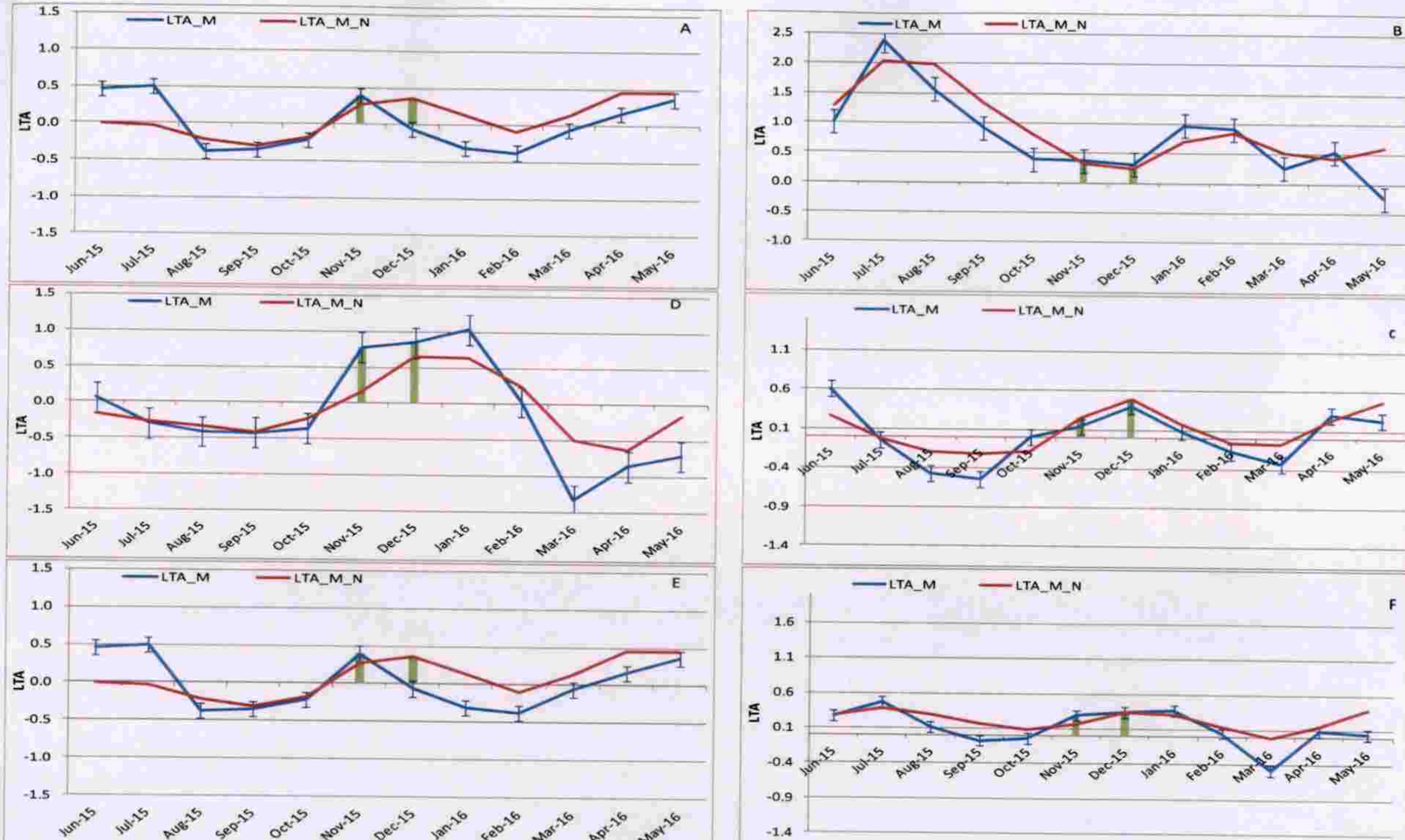

Fig 4.6 - Monthly mean LTA (Local Temperature Anomaly) values and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; LTA: Monthly mean LTA value, LTA_M_N: Month wise 10 year average LTA Value

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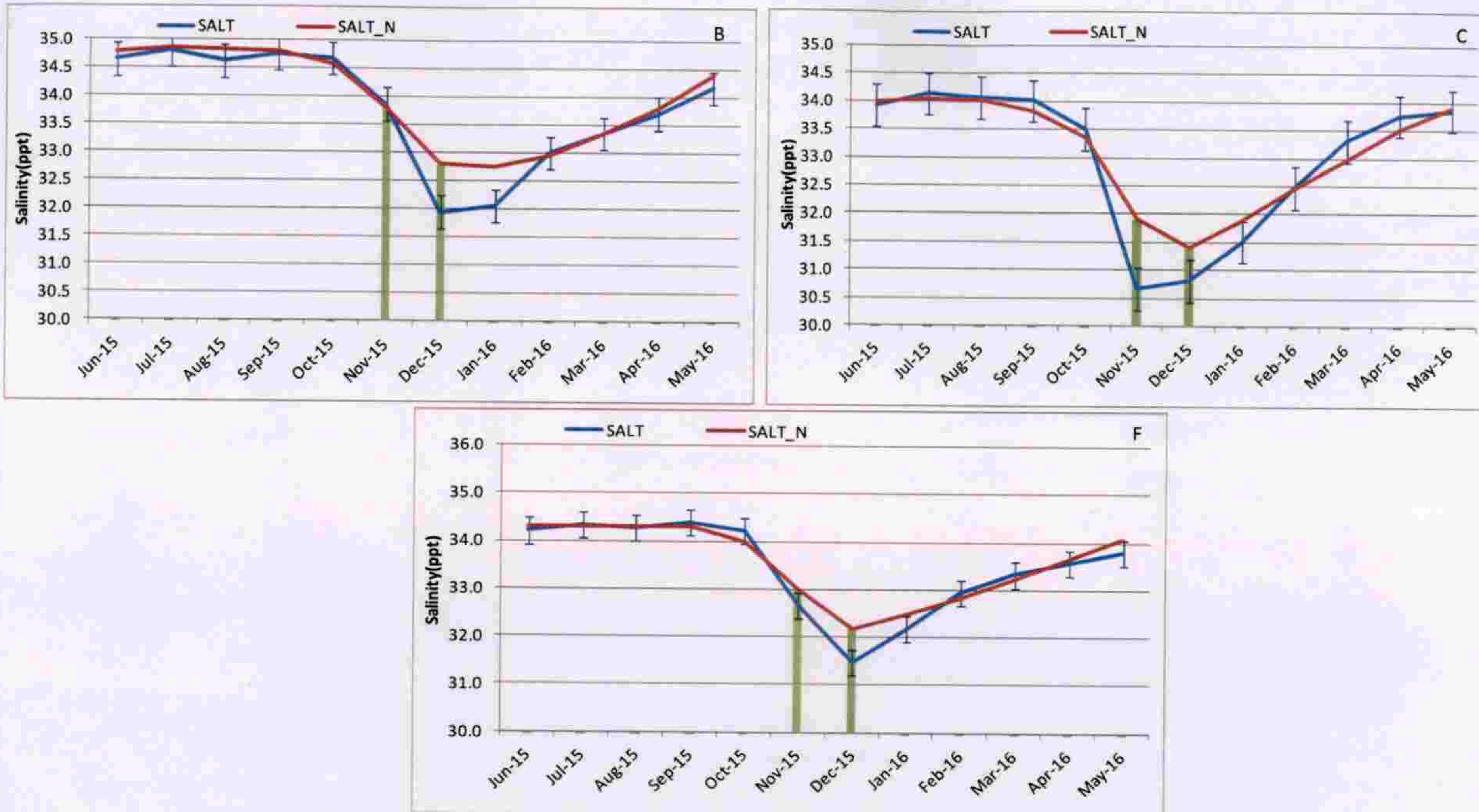

Fig 4.7 - Monthly mean sea surface salinity and standard error from June 2015 to May 2016; B) Cuddalore C) Kancheepuram F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; SALT: Monthly mean sea surface salinity, SALT_N: Month wise 10 year average sea surface salinity

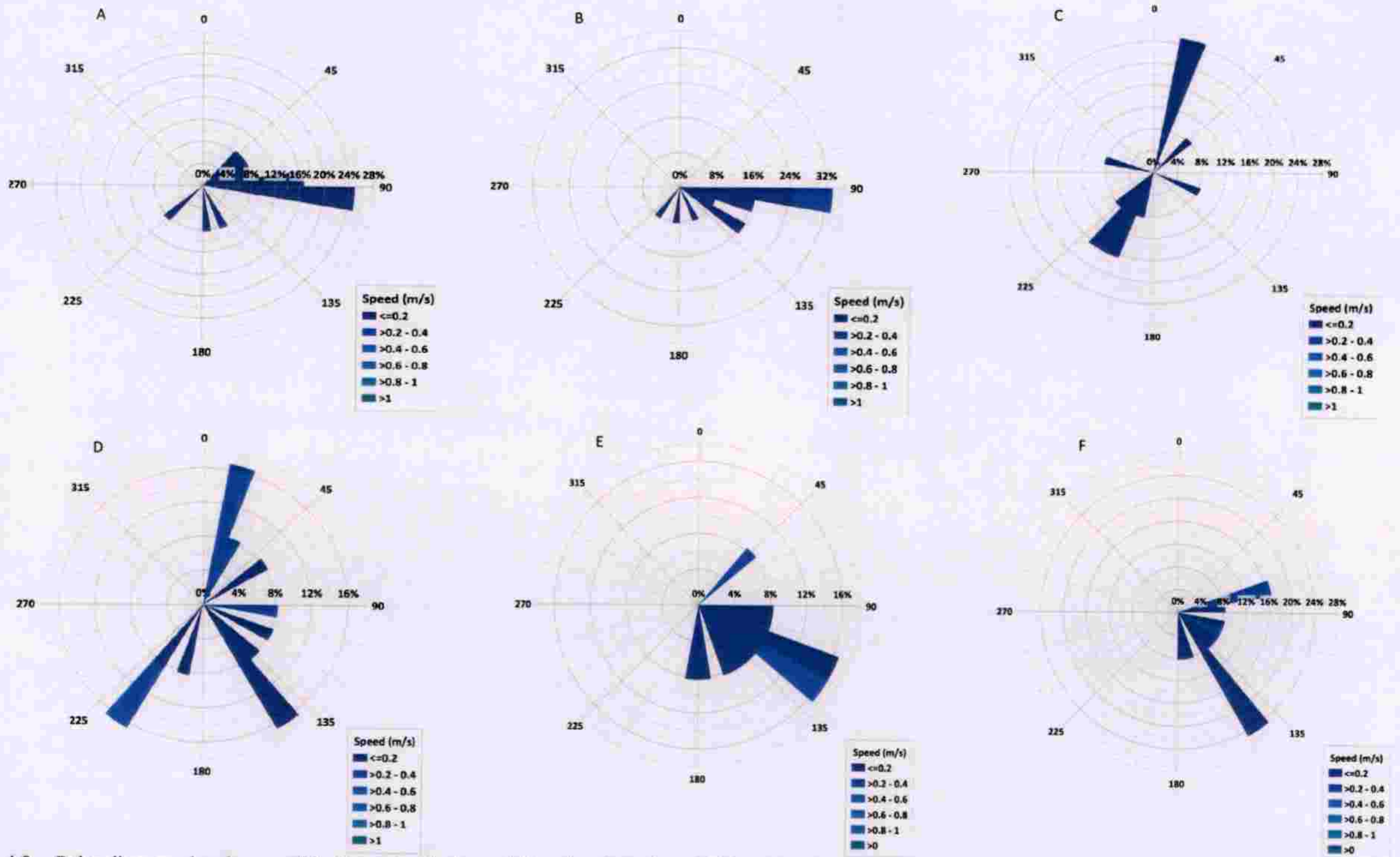

Fig 4.8 – Polar diagram showing monthly Current velocity and direction from June 2015 to May 2016; A) Cuddalore B) Month wise 10 year average Cuddalore current velocity & direction in Cuddalore coast C) Kancheepuram D) Month wise 10 year average Kancheepuram current velocity and direction in the Kancheepuram coast E) Tamil Nadu F) Month wise 10 year average Cuddalore current velocity & direction in Tamil Nadu coast

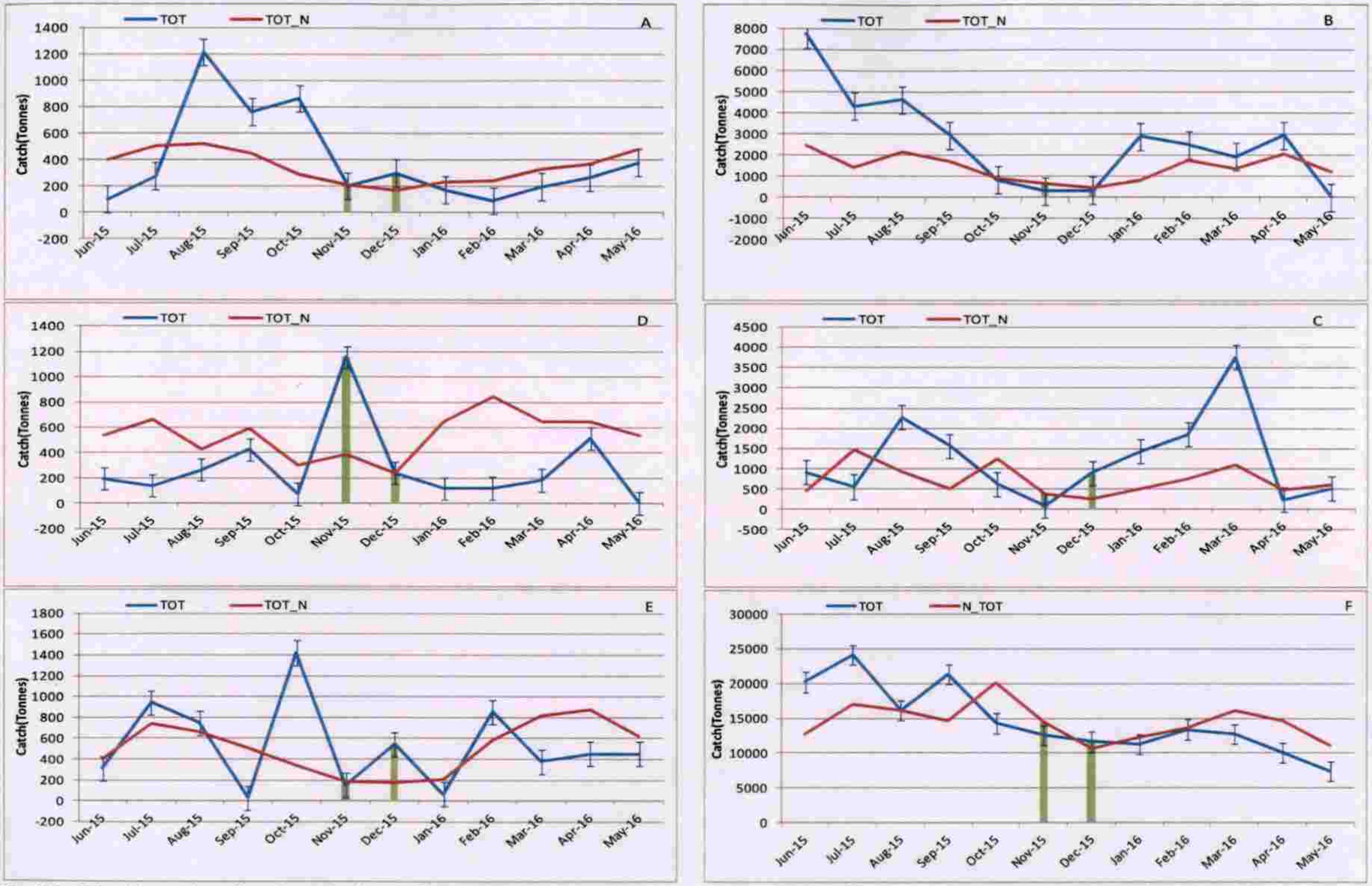

Fig 4.9 - Monthly total catch and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; TOT: Monthly total catch, TOT_N: Month wise 10 year average of Total catch

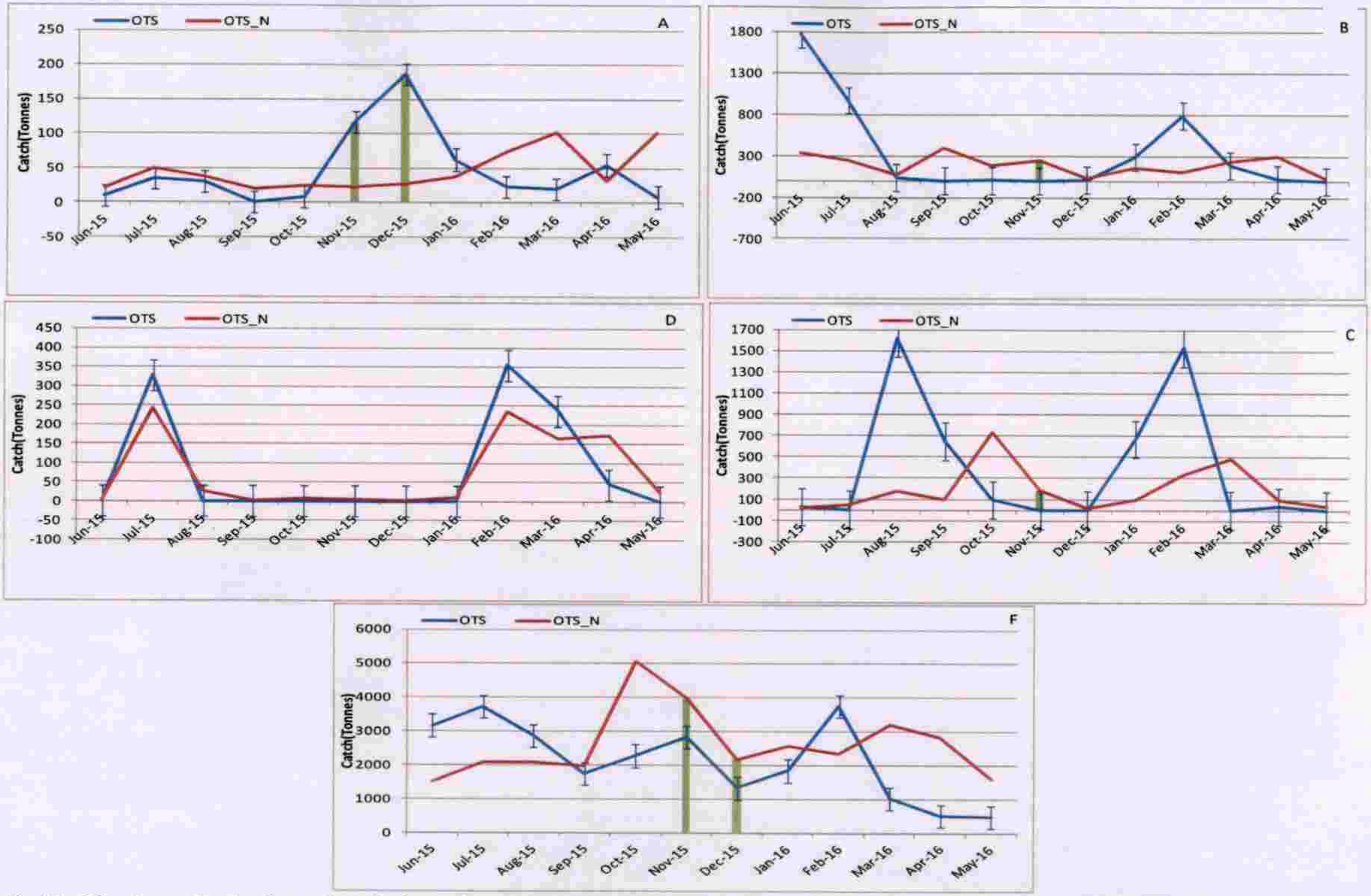

Fig 4.10 - Monthly other sardine landing and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; OTS: Monthly other sardine catch, OTS_N: Month wise 10 year average of other sardine landings

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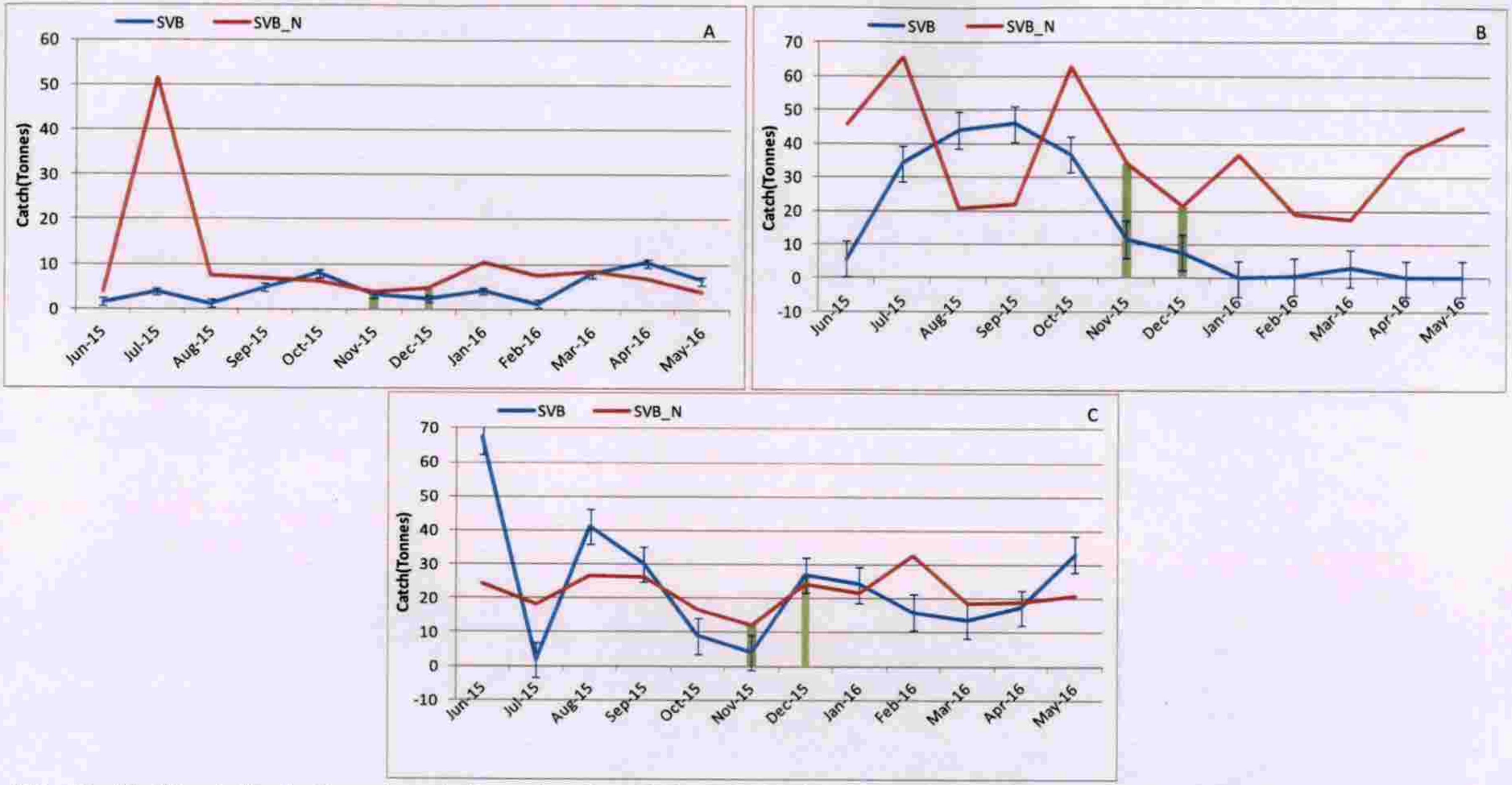

Fig 4.11 - Monthly Silver bellies landing and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram [Green bar indicate the time of occurrence of Flood]; SVB: Monthly silver bellies catch, SVB_N: Month wise 10 year average silverbellies landing

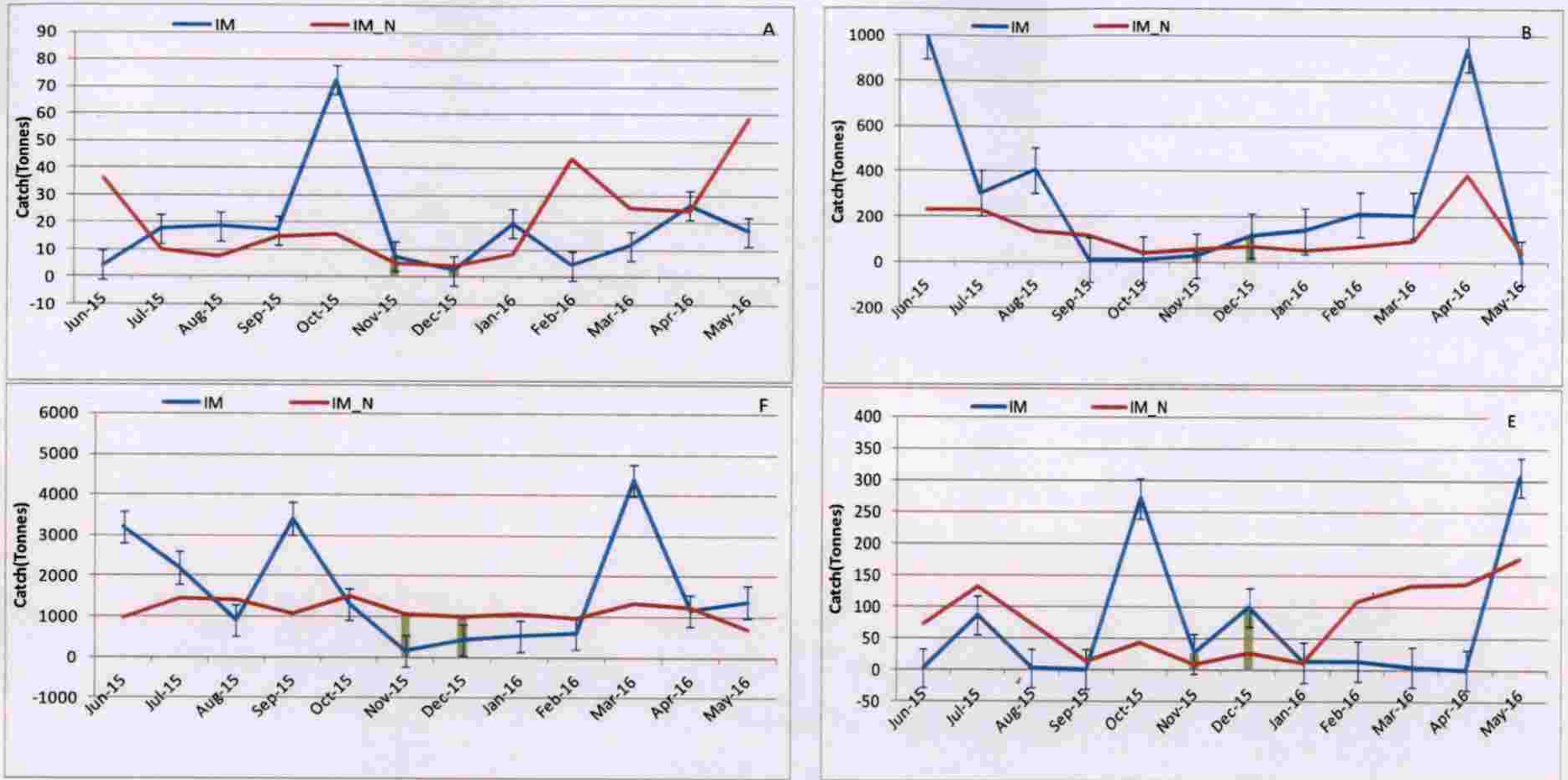

Fig 4.12 - Monthly Indian mackerel landing and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; IM: Monthly Indian mackerel catch, IM_N: Month wise 10 year average Indian mackerel catch

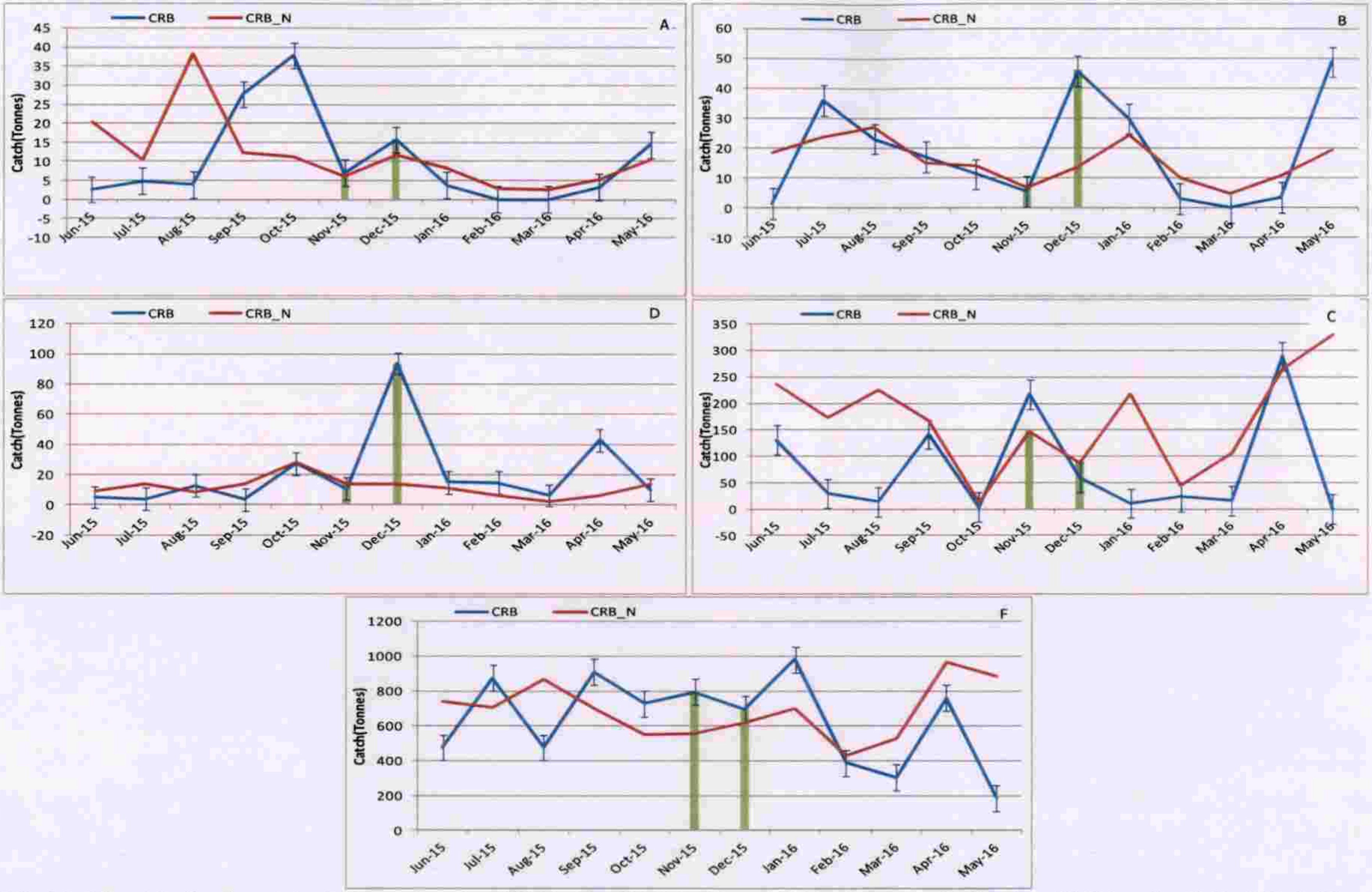

Fig 4.13 - Monthly catch of crabs and standard error from June 2015 to May 2016; A) Chennai C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; CRB: Monthly crab catch, CRB_N: Month wise 10 year average crab catch

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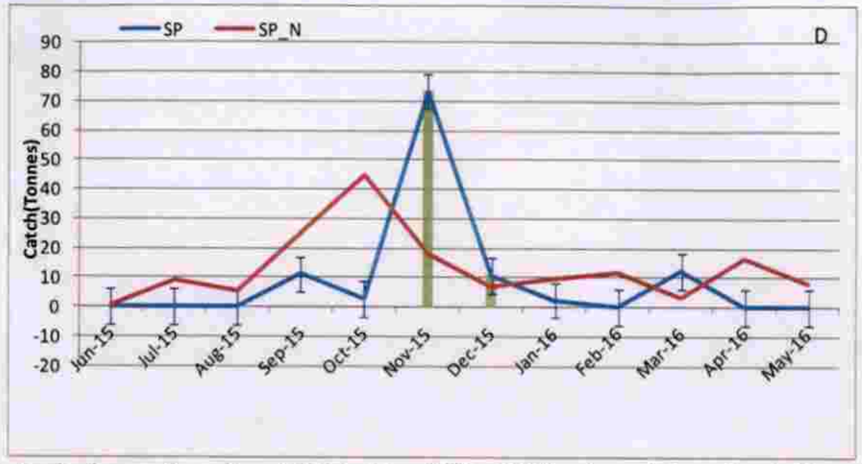

Fig 4.14 - Monthly catch of silver pomfret and standard error from June 2015 to May 2016; D) Thanjavur [Green bar indicate the time of occurrence of Flood]; SP: Monthly silver pomfret catch, SP_N: Month wise 10 year average silver pomfret catch

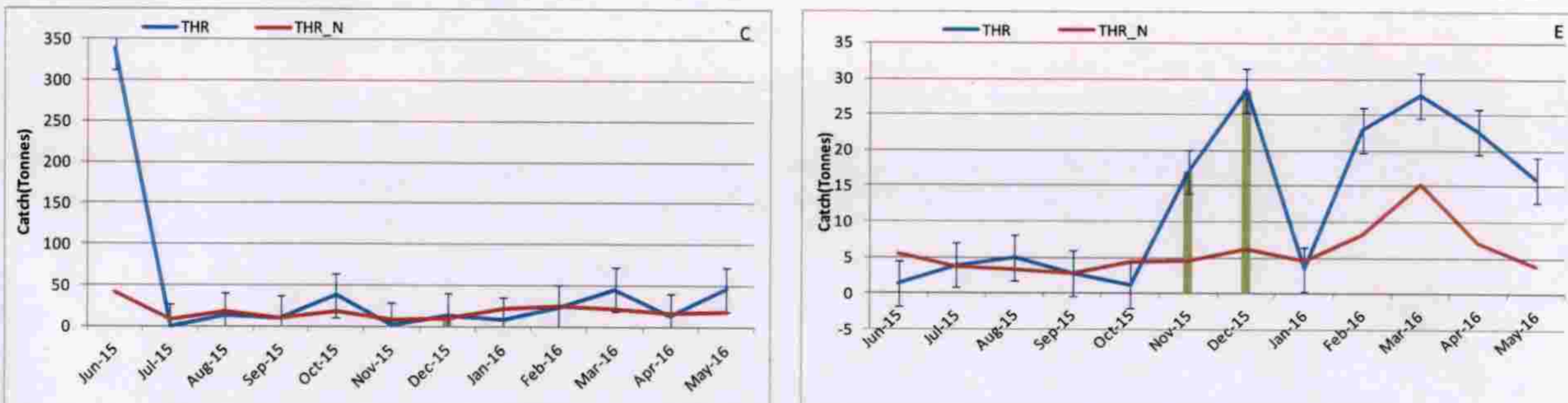

Fig 4.15 - Monthly *Thryssa* catch and standard error from June 2015 to May 2016; C) Kancheepuram E) Thiruvallur [Green bar indicate the time of occurrence of Flood]; THR: Monthly *Thryssa* landing, THR_N: Month wise 10 year average *Thryssa* landing

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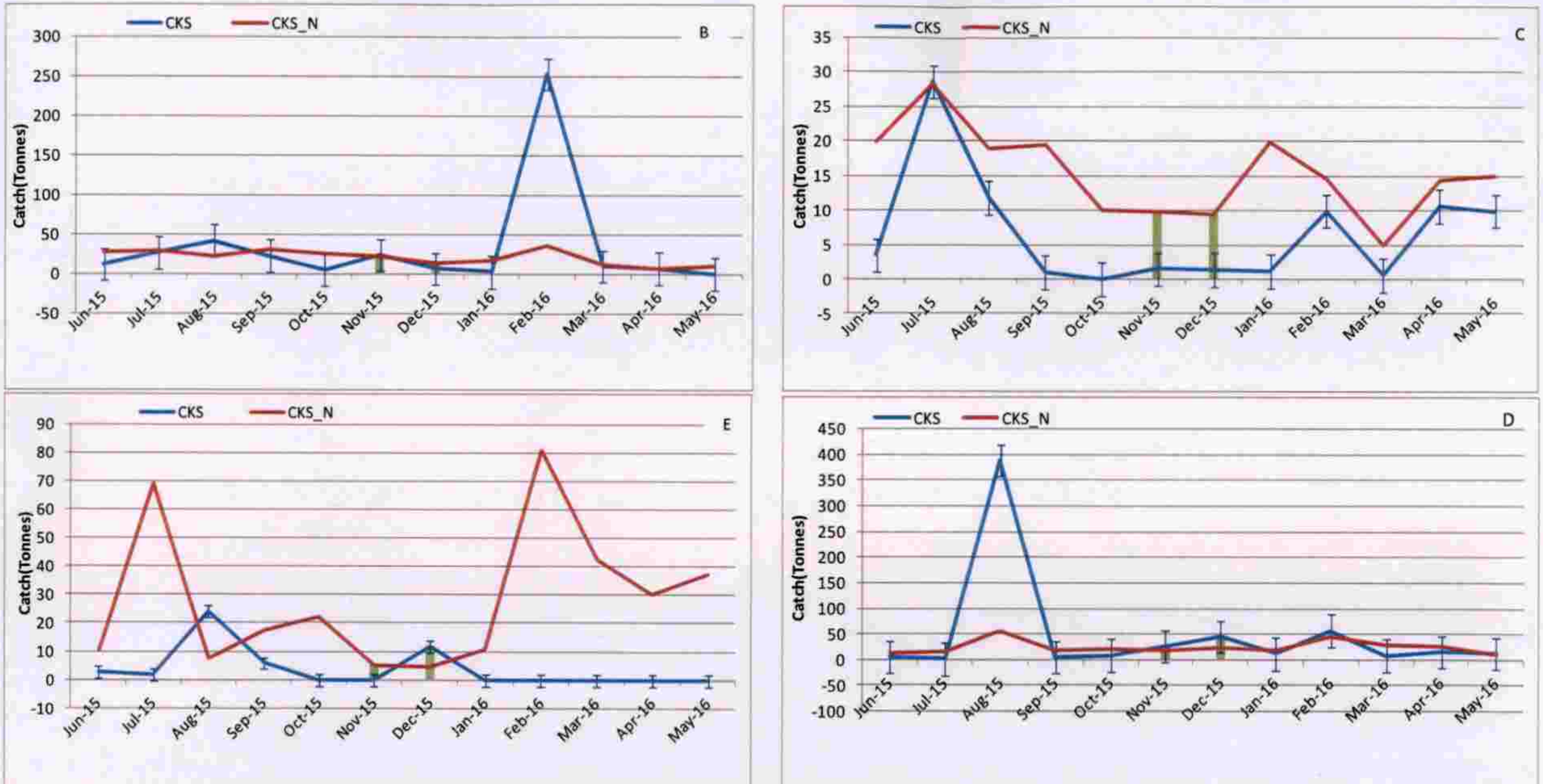

Fig 4.16 - Monthly croaker catch and standard error from June 2015 to May 2016; B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur [Green bar indicate the time of occurrence of Flood]; CKS: Monthly Croaker catch, CKS_N: Month wise 10 year average croker landings

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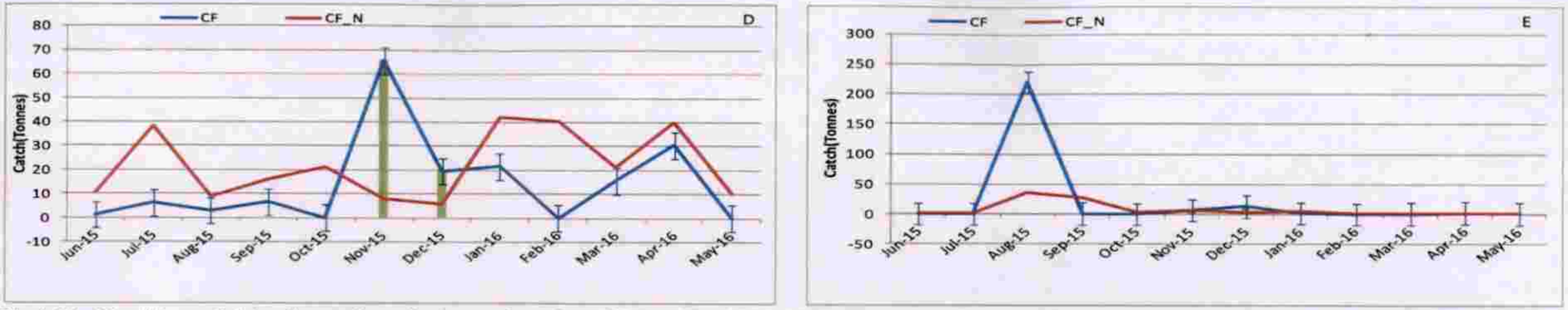

Fig 4.17 - Monthly cat fish landing and standard error from June 2015 to May 2016; D) Thanjavur E) Thiruvallur [Green bar indicate the time of occurrence of Flood] ; CF: Monthly catfish landing, CF_N: Month wise 10 year average catfish landings

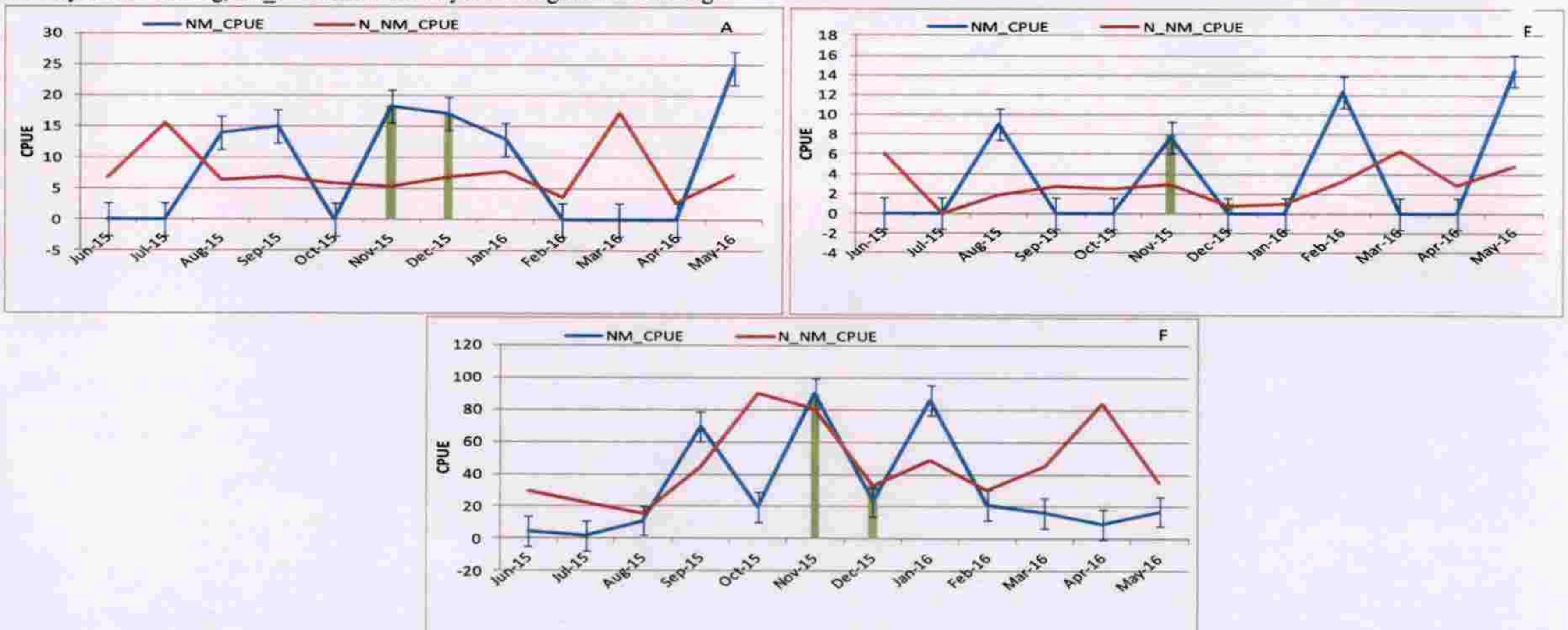

Fig 4.18 - Monthly CPUE (Catch per unit effort) of NM (Non-mechanized craft) and standard error from June 2015 to May 2016; A) Chennai E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; NM_CPUE: Monthly CPUE of NM, N_NM_CPUE: Month wise 10 year average CPUE of NM

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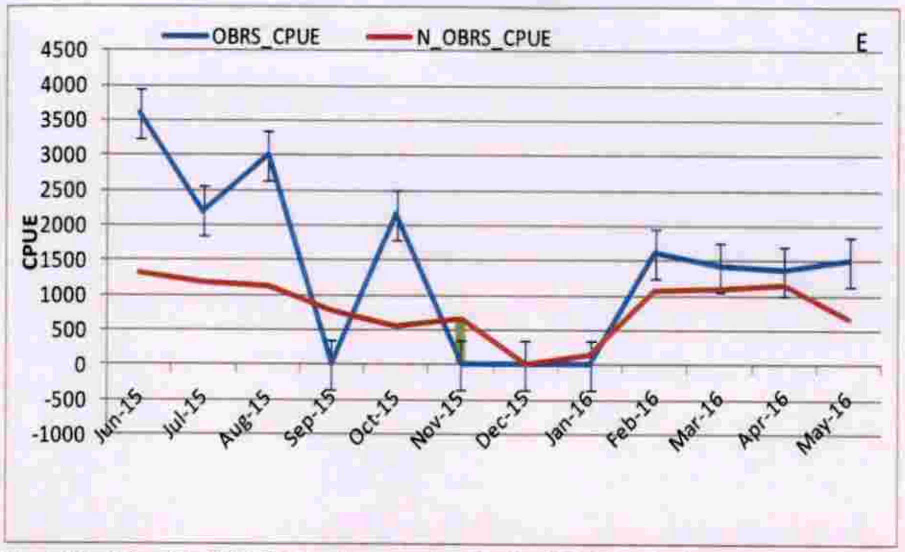

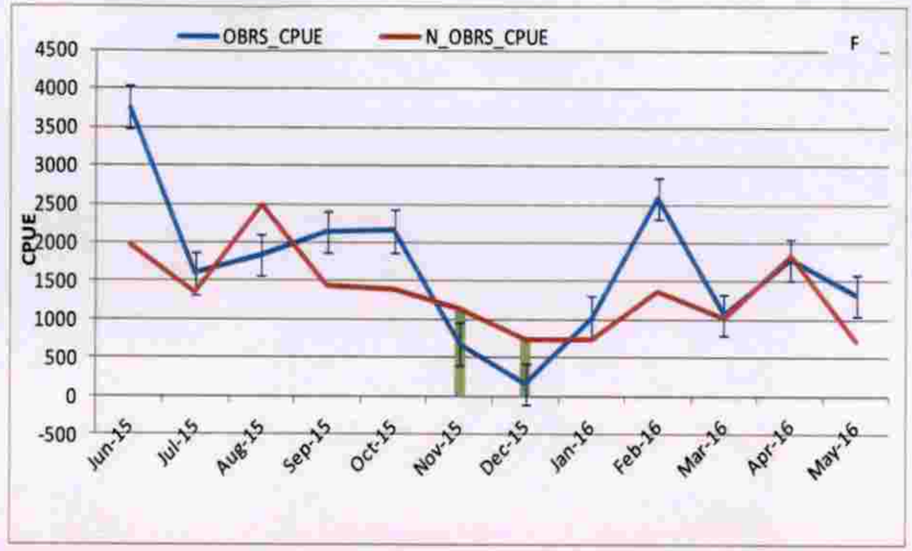

Fig 4.19 - Monthly CPUE (Catch per unit effort) of OBRS (Outboard Ring seine) and standard error from June 2015 to May 2016; E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; OBRS_CPUE: Monthly CPUE of OBRS, N_OBRS_CPUE: Month wise 10 year average CPUE of OBRS

Fig 4.20 - Monthly CPUE (Catch per unit effort) of OBGN (Outboard Gill net) and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; OBGN_CPUE: Monthly CPUE of OBGN, N_OBGN_CPUE: Month wise 10 year average CPUE of OBGN

Fig 4.21 - Monthly CPUE (Catch per unit effort) of OBHL (Outboard Hook and line) and standard error from June 2015 to May 2016; A) Chennai B) Cuddalore C) Kancheepuram D) Thanjavur E) Thiruvallur F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; OBHL_CPUE: Monthly CPUE of OBHL, N-OBHL_CPUE: Month wise 10 year average CPUE of OBHL

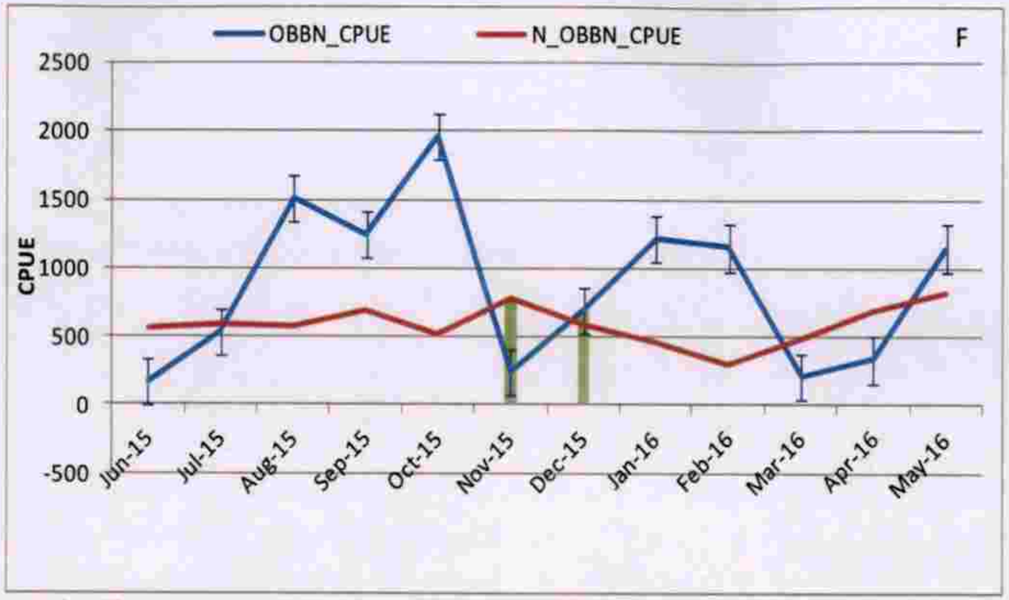

Fig 4.22 - Monthly CPUE (Catch per unit effort) of OBBN (Outboard Bag net) and standard error from June 2015 to May 2016; F) Tamil Nadu [Green bar indicate the time of occurrence of Flood]; OBBN_CPUE: Monthly CPUE of OBBN, N_OBBN_CPUE: Month wise 10 year average CPUE of OBBN

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CHAPTER 5

Impact of Cyclone Ockhi on marine fisheries of Kerala and Tamil Nadu

5.1 Impact of cyclone Ockhi on marine fisheries catch, effort and catch per unit effort of Kerala

In Kerala there are about thirteen different specific mechanized and motorised craft-gear combinations along with miscellaneous gears and the traditional non-motorised vessels (Fig 5.1). Of these, highest number of units operated is out-board gill net (OBGN) followed by non- motorised (NM) and out-board hook and line (OBHL) contributing to 34.8, 21.4 and 11.1 percentage of the number of units operated in the state during the period 2007 to 2018 (Table 5.1). However, highest contribution to the states total landing is by MDTN (29.9%) followed by the MRS and OBRS (23% shared by each individually) and OBGN (7.4%). There is considerable variation in the major type of gear operated in different districts. Results of the impacts on the catch, effort and CPUE of the cyclone Ockhi in Thiruvananthapuram, Kollam, Alappuzha and Ernakulum, the four major districts affected by Ockhi is given below

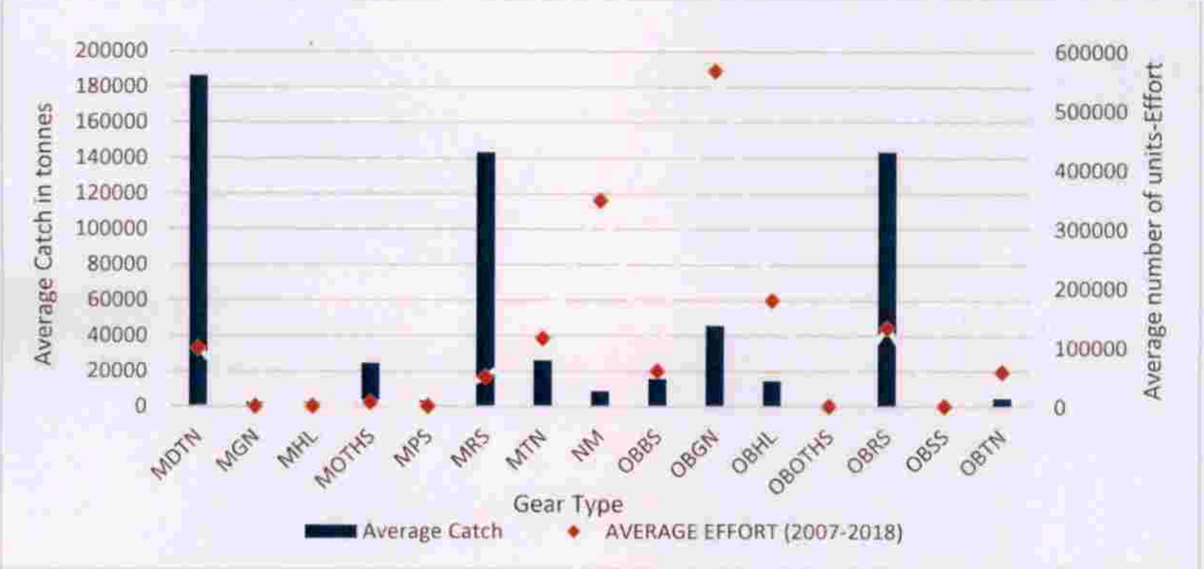

Fig 5.1 Average catch (in tonnes) and effort (in numbers) of diferent gears operated along Kerala Coast during 2007 to 2018

TABLE 5.1 – Average catch (in tonnes) and percentage contribution (in parenthesis) of different craft – gear combinations operated in the cyclone affected districts of Kerala (Neg = negligible)

District	Craft - Gear	MDT N	MGN	MHL	MOTHS	MPS	MRS	MTN	NM	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBSS	OBT N
Thiruvanan thapuram	Average catch(t)					259 (0.6)		2969 (7.1)	13229 (31.8)	15955 (38.3)	8566 (20.6)	4 (neg)	532 (1.3)	102 (0.2)	34 (0.1)	
Kollam	Craft - Gear	MDT N	MGN	MHL	MOTHS	MPS	MRS	MTN	NM	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBSS	OBT N
	Average catch(t)	52088 (56)	299 (0.3)	28 (neg)	272 (0.3)		15431 (16.6)	5693 (6.1)	1364 (1.5)	520 (0.6)	6522 (7)	1676 (1.8)	311 (0.3)	8857 (9.5)		21 (neg)
Ernakulam	Craft - Gear	MDT N	MGN	MHL	MOTHS	MPS	MRS	MTN	NM	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBSS	OBT N
	Average catch(t)	68440 (54.1)	1968 (1.6)	1520 (1.2)	16282 (12.9)	3318 (2.6)	19841 (15.7)	2502 (2.0)	582 (0.5)	3 (neg)	1927 (1.5)	586 (0.5)	359 (0.3)	9153 (7.2)		103 (0.1)
Alappuzha	Craft - Gear	MDT N	MGN	MHL	MOTHS	MPS	MRS	MTN	NM	OBBS	OBGN	OBHL	OBOTHS	OBRS	OBSS	OBT N
	Average catch(t)	817 (1.2)					1634 (2.5)	1 (neg)	2733 (4.1)	1 (neg)	7466 (11.3)	172 (0.3)		51643 (78.4)		1433 (2.2)

Thiruvananthapuram district : In Thiruvananthapuram district there are about eight craft gear combinations and the maximum contribution to the district's annual landings is by OBBS followed by NM and OBGN during the period 2007 to 18 (Table 5.1). Due to Ockhi the marine fisheries of the district had very high negative impact; 85 to 57% reductions in catch and about 77.7% decrease in effort expended. The details of impact of cyclone Ockhi on the catch, effort and CPUE of the district is given in (Table 5.2). During the post cyclone period the impact remained negative but had improved and the percentage decline in catch and effort became 40.9% and 15.37% improving the overall grade to medium.

Gear-wise impact assessment showed a very high impact on the catch for gears like MRS, OBBS, OBGN, OBHL and OBRS with percentage reduction reaching 97.8, 80.85, 83.52, 94.3 and 97.9% of the catch during the pre-cyclone period. The effort expended was reduced drastically for all the gears (Table 5.2). The catch per unit effort was also impacted negatively but, the intensity was not as high as that for catch and effort. Only for MRS and OBRS was the reduction was high but for other gears it was medium and OBBS and OBGN the reduction in CPUE was only 26.2 and 20.3%. During the post cyclone period the high negative improved only slightly for MRS, OBHL and OBRS. For OBGN for though the impact remained negative, the intensity improved to medium impact. There was improvement in effort expended, the catch remained low (Table 5.2).

Kollam district: In Kollam district where two major harbours (Neendakara and Sakthikulangara) are located there are about eleven craft and gear combinations along with other gears (MOTHS & OBOTHS). Among all these gears, the MDTN is the major contributor to the district's catch (56%) followed by MRS (16.6%) and OBRS (9.6%) (Table 5.1). During the Ockhi cyclone, the catch and effort of the district declined by 54 and 73.6% respectively, indicating high negative impact. The details of impact of cyclone Ockhi on the catch, effort and CPUE of the district is given in (Table 5.3).

Though the negative impact continued after cyclone, it reduced to 15.8 and 18.4% respectively thereby becoming medium impact. During the cyclone period the impact was high negative for catch and effort of MRS, OBGN, OBHL, OBRS and NM it improved during the post cyclone period to medium grade for MRS and become positive for OBGN and OBHL. Though the impact on MDTN catch was negative during the cyclone period, it improved and became positive during post cyclone. Similarly the MDTN effort also increased. The CPUE of MDTN, MRS, MTN, OBHL and OBRS was positive and did not decline. However, during the post-cyclone period, the CPUE declined for MTN and OBRS.

Table 5.2 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Thiruvananthapuram districts of Kerala during the cyclone (Dec 2017) and post cyclone (Jan-March 2018) (N=Negative; P=Positive)

	Thiruvananthapuram District	Cyclone				Post Cyclone			
		Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
	Total Catch(t)	-3641.5	N	-85.57	High	-1744.5	N	-40.99	Medium
	Total Effort	-20953.7	N	-77.73	High	-4142.3	N	-15.37	Medium
MRS	Catch(t)	-268.4	N	-97.85	High	-231.7	N	-84.47	High
	Effort	-186.7	N	-94.92	High	-151.7	N	-77.12	High
	CPUE	-678.8	N	-53.50	High	-611.6	N	-48.20	Medium
NM	Catch(t)	-66.5	N	-60.90	High	63.2	P	57.89	High
	Effort	-1211.7	N	-44.95	Medium	3268.7	P	121.26	High
	CPUE	-15.3	N	-34.73	Medium	-13.0	N	-29.54	Medium
OBBS	Catch(t)	-1192.7	N	-80.85	High	-434.4	N	-29.45	Medium
	Effort	-1865.7	N	-73.32	High	-1075.3	N	-42.26	Medium
	CPUE	-148.2	N	-26.26	Medium	167.8	P	29.74	Medium
OBGN	Catch(t)	-1250.0	N	-83.52	High	-570.5	N	-38.12	Medium
	Effort	-12010.3	N	-79.24	High	-3705.3	N	-24.45	Medium
	CPUE	-20.0	N	-20.33	Medium	-9.5	N	-9.66	Medium
OBHL	Catch(t)	-473.4	N	-94.37	High	-265.1	N	-52.85	High
	Effort	-5356.7	N	-89.03	High	-2509.3	N	-41.71	Medium
	CPUE	-39.6	N	-48.09	Medium	-16.1	N	-19.53	Medium
OBRS	Catch(t)	-390.6	N	-97.92	High	-309.8	N	-77.67	High
	Effort	-322.7	N	-92.81	High	24.7	P	7.09	Low
	CPUE	-668.1	N	-66.80	High	-765.0	N	-76.49	High

Table 5.3 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Kollam districts of Kerala during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post Cyclone			
	Kollam District	Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
	Total Catch(t)	-4883.0	N	-54.07	High	-1429.5	N	-15.83	Medium
	Total Effort	-7579.7	N	-73.60	High	-1898.0	N	-18.43	Medium
MDTN	Catch(t)	-2091.5	N	-42.22	Medium	248.2	P	5.01	Low
	Effort	-1177.7	N	-52.12	High	-605.0	N	-26.77	Medium
	CPUE	445.6	P	20.26	Medium	950.9	P	43.23	Medium
MRS	Catch(t)	-1478.8	N	-67.25	High	-1024.6	N	-46.60	Medium
	Effort	-940.3	N	-78.01	High	-435.7	N	-36.14	Medium
	CPUE	684.1	P	33.65	Medium	-531.9	N	-26.16	Medium
MTN	Catch(t)	-66.7	N	-32.47	Medium	-84.4	N	-41.05	Medium
	Effort	-271.0	N	-40.27	Medium	-136.0	N	-20.21	Medium
	CPUE	37.7	P	12.24	Medium	-86.1	N	-28.00	Medium
NM	Catch(t)	-29.3	N	-100.00	High	-14.9	N	-50.70	High
	Effort	-1973.7	N	-100.00	High	-1301.7	N	-65.95	High
	CPUE	-13.8	N	-100.00	High	-6.6	N	-47.91	Medium
OBGN	Catch(t)	-504.8	N	-92.93	High	74.7	P	13.74	Medium
	Effort	-2173.7	N	-79.40	High	95.7	P	3.49	Low
	CPUE	-127.4	N	-65.18	High	27.0	P	13.80	Medium
OBHL	Catch(t)	-31.4	N	-68.46	High	138.3	P	301.78	High
	Effort	-525.3	N	-76.77	High	766.0	P	111.93	High
	CPUE	1.4	P	1.59	Low	66.9	P	74.75	High
OBRS	Catch(t)	-642.1	N	-63.18	High	-793.7	N	-78.10	High
	Effort	-499.0	N	-66.89	High	-393.0	N	-52.68	High
	CPUE	251.8	P	19.93	Medium	-592.0	N	-46.86	Medium

Alappuzha district: In Alappuzha district about nine craft gear combinations were operated during the period 2007-18 and among these the highest contribution to catch was by OBRS (78.4%) followed by OBGN (11.3%) and Non-Motorised gears (Table 5.1). The total catch of Alappuzha declined by 80.8% during the cyclone period but improved slightly and the impact grade changed from high negative to medium negative. The effort had also reduced by 36% but increased and became positive during the post cyclone period. The details of impact of cyclone Ockhi on the catch, effort and CPUE of the district are given in Table 5.4.

Though the catch and CPUE of the NM increased during the cyclone and post cyclone period, the effort had declined during cyclone period (high negative) and improved to low-positive during post-cyclone period. However, the impact on catch and effort of OBGN, OBHL and OBRS was negative and high during the cyclone period and continued to remain negative for

OBHL and OBRS. But the CPUE of OBGN became positive during the post cyclone period. The catch, effort and CPUE of OBTN were higher during and after the cyclone along Alappuzha coast.

Table 5.4 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Alappuzha districts of Kerala during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post Cyclone			
	Alappuzha District	Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
	Total Catch(t)	-4492.7	N	-80.88	High	-1913.2	N	-34.44	Medium
	Total Effort	-7653.3	N	-36.01	Medium	2550.3	P	12.00	Medium
NM	Catch(t)	69.3	P	15.76	Medium	419.6	P	95.44	High
	Effort	-1221.0	N	-10.66	Medium	244.0	P	2.13	Low
	CPUE	11.8	P	31.09	Medium	30.6	P	80.74	High
OBGN	Catch(t)	-962.0	N	-80.66	High	-63.1	N	-5.29	Low
	Effort	-3479.0	N	-62.35	High	-471.7	N	-8.45	Low
	CPUE	-107.5	N	-49.48	Medium	14.1	P	6.47	Low
OBHL	Catch(t)	-64.9	N	-87.54	High	-43.9	N	-59.18	High
	Effort	-369.3	N	-73.67	High	-141.7	N	-28.26	Medium
	CPUE	-72.3	N	-50.82	High	-74.6	N	-52.44	High
OBRS	Catch(t)	-3327.6	N	-92.68	High	-2801.7	N	-78.04	High
	Effort	-3026.3	N	-88.43	High	-2379.0	N	-69.51	High
	CPUE	-466.5	N	-41.29	Medium	-336.4	N	-29.77	Medium
OBTN	Catch(t)	30.1	P	146.53	High	348.1	P	348.1	High
	Effort	588.0	P	376.92	High	5035.3	P	5035.3	High
	CPUE	24.1	P	55.07	High	23.8	P	54.39	High

Ernakulam district: In Ernakulam district there are about thirteen craft and gear combinations and among these, the MDTN contributes slightly more than half of the districts catch (54.1%) followed by MRS (17.7%) and other Motorised vessel (MOTHS) (Table 5.1). The overall catch of Ernakulam district declined by 61.24% during the cyclone period. This improved slightly and became 43.58% during the post cyclone period. However, the effort has not declined drastically during the both the periods. The details of impact of cyclone Ockhi on the catch, effort and CPUE of the district are given in (Table 5.5).

The catch, effort and CPUE of MDTN, MGN, MHL, MRS and OBRS were either highly negative or medium negative. The negative impact continued to remain high during the post cyclone period for MRS Though all the fishery aspects of MDTN and MGN improved during the post cyclone period, it did not become positive. For MTN and OBTN, the effort increased both during the cyclone and post cyclone period. The MTN catch and CPUE was also high and positive during the cyclone period. Contrary to all these the OBTN catch, effort and CPUE had shown positive impacts during the cyclone and post cyclone period.

Table 5.5 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Ernakulam district of Kerala during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post Cyclone			
	Ernakulam District	Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
	Total Catch(t)	-9391.9	N	-61.24	High	-6683.4	N	-43.58	Medium
	Total Effort	129.0	P	1.66	Low	937.3	P	12.05	Medium
MDTN	Catch(t)	-4992.3	N	-56.02	High	-3049.7	N	-34.22	Medium
	Effort	-571.3	N	-26.20	Medium	-232.7	N	-10.67	Medium
	CPUE	-1514.1	N	-38.34	Medium	-1065.2	N	-26.97	Medium
MGN	Catch(t)	-614.4	N	-98.92	High	-8.7	N	-1.40	Low
	Effort	-158.3	N	-90.82	High	-12.0	N	-6.88	Low
	CPUE	-2868.7	N	-87.23	High	-186.3	N	-5.67	Low
MHL	Catch(t)	-523.7	N	-73.72	High	-114.5	N	-16.11	Medium
	Effort	-203.0	N	-69.28	High	-116.3	N	-39.70	Medium
	CPUE	-308.5	N	-12.95	Medium	73.5	P	3.09	Low
MOTHS	Catch(t)	-841.0	N	-62.16	High	-854.0	N	-63.13	High
	Effort	-142.3	N	-52.65	High	-128.3	N	-47.47	Medium
	CPUE	-1416.9	N	-26.16	Medium	-1846.1	N	-34.09	Medium
MRS	Catch(t)	-1964.9	N	-76.34	High	-2195.5	N	-85.30	High
	Effort	-385.3	N	-62.93	High	-409.0	N	-66.79	High
	CPUE	-1323.6	N	-33.03	Medium	-2310.6	N	-57.67	High
MTN	Catch(t)	73.0	P	43.83	Medium	-66.6	N	-40.01	Medium
	Effort	200.0	P	99.01	High	298.0	P	147.52	High
	CPUE	51.4	P	9.43	Low	-352.4	N	-64.71	High
NM	Catch(t)	-1.4	P	-16.41	Medium	19.0	N	220.44	High
	Effort	210.3	P	44.22	Medium	569.3	P	119.69	High
	CPUE	1.7	P	19.29	Medium	19.5	P	221.03	High
OBGN	Catch(t)	-150.2	N	-69.64	High	-48.2	N	-22.35	Medium
	Effort	1212.0	P	84.17	High	1314.0	P	91.25	High
	CPUE	-163.6	N	-86.89	High	-125.8	N	-66.80	High
OBHL	Catch(t)	-13.5	N	-51.98	High	-2.2	N	-8.39	Low
	Effort	-197.3	N	-34.48	Medium	-70.7	N	-12.35	Medium
	CPUE	-17.2	N	-34.15	Medium	-2.9	N	-5.75	Low
OBRS	Catch(t)	-281.4	N	-45.23	Medium	-268.2	N	-43.10	Medium
	Effort	113.3	P	7.97	Low	-615.7	N	-43.31	Medium
	CPUE	-183.2	N	-45.21	Medium	22.2	P	5.47	Low
OBTN	Catch(t)	8.7	P	187.17	High	28.0	P	600.78	High
	Effort	96.3	P	112.45	High	394.0	P	459.92	High
	CPUE	45.4	P	160.88	High	34.9	P	123.68	High

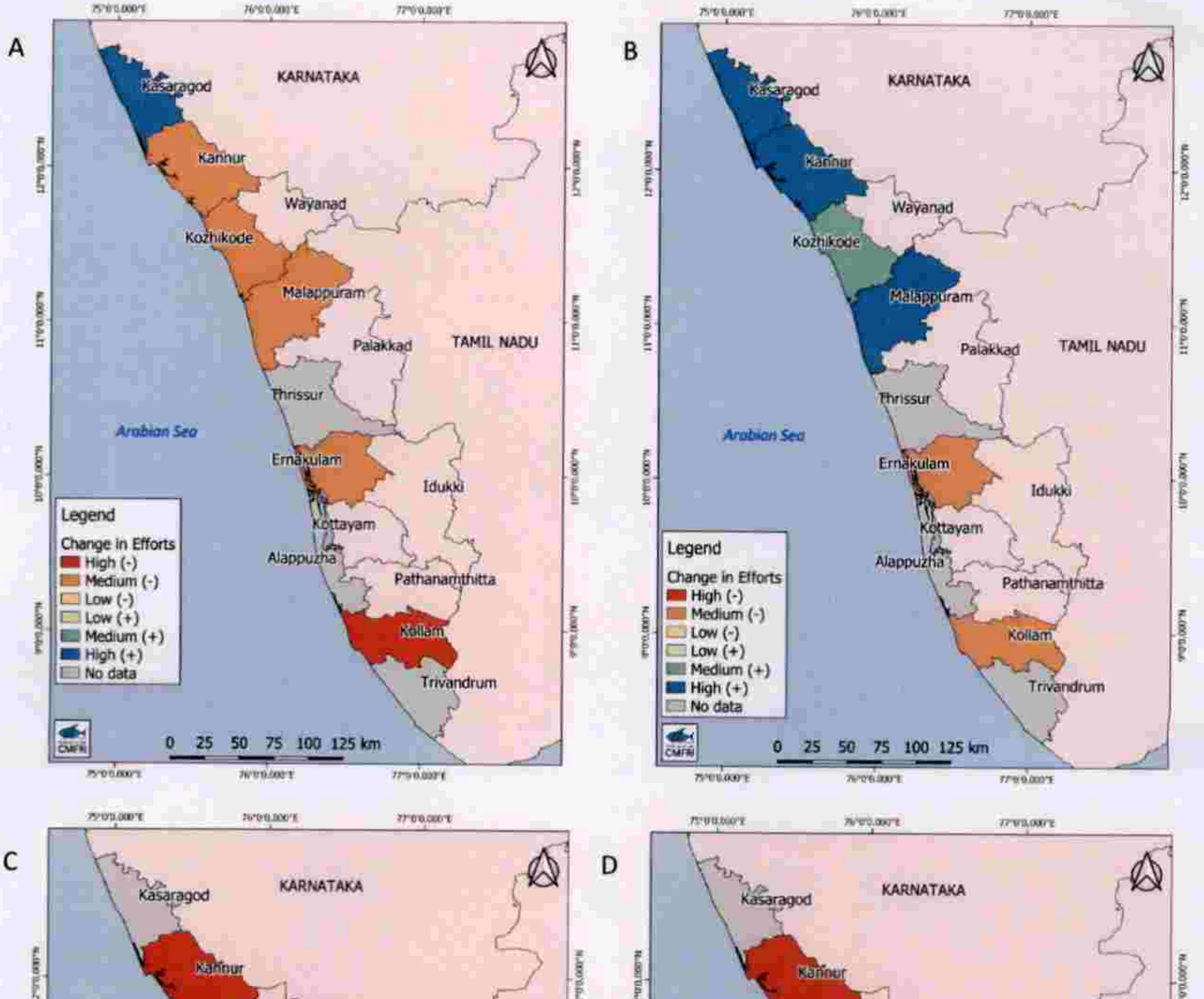

Fig 5.2 - Impact of cyclone Ockhi-2017 on MDTN and MRS Effort in the coastal districts of Kerala A) Impact on MDTN effort during cyclone period B) Impact MDTN effort during post cyclone period C) Impact on MRS effort during cyclone period D) Impact on MRS effort during post cyclone period

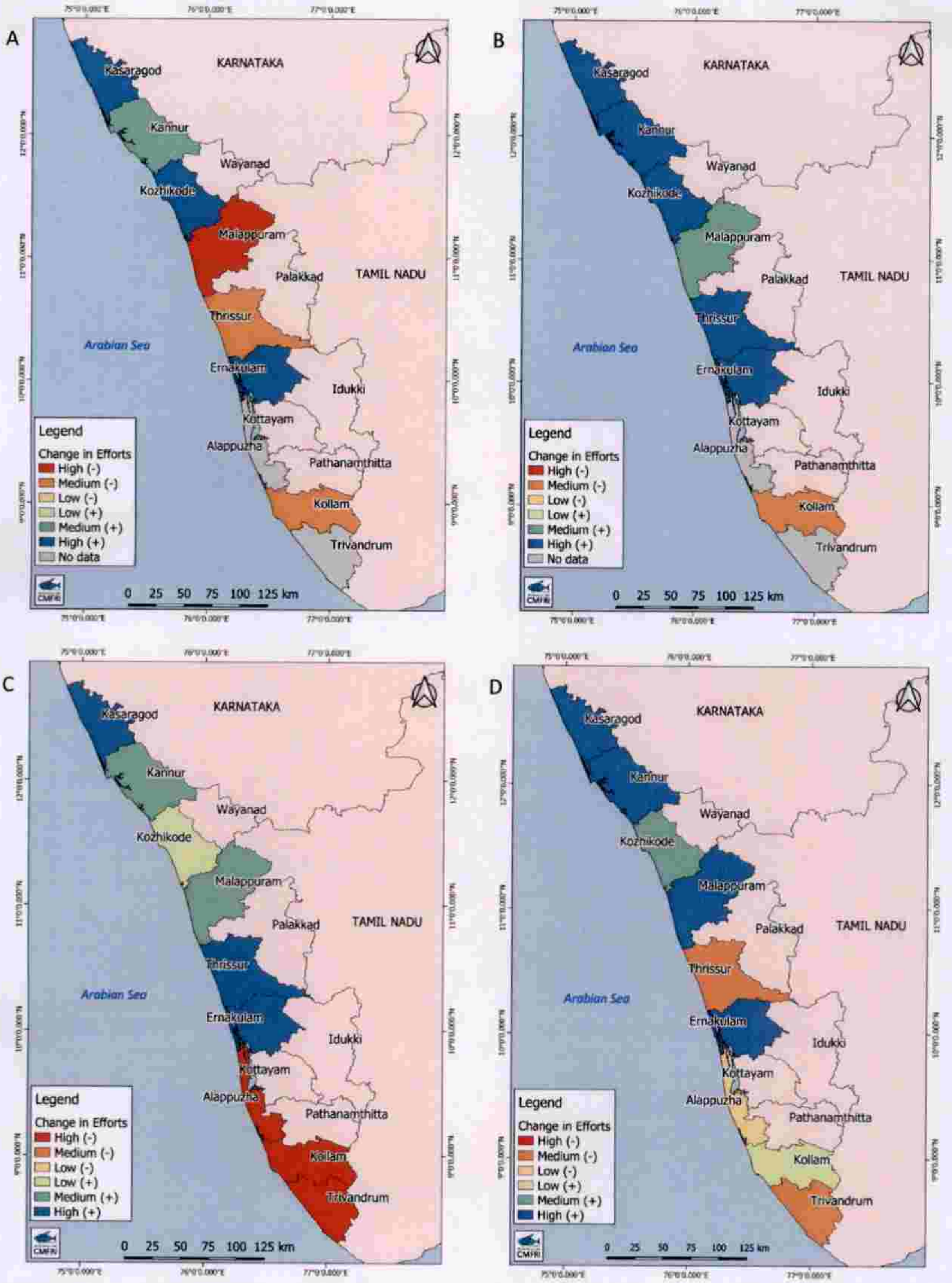

Fig 5.3 - Impact of cyclone Ockhi-2017 on MTN and OBGN Effort in the coastal districts of Kerala A) Impact on MTN effort during cyclone period B) Impact MTN effort during post cyclone period C) Impact on OBGN effort during cyclone period D) Impact on OBGN effort during post cyclone period

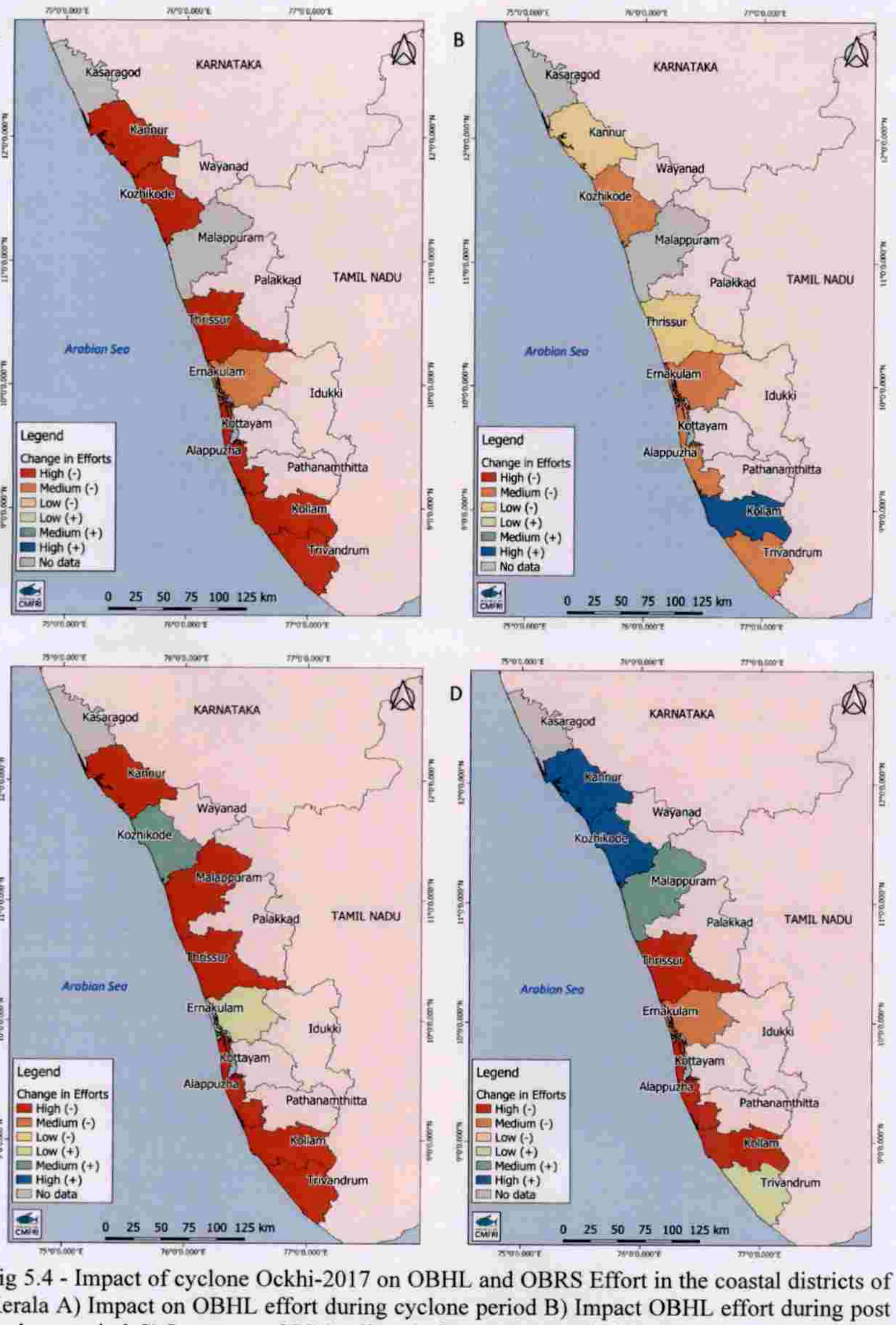

Fig 5.4 - Impact of cyclone Ockhi-2017 on OBHL and OBRS Effort in the coastal districts of Kerala A) Impact on OBHL effort during cyclone period B) Impact OBHL effort during post cyclone period C) Impact on OBRS effort during cyclone period D) Impact on OBRS effort during post cyclone period

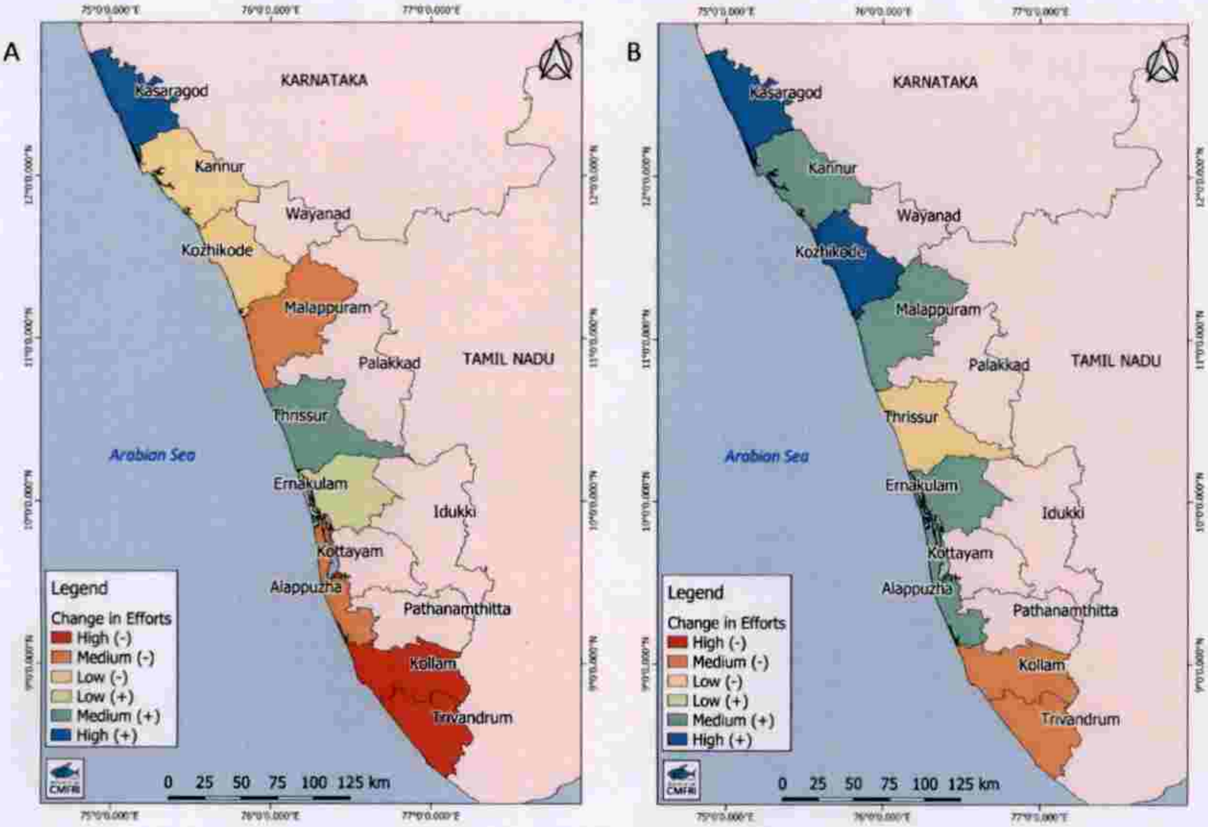

Fig 5.5 - Impact of cyclone Ockhi-2017 on Total Effort in Kerala A) Impact on total effort during cyclone period B) Impact on total effort during post cyclone period

5.2 Impact of Cyclone Ockhi on Marine Fisheries of Tamil Nadu

In Tamil Nadu about sixteen different craft and gear combinations are used and the dominance of each of these between districts varies (Fig 5.6). Based on the average of the catch obtained in different gears and the number of units operated during the period 2007 to 2018 it was observed that in Tamil Nadu, the catch by MTN contributes the major share, 46% followed by OBGM (16.4%) and MDTN (16.2%). However, maximum number of units operated is OBGN (36%) followed by NM (11.7%) and OBTN (11.1%) (Table 5.6). The impact of Ockhi on the catch, effort and CPUE in the three main districts Kanyakumari, Tuticorin and Thirunelveli is given below.

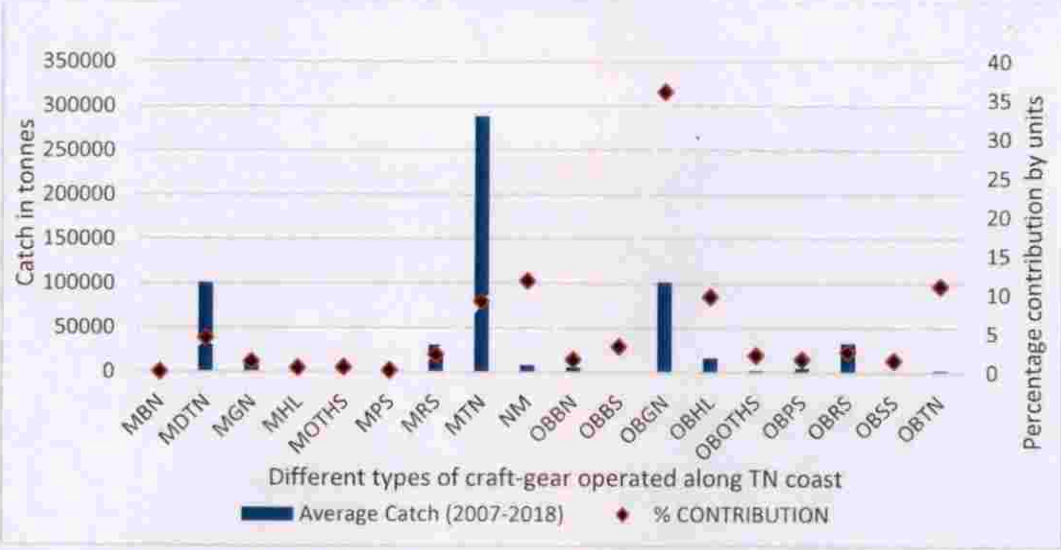

Fig 5.6 Average catch by different gears during the period 2007 to 2018 and the percentage contribution of gears to total units operated in Tamil Nadu

Kanyakumari

In Kanyakumari district there were about eleven craft gear combinations and the contribution by MTN was more than half, 53.4% followed by OBGN (16.4%) and MDTN (13.8%). Details of the impact on catch, effort and CPUE are given in Table 5.6. There was very high negative impact since both the catch and effort declined by more than 98%. In the post cyclone period the catch and effort improved slightly, but still remained as high and negative. The same situation was observed for OBGN also and there was no improvement during the post cyclone period also, though the CPUE increased. The OBHL sector also had very high negative impact by Ockhi and during the post cyclone period there was slight improvement (Table 5.7).

Table 5.6 – Average catch (in tonnes) and percentage contribution (in parenthesis) of different craft –gear combinations operated in the cyclone affected districts of Tamil Nadu (Neg = negligible)

District	Craft-Gear	MBN	MDTN	MGN	MHL	MOTHS	MTN	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBPS	OBRS	OBSS	OBTN
Kanyakumari	Average catch(t)		15349 (13.8)	228 (0.2)	463 (0.4)	4859 (4.4)	59335 (53.4)	3294 (3.0)	507 (0.5)	208 (0.2)	18210 (16.4)	7828 (7.0)	318 (0.3)		155 (0.1)	231 (0.2)	51 (neg)
Thirunelveli	Craft-Gear	MBN	MDTN	MGN	MHL	MOTHS	MTN	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBPS	OBRS	OBSS	OBTN
	Average catch(t)							6 (neg)		11 (0.1)	6718 (38.5)	276 (1.6)	205 (1.2)	674 (3.9)	9545 (54.7)	20 (0.1)	
Tuticorin	Craft-Gear	MBN	MDTN	MGN	MHL	MOTHS	MTN	NM	OBBN	OBBS	OBGN	OBHL	OBOTHS	OBPS	OBRS	OBSS	OBTN
	Average catch(t)	31 (neg)	103 (0.1)	1911 (2.6)	3 (neg)	1 (neg)	38176 (52.6)	171 (0.2)	384 (0.5)	74 (0.1)	21915 (30.2)	5056 (7.0)	1739 (2.4)	873 (1.2)	1897 (2.6)	197 (0.3)	93 (0.1)

Table 5.7 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Kanyakumari districts of TN during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post Cyclone			
	Kanyakumari District	Deviation	Impact	Percentage deviation	Grade	Deviation	Impact	Percentage deviation	Grade
Total	Total Catch(t)	-11742.9	N	-98.82	High	-6709.3	N	-56.46	High
Total	Total Effort	-25147.7	N	-97.79	High	-20676.7	N	-80.40	High
MDTN	Catch(t)	-4218.0	N	-97.57	High	-4091.3	N	-94.64	High
MDTN	Effort	-1073.0	N	-98.89	High	-816.3	N	-75.24	High
MDTN	CPUE	128.4	P	1.49	Low	-8324.8	N	-96.66	High
OBGN	Catch(t)	-627.3	N	-97.57	High	-602.8	N	-93.76	High
OBGN	Effort	-16061.7	N	-98.27	High	-15576.0	N	-95.30	High
OBGN	CPUE	16.0	P	40.69	Medium	13.6	P	34.55	Medium
OBHL	Catch(t)	-158.7	N	-88.86	High	-75.1	N	-42.03	Medium
OBHL	Effort	-3692.7	N	-93.07	High	-1777.7	N	-44.80	Medium
OBHL	CPUE	29.5	P	68.69	High	4.2	P	9.76	Low

Tuticorin District

In Tuticorin District there were fourteen different craft gear combinations and of these the maximum contribution was by MTN (52.6%) followed by OBGN (30.2%) and OBHL (7%) (Table 5.6). There was about 28.9% decline in catch and about 30 % decline in effort in Tuticorin during the cyclone period. However, the catch improved during the post cyclone period and the effort showed only mild increase. The MGN catch and effort decreased during the Ockhi period by less than 50% and the impact continued in the post cyclone period also. The CPUE of MGN showed improvement during the post cyclone period. In the MTN sector the catch and CPUE declined during the Ockhi and post Ockhi period. However, the effort increased. In OBGN, there was reduction in catch and effort during the Ockhi period, but the CPUE had increased. During the post Ockhi period, both catch and CPUE increased but the effort was still negative. The OBHL sector all aspects of fishery were negative during Ockhi period but the situation improved during the post Ockhi period except for effort (Table 5.8).

Table 5.8 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Tuticorin districts of TN during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post Cyclone			
	Tuticorin District	Deviation	Impact	Percentage deviation	Grade	Deviation	Impact	Percentage deviation	Grade
Total	Total Catch(t)	-1140.5	N	-28.95	Medium	654.9	P	16.62	Medium
Total	Total Effort	-10257.7	N	-30.28	Medium	-1581.0	N	-4.67	Low
MGN	Catch(t)	-104.5	N	-48.06	Medium	-115.4	N	-53.10	High
MGN	Effort	-95.0	N	-44.81	Medium	-129.3	N	-61.01	High
MGN	CPUE	-63.6	N	-6.18	Low	143.3	P	13.93	Medium
MTN	Catch(t)	-364.7	N	-33.06	Medium	-131.4	N	-11.91	Low
MTN	Effort	145.0	P	12.38	Medium	442.7	P	37.80	Medium
MTN	CPUE	-206.6	N	-26.90	Medium	-164.5	N	-21.42	Medium
OBGN	Catch(t)	-354.8	N	-18.64	Medium	211.4	P	11.11	Medium
OBGN	Effort	-8145.3	N	-35.44	Medium	-273.0	N	-1.19	Low
OBGN	CPUE	19.6	P	23.07	Medium	4.0	P	4.76	Low
OBHL	Catch(t)	-155.2	N	-31.98	Medium	20.1	P	4.15	Low
OBHL	Effort	-1677.0	N	-23.89	Medium	-1823.7	N	-25.97	Medium
OBHL	CPUE	-9.2	N	-12.93	Medium	23.6	P	33.23	Medium

Thirunelveli

In Thirunelveli district there are only seven craft gear combinations and the maximum is OBRS (54.7%) followed by OBGN (38.5%) and OBPS (3.9%) (Table 5.6). In Thirunelveli district there was high negative impact on the catch since there was a reduction in catch by 85.6% during Ockhi and 75.8% during post Ockhi period. However, the OBGN catch and effort increased during the Ockhi period as well as during post cyclone period. However, there was a slight reduction in CPUE during the cyclone period (Table 5.9).

Table 5.9 - Variations in catch, effort and CPUE in comparison with the pre-cyclone period (Sep-Nov 2017) by different gears in the Thirunelveli districts of TN during the cyclone (Dec 2017) and after the cyclone (Jan-March 2018) (N=Negative; P=Positive)

		Cyclone				Post-Cyclone			
	Thirunelveli District	Deviation	Impact	Percentage Deviation	Grade	Deviation	Impact	Percentage Deviation	Grade
	Total Catch(t)	-1865.7	N	-85.67	High	-1650.9	N	-75.81	High
	Total Effort	4807.0	P	147.18	High	2008.0	P	61.48	High
OBGN	Catch(t)	173.2	P	124.71	High	328.1	P	236.18	High
	Effort	5737.7	P	245.69	High	2626.7	P	112.48	High
	CPUE	-9.6	N	-19.93	Medium	17.1	P	35.44	Medium

5.3 Impact of cyclone Ockhi on the marine species assemblage of commercial fishing grounds off Kerala

The analysis done using PRIMER software to identify the changes in resource assemblages in the Ockhi impacted districts showed that there were variations between districts. The percentage dissimilarity ranged from high values (above 50%) in MRS operated areas in general and also in area where MGN was operated. The variation was found to decrease with time most often, but in some instances the impacts were found to persist or even increase with time (Table 5.10).

Table 5.10 - Percentage dissimilarity in the species / group composition of landings by different gears operated in the 2017 cyclone Ockhi affected districts of Kerala				
District		Pre-cyclone vs Cyclone	Cyclone vs Post cyclone	Pre-cyclone vs Post cyclone
Thiruvanathapuram	TVM-MRS	97.53	87.12	75.73
Kollam	KLM-MRS	58.91	58.34	42.44
Ernakulam	EKM-MRS	67.22	11.7	70.74
Thiruvanathapuram	TVM-OBRS	96.64	92.3	42.1
Kollam	KLM-OBRS	59.31	30.32	67.66
Ernakulam	EKM-OBRS	65.85	53.05	45.89
Alappuzha	ALZ-OBRS	89.61	63.93	77.51
Thiruvanathapuram	TVM-OBGN	75.59	61.28	43.32
Kollam	KLM-OBGN	87.8	89.11	25.52
Ernakulam	EKM-OBGN	77.26	64.86	46.62
Alappuzha	ALZ- OBGN	73.36	73.58	37.18
Thiruvanathapuram	TVM-OBHL	91.05	81.51	52.59
Kollam	KLM-OBHL	73.01	87.87	51.84
Alappuzha	ALZ- OBHL	82.6	66	42.1
Ernakulam	EKM-OBHL	59.55	52.57	32.34
Thiruvanathapuram	TVM- NM	66.63	79.65	67.43
Kollam	KLM-NM	no	no	42.32
Ernakulam	EKM-NM	74.47	76.67	75.95
Alappuzha	ALZ-NM	32.53	36.91	39.96
Ernakulam	EKM-OBTN	33.33	42.61	66.25
Alappuzha	ALZ- OBTN	21.25	48.4	49.98
Kollam	KLM - MDTN	36.17	30.53	26.12
Ernakulam	EKM- MDTN	51.58	35.72	42.97
Kollam	KLM-MTN	24.97	21.2	35.51
Ernakulam	EKM-MTN	41.9	69.66	87.28
Ernakulam	MGN	97.99	97.55	45.59
Ernakulam	MHL	70.11	73.08	66.14
Ernakulam	MOTHS	54.49	46.92	57.78
Thiruvanathapuram	TVM- OBBS	80.59	68.99	56.64

5.3.1 Variations in the resource assemblage in MRS operated marine areas

Thiruvananthapuram MRS: The percentage dissimilarity was highest at TVM; 97.53% between pre-cyclone and cyclone, which reduced to 87.12% during cyclone and post cyclone and 75.73% between pre-cyclone and post cyclone (Fig 5.7). The main resource during the pre-cyclone period was Indian Mackerel followed by barracuda. During cyclone period the catch reduced and this contributed to 32.17% of the dissimilarity. Complete absence of barracuda, *Stolephorus* and other carangids during the cyclone period contributed to 22, 13 and 12 percentage of the total dissimilarity (Table 5.12).

The same resources (Indian Mackerel, barracudas and *Stolephorus* and other carangids) contributed to 32.38, 24.37, 14.7 and 12.06 percentage of the total dissimilarity of 75.73% between the pre-cyclone cyclone and post cyclone period. Slight increase in the catch of other sardine, sardines, Indian mackerel and other clupeids contributed to 26.42, 23.76, 15.88 and 14.18% of the total dissimilarity of 87.12 percentages in species assemblage between cyclone and post cyclone period.

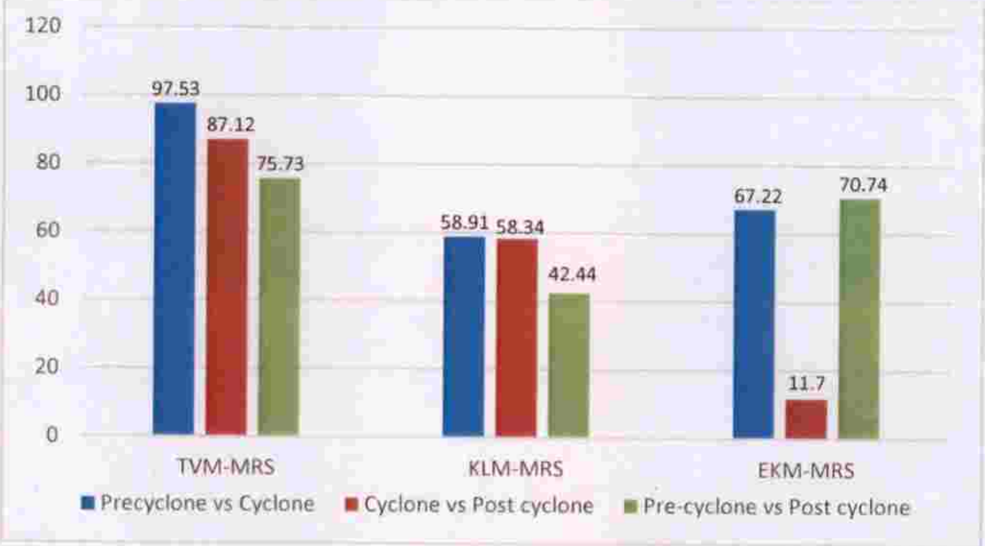

Fig 5.7 Percentage dissimilarity in the species assemblage in the MRS operated area

Kollam MRS: The percentage dissimilarity in the species assemblage in MRS was much lower at Kollam than TVM. The decline in resources during cyclone and post cyclone was notable (Fig 5.7). Oil sardine, Indian mackerel, *Stolephorus* contributed to 28.4, 22.28 and 17.11 percentage of the total dissimilarity of 58.91 percentage between pre-cyclone and cyclone period (Table 5.12). The percentage dissimilarity was almost same (57.34%) in the species assemblage between cyclone and post cyclone and the major resources were Indian Mackerel, other sardine, oil sardine and scads contributing to 26.3, 17.91, 14.56 and 13.36 percentage respectively. However, there was an increase in catch of *Stolephorus* and oil sardine during the post cyclone period and this reduced the dissimilarity to 42.4%. These two resources contributed 37.76 and 29.62 percentage of the total dissimilarity.

Ernakulam MRS: In Ernakulam, the percentage dissimilarity between the pre-cyclone and cyclone period was 62.2 which got reduced to 11.7 when compared with cyclone and post cyclone period. However, there was high dissimilarity between pre-cyclone and post cyclone resources assemblage (Fig 5.7). In all the three comparisons, oil sardine was the dominant resources which contributed 39.2, 40.56 and 53.99 percentage of the total dissimilarity (Table 5.12). Scads were present during the pre-cyclone period but absent thereafter. The details of variation are given in Table 5.11.

5.3.2 Variations in the resource assemblage in OBGN operated marine areas

Thiruvananthapuram OBGN: The percentage dissimilarity between the pre-cyclone and cyclone resource assemblages was 75.59% (Fig 5.8). Indian mackerel (17.58%), Ribbon fishes (16.80%), *Auxis* spp (13.74%) and *E. affinis* (11.64%) were the main resources contributing to the dissimilarity (Table 5.13 a&b). Of this Ribbon fishes were completely absent during the cyclone period. However, they were present during the post cyclone period and almost the same resources, Ribbon fishes (19.56%), *Auxis* spp (14.9%) Indian mackerel (9.03%) and *E. affinis* (9.03%) contributed to the total dissimilarity of 43.32 percentages in the fish assemblage between pre-cyclone and post cyclone. The percentage dissimilarity between cyclone and post cyclone was higher (61.28%) and the main resources responsible for this were Indian mackerel (18.67%) other carangids (18.14%) and other tunnies (16.81%).

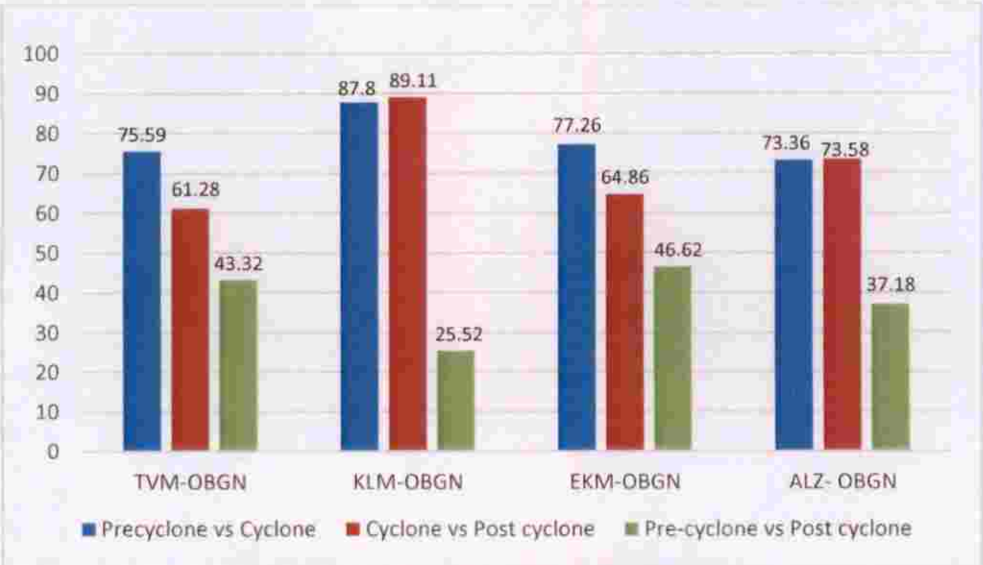

Fig 5.8 Percentage dissimilarity in the species assemblage in the OBGN operated area

Kollam OBGN: There was very high (87.8%) dissimilarity between the resource assemblage during the cyclone and Pre-cyclone period and also during the cyclone and post cyclone period (89.11). However, the dissimilarity was low (25.52%) when the resources of the Pre-cyclone and post cyclone periods were compared (Fig 5.8). *K. pelamis* which formed an important catch during the pre-cyclone period was absent during the cyclone period. This resource contributed to 11.78% of the assemblage variation and 13.51 percentage of the variation during the cyclone and post cyclone period. The main resources which contributed to the dissimilarity between pre-cyclone and cyclone were *E. affinis* (11.51%), oil sardine (11.21%) and Indian mackerel (11.12%). Oil sardine (14.44%), *Auxis* spp (11.65%) and other sardine (11.49%) contributed almost equally for the variation between pre-cyclone and post cyclone. Low abundance of oil sardine led to a dissimilarity of 17.66% between the cyclone and post cyclone period (Table 5.14 a&b).

Ernakulam OBGN: The percentage dissimilarity between the pre-cyclone and cyclone period off Ernakulam was 77.27 and the major resource contributing to this was oil sardine 49.70. The same resource contributed to 41.23% of the total dissimilarity of 46.62% between pre-cyclone and post cyclone. *K. pelamis* and oil sardine were responsible for 27.04 and 15.54% of the total dissimilarity of 64.86 percentages between the cyclone and post cyclone period (Fig 5.8; Table 5.14 a&b).

Alappuzha OBGN: The dissimilarity between the resource assemblage of Pre-cyclone and cyclone period was 73.36 and oil sardine (18.32%), other carangids (17.69%) and Indian mackerel (17.22%) were the major resources responsible for the variation (Fig 5.8; Table 5.14 a&b). The percentage dissimilarity between cyclone and post cyclone resource assemblage was 73.58 and that between pre and post cyclone was 37.13 percentages and the contribution by oil sardine was maximum, 43.15% and 28.74% respectively.

5.3.3 Variations in the resource assemblage in OBHL operated marine areas

Thiruvananthapuram OBHL: The dissimilarity was high (91.05%) between the resource assemblage of pre-cyclone and cyclone period and the main reason was the reduction in *Auxis* spp which contributed 31.64% of the total dissimilarity (Fig 5.9; Table 5.15 a&b). There was high (81.51%) dissimilarity between cyclone and post cyclone and the presence of sharks during post cyclone period contributed to 15.85 % of the total dissimilarity. The dissimilarity was low (52.59%) between pre-cyclone and post cyclone period, *Auxis* spp contributed to 31.34% of the total dissimilarity.

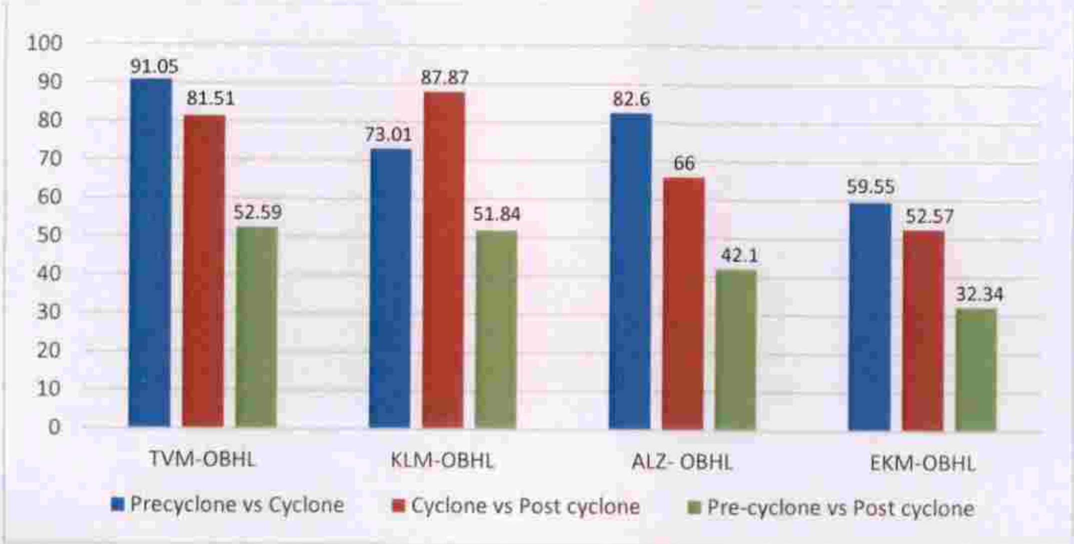

Fig 5.9 Percentage dissimilarity in the species assemblage in the OBHL operated area

Kollam OBHL: The dissimilarity was highest (87.87%) between the cyclone and post cyclone period and the increased catch of *E. affinis* led to 32.58% of the total dissimilarity (Fig 5.9; Table 5.15 a&b). Also absence of *K. pelamis* during the cyclone period contributed to 22.41% of the dissimilarity. *E. affinis* and *K. pelamis* contributed to 41.06 and 32.42% of the total dissimilarity of 73.01 percentage of the species assemblage dissimilarity between pre-cyclone and cyclone period. These two resources were also responsible for 26.71 and 16.61 percentage respective of the total dissimilarity percentage of 51.84 between the pre-cyclone and post cyclone assemblage.

Alappuzha OBHL: The percentage dissimilarity between pre-cyclone and cyclone marine resource assemblage in the OBHL fishing area off Alappuzha was 82.6 and this was mainly contributed by *S. commersoni* (27.07%), *E. affinis* (25.14%) and other tunnies (19.14%). The percentage dissimilarity was reduced and became 66% in comparison between cyclone and post cyclone period and the absence of *S. commersoni* contributed to 44.32% of this variation followed by other tunnies (37.67%) (Fig5.9; Table 5.15a&b). The pre-cyclone and post cyclone comparison indicated a dissimilarity of 42.1% contributed mainly by *E. affinis* (36.88%), Horse mackerel (13.95%) and *S. commersoni* (13.21%).

Ernakulam OBHL: The variation in species assemblage in the OBHL fishing area was 59.55 percentages when compared with between the cyclone and pre-cyclone period and this was mainly due to cuttlefish (20.38%), squids (13.58%), *S. commersoni* (12.83%) and Indian mackerel (11.70%). During the post cyclone period also, the dissimilarity percentage was similar (52.57%) and was contributed mainly by half beaks and full beaks (23.26%), *S. commersoni* (13.49%), other carangids (12.56%) and Indian mackerel (11.16%) (Fig 5.9; Table 5.15 a&b). The pre-cyclone and post cyclone resource assemblage dissimilarity was 32.34% and was mainly due to full beaks and half beaks (22.96%), cuttlefish (20.41%) and squids (18.88%).

5.3.4 Variations in the resource assemblage in OBRS operated marine areas

Thiruvananthapuram OBRS: The dissimilarity in resource assumable between pre-cyclone and cyclone and that of cyclone and post cyclone was 96.64% and 92.34% and this was mainly due to *Stolephorus* contributing to 42.13% and 69.91% respectively. The pre-cyclone and post cyclone resource assemblage dissimilarity was 42.73 and was contributed by oil sardine (31.31%), Indian mackerel (22.63%) and *Stolephorus* (18.28%) (Fig 5.10; Table 5.17).

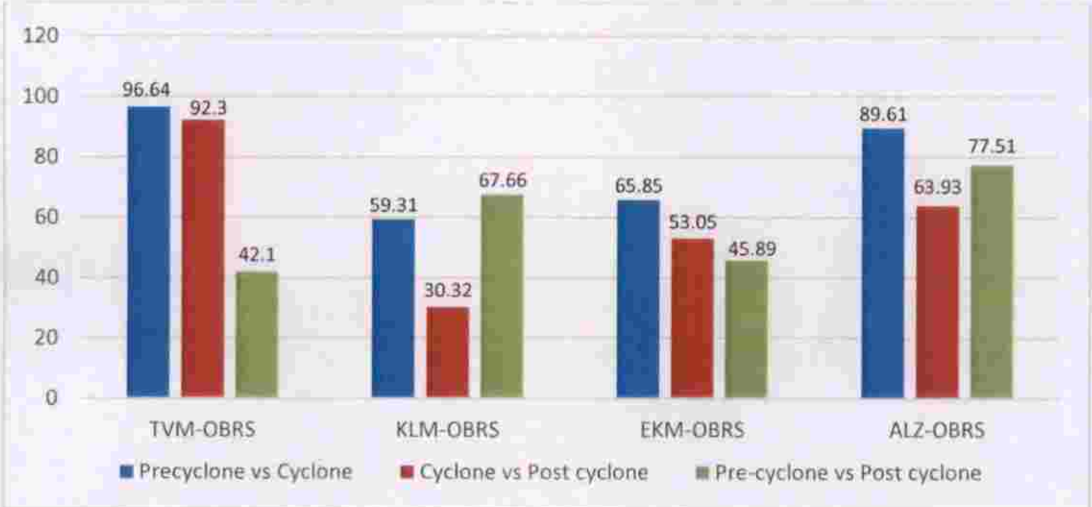

Fig 5.10 Percentage dissimilarity in the species assemblage in the OBRS operated area

Kollam OBRS: The percentage dissimilarity between cyclone and pre-cyclone species assemblage in the OBRS operating grounds off Kollam was 59.31% and this was mainly due to *Stolephorus* (46.4%), oil sardine (18.41%) and other perches (13.96%). The dissimilarity percentage between cyclone and post cyclone period was 30.32 and this was mainly due the abundance of other sardine during the cyclone period which contributed to 57.62% of the total dissimilarity. There was higher dissimilarity (67.66%) between the resource assemblage of pre-cyclone and post cyclone period and the major difference was due to *Stolerphorus* (42.39%), oil sardine (16.52%) and other sardines (15.22%) (Fig 5.10; Table 5.17).

Alappuzha OBRS: The dissimilarity percentage of the resource assemblage during the cyclone and pre-cyclone period and between the cyclone and post cyclone period was 89.61% and 77.51 % respectively and this variation was mainly due to oil sardine with a contribution of 40.29 and 39.75 percentages respectively (Fig 5.10; Table 5.17). Other carangids contributed 21.60 and 12.69% of the variation during this period. The dissimilarity was slightly lower (63.83%) during the pre-cyclone and post cyclone period and the contribution to this was mainly due to oil sardine (35.57%) and other carangids (21.66%).

Ernakulam OBRS: The percentage dissimilarity between the resource assemblage in the fishing ground of OBRS off Ernakulam during the cyclone and pre-cyclone and cyclone and post cyclone period was 65.85 and 53.05 respectively (Fig 5.10). The major contribution to this variation was by oil sardine and penaeid prawns, 46.97 and 10.58 percentages during first phase and 23.66 and 20.49 percentage respectively during the second phase. The dissimilarity during the pre and post cyclone period was much lower, 45.89 % and this was mainly due the abundance variation of oil sardine 47.68% followed by *Stolephorus*, soles and other sardines contributing to about 10 percentage each (Table 5.17).

5.3.5 Variations in the resource assemblage in NM operated marine areas

Non mechanized fishing crafts were not operated in Kollam district during the cyclone period. The variation in the resource assemblages is different districts is depicted in Fig 5.11 described given below

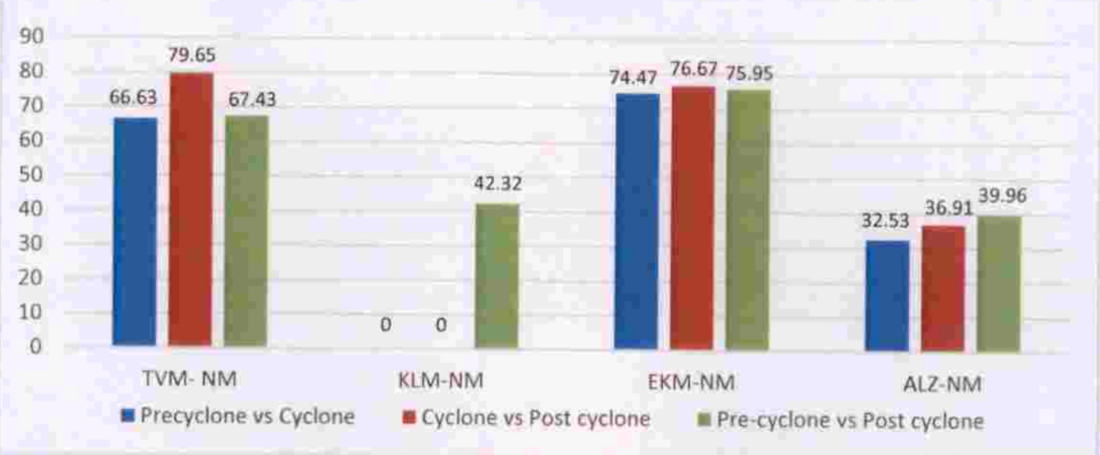

Fig 5.11 Percentage dissimilarity in the species assemblage in the NM operated area

Thiruvananthapuram NM: The dissimilarity in resource assemblages in the near shore waters where NMs are operated were high in all the groups like pre-cyclone and cyclone; cyclone and post cyclone and also between pre and post cyclone and the percentage dissimilarity was estimated as 66.63, 79.65 and 67.43% respectively (Fig 5.11). *Stolephorus*, silver bellies and crabs were the main resources which contributed 25.05, 18.05 and 15.47 percentage of the variation during the cyclone and pre-cyclone period. Bivalves which occurred in the catch during the post cyclone period where the major contribute (59%) to the variation between cyclone and post cyclone period. This resource which was absent during the pre-cyclone period also contributed significantly (56.51%) in the species assemblage variation between pre-cyclone and post cyclone (Table 5.18).

Kollam NM: Since there was no fishing during by these crafts, only the pre-cyclone and post cyclone variation was estimated and there was 42.32% dissimilarity (Fig 5.11). Crabs and other sardines were the main resources which contributed to the variation, 13.99 and 13.47% respectively (Table 5.18).

Alappuzha NM: The dissimilarity percentage in the species assemblage during the cyclone and pre-cyclone period in the NM operated area off Alappuzha was 32.53 % and the Indian mackerel, penaeid prawns and oil sardines were the main resources which contributed the variation. The variation between cyclone and post cyclone period was 36.91% and the oil sardine contributed 52.52 % of the total dissimilarity. Between the pre and post cyclone period also these resources were the major resources which cause variation (Fig 5.11; Table 5.18).

Ernakulam NM: In Ernakulam district, there was considerable higher variation in the species assemblage in the NM fishing areas. It was 74.17% between cyclone and post cyclone period and was mainly be cat fishes (35.32%), croakers (14.43%) and *Thryssa* (11.44%). The dissimilarity between the cyclone and post cyclone period was 76.76 and oil sardine contributed to 64.79% of the total dissimilarity (Fig 5.11; Table 5.18). In the assemblage between pre and post cyclone, the dissimilarity percentage was 75.95 and the variation was mainly contributed by oil sardine (49.08%) and catfishes (18.73%).

5.3.6 Variations in the resource assemblage in OBTN, MDTN and MTN operated Marine areas

Trawls were not operated in Thiruvananthapuram, but there were trawls in Ernakulum (OBTN, MDTN, and MTN) Kollam (MDTN and MTN) and Alappuzha (OBTN). The dissimilarity in the species assemblage in their areas of operation is given below (Fig 5.12).

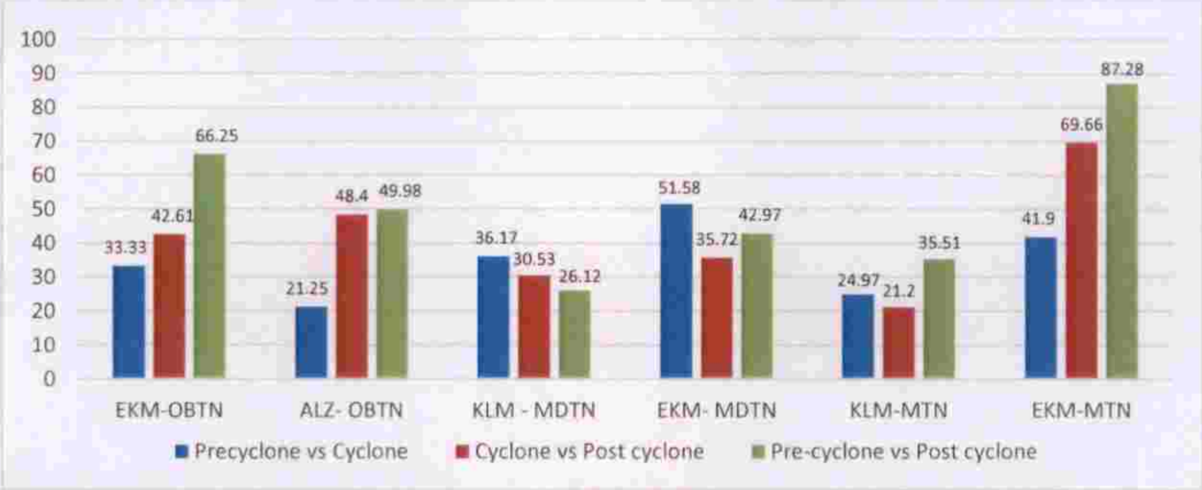

Fig 5.12 Percentage dissimilarity in the species assemblage in different trawl operated areas

Ernakulam OBTN: Croakers were the most important resource (53.16%) the cyclone and post-cyclone months. The *E. Affinis* catch increased during the post-cyclone period (31.16%). The percentage dissimilarity between pre-cyclone and post cyclone was high (66.25%) and 54.68% of dissimilarity was contributed by croackers.

Alappuzha OBTN: The dissimilarity between the cyclone and pre-cyclone was 21.25 and was mainly contributed by cuttlefish and crabs. The percentage dissimilarity increased (48.4%) between the cyclone and post cyclone and the main variation was due to penaeid prawns (46.05) followed by soles (20.89). The percentage dissimilarity between pre-cyclone and post cyclone was 49.98 contributed mainly by penaeid prawn 43.29 and soles 19.54(Fig 5.12; Table 5.16).

Kollam MDTN: The marine resource assemblage in the fishing area off Kollam by MTN had a dissimilarity percentage of 36.17% between cyclone and pre-cyclone which was mainly contributed by penaeid prawns 11.74% and scads, squids and ribbon fishes each contributing about 10%. The dissimilarity was much lower, 30.53% between cyclone and post cyclone and was contributed by scads 23.2, penaeid prawns 12.49, and non penaeid 11.73 percentage (Fig 5.12; Table 5.11). The pre-cyclone and post cyclone species assemblage dissimilarity was 26.12 % contributed mainly by ribbon fishes 10.67 and scads 10.14 percentages respectively.

Ernakulam MDTN: The percentage dissimilarity of the resource assemblages in the off shore areas where trawlers are operated differed between cyclone and pre-cyclone and with respect to cyclone and post cyclone. The dissimilarity percentage was 51.58 and was mainly contribute by ribbon fishes (19.45%), squids, (14.91%) and cuttle fishes (12.60%). The dissimilarity reduced between the cyclone and post cyclone period reaching 35.72%, which was mainly contributed by threadfin breams (24.64%) (Fig 5.12; Table 5.11). In addition to this, oil sardine, penaeid prawns, ribbon fishes and other carangids also contributed significantly. The dissimilarity between pre-cyclone and post cyclone period was 42.97% and the main resources responsible for this variation were ribbon fishes, squids and cuttle fishes.

Kollam MTN: The dissimilarity percentage in the resource assemblage during cyclone and pre-cyclone in the MTN operated area was 24.97 contributed mainly by *Stolephorus* (25.90 %) and ribbon fishes (14.8%). This further reduced to 21.2 % in the cyclone and post cyclone comparison contributed by several resources. However, the dissimilarity was 35.51% when the pre and post cyclone assemblages were compared and the main difference was due to *Stolephorus* (21.06%) (Fig 5.12; Table 5.13).

Ernakulam MTN: The percentage dissimilarity in the resource assemblage during the cyclone and pre-cyclone period was 41% and was higher (69.66%) when the cyclone and post cyclone assemblages were compared (Fig 5.12). In the former scads contributed 41.40 % followed by oil sardine 40.99%. Oil sardine singly contributed to 72% of the total dissimilarity in the latter (cyclone vs post cyclone). Similarly, oil sardine and scads formed

59.54 and 24.71% of the total dissimilarity of 87.28% of the pre-cyclone and post cyclone resource assemblages (Table 5.13).

5.3.7 Variations in the Resource Assemblage in OBBS, MGN and MHL operated Marine Areas

OBBS was observed only at Thiruvananthapuram while MGN and MHL were operated off Ernakulam. The details of variation in assemblages are given below.

Thiruvananthapuram OBBS: The dissimilarity percentage was very high (80.59%) when the cyclone and pre-cyclone assemblages were compared (Fig 5.13). Changes in abundance of *Auxis* spp and oil sardine contributed to 31.68 and 18.94 percentage of the dissimilarity. The dissimilarity was slightly lower (68.99%) when the cyclone and post cyclone assemblages were analysed and the main resources responsible were lobsters (39.83%) and oil sardine (16.20%). There was still lower variation between pre-cyclone and post cyclone comparison and *Auxis* spp and tunas contributed to 30.49 and 29.83% of the total variation (Table 5.19).

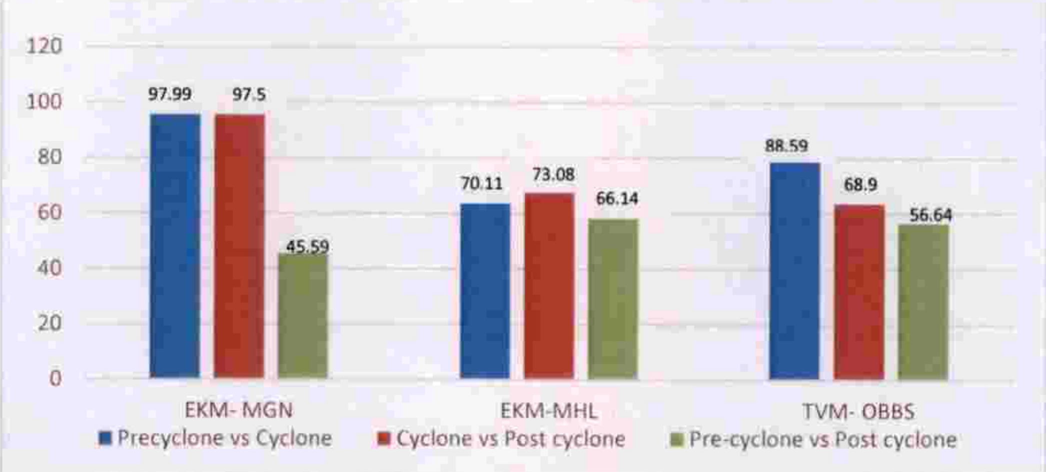

Fig 5.13 Percentage dissimilarity in the species assemblage in MGN, MHL and OBBS operated areas

Ernakulam MGN: The average dissimilarity was very high (97.99%) when the resource assemblages between cyclone and pre-cyclone were compared and the main resources responsible for this variation were other tunnies and billfishes contributing to 18.34% and 16.32% respectively. The assemblage of cyclone and post cyclone period also showed wide variation (97.95%) and the variation was mainly due to *K. pelamis* (49%) and other tunnies

(17.59%). *K. pelamis* contributed to 47.89% of the total dissimilarity percentage of 45.59% between the pre and post cyclone assemblages (Fig 5.13; Table 5.20).

Ernakulam MHL: The dissimilarity percentage was high (70.11) when the resource assemblage of cyclone and pre-cyclone period in the areas where MHL were operated (Fig 5.13). The presence and absence of resources like ribbon fishes, squids and cuttlefishes contributed to 32.93%, 28.15% and 20.18% respectively. These three resources in varying percentages were responsible for the total dissimilarity percentage of 73.08 % of the pre and post cyclone resource assemblage comparison. Bill fishes and *K. pelamis* contributed to 23.89 and 16.44% of the total dissimilarity of 66.14% of the cyclone and post cyclone comparison (Table 5.21).

Table 5.11 - Results of SIMPER test on resources caught by MDTN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed

Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 36.17%					
Penaeid prawns	750.7	415.3	4.25	11.74	11.74
Scads	405	102.5	3.83	10.59	22.32
Squids	421.4	129.9	3.69	10.2	32.52
Ribbon Fishes	329.3	41.5	3.64	10.07	42.59
Lizard Fishes	495.6	226.6	3.4	9.41	52.01
Average dissimilarity Cyclone & Post cyclone - 30.53%					
Scads	102.5	677	7.1	23.24	23.24
Penaeid prawns	415.3	723.9	3.81	12.49	35.73
Non-penaeid prawns	233.7	523.7	3.58	11.73	47.46
Other carangids	135.3	393.7	3.19	10.45	57.92
Average dissimilarity Pre-cyclone & Post cyclone - 26.12%					
Ribbon Fishes	329.3	43	2.79	10.67	10.67
Scads	405	677	2.65	10.14	20.81
Lizard Fishes	495.6	268.6	2.21	8.46	29.27
Other carangids	171.9	393.7	2.16	8.27	37.53
Threadfin breams	560.5	764.8	1.99	7.61	45.15
Squids	421.4	220.1	1.96	7.5	52.65
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 51.58%					
Ribbon Fishes	1689.8	387	10.03	19.45	19.45
Squids	1269.8	271.2	7.69	14.91	34.35
Cuttlefish	922.1	77.7	6.5	12.6	46.96
Threadfin breams	1496.2	735.3	5.86	11.36	58.32
Average dissimilarity Cyclone & Post cyclone - 35.72%					
Threadfin breams	735.3	1600.5	8.8	24.64	24.64
Miscellaneous	31.5	395.3	3.7	10.36	35
Oil sardine	466.6	130.1	3.42	9.58	44.59
Penaeid prawns	434.5	765.6	3.37	9.43	54.02
Average dissimilarity Pre-cyclone & Post cyclone - 42.97%					
Ribbon Fishes	1689.8	57.9	10.89	25.35	25.35
Squids	1269.8	370.1	6.01	13.98	39.33
Cuttlefish	922.1	147.8	5.17	12.03	51.36

Table 5.12 - Results of SIMPER test on resources caught by MRS in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 97.53%					
Indian mackerel	154.8	2.3	31.38	32.17	32.17
Barracudas	104.9	0	21.58	22.13	54.3
Stolephorus	63.3	0	13.02	13.35	67.66
Average dissimilarity Cyclone & Post cyclone - 87.12%					
Other sardines	2	23.8	23.02	26.42	26.42
Oil sardine	1.3	20.9	20.7	23.76	50.18
Indian mackerel	2.3	15.4	13.83	15.88	66.06
Average dissimilarity Pre-cyclone & Post cyclone - 75.73%					
Indian mackerel	154.8	15.4	24.52	32.38	32.38
Barracudas	104.9	0	18.45	24.37	56.75
Stolephorus	63.3	0	11.13	14.7	71.45
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 58.91%					
Oil sardine	878.2	301.8	16.75	28.43	28.43
Indian mackerel	456.6	4.8	13.13	22.28	50.71
Stolephorus	400.1	53.2	10.08	17.11	67.82
Average dissimilarity Cyclone & Post cyclone - 58.34%					
Stolephorus	53.2	478.3	22.03	37.76	37.76
Oil sardine	301.8	635.2	17.28	29.62	67.38
Other sardines	326.6	14.8	16.16	27.7	95.08
Average dissimilarity Pre-cyclone & Post cyclone - 42.44%					
Indian mackerel	456.6	16.3	11.2	26.39	26.39
Other sardines	313.7	14.8	7.6	17.91	44.3
Oil sardine	878.2	635.2	6.18	14.56	58.86
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 67.22%					
Oil sardine	1532.3	559.1	26.36	39.22	39.22
Scads	848.4	0	22.98	34.19	73.41
Other sardines	342.9	0	9.29	13.82	87.23
Average dissimilarity Cyclone & Post cyclone - 11.7%					
Oil sardine	559.1	484.7	6.32	53.99	53.99
Other carangids	0	18.4	1.56	13.35	67.34
Penaeid prawns	0	16	1.36	11.61	78.96
Average dissimilarity Pre-cyclone & Post cyclone - 70.74%					
Oil sardine	1532.3	484.7	28.69	40.56	40.56
Scads	848.4	0	23.24	32.84	73.4
Other sardines	342.9	4.3	9.27	13.11	86.51

Table 5.13 - Results of SIMPER test on resources caught by MTN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed

Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 24.97%					
Stolephorus	28.2	4.4	6.47	25.9	25.9
Ribbon Fishes	13.6	0	3.69	14.8	40.7
Lizard Fishes	8.4	0.1	2.25	9.03	49.73
Other sardines	8.4	1	2.01	8.05	57.78
Average dissimilarity Cyclone & Post cyclone - 21.2%					
Miscellaneous	7.6	20.1	4.51	21.29	21.29
Cuttlefish	8	0	2.89	13.63	34.92
Penaeid prawns	48.5	42.3	2.24	10.56	45.49
Silverbellies	5.5	10	1.63	7.67	53.15
Average dissimilarity Pre-cyclone & Post cyclone - 35.51%					
Stolephorus	28.2	0.7	7.48	21.06	21.06
Miscellaneous	8.3	20.1	3.21	9.04	30.09
Ribbon Fishes	13.6	2	3.15	8.88	38.97
Cuttlefish	11.5	0	3.13	8.81	47.78
Penaeid prawns	51.6	42.3	2.53	7.12	54.9
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 41.9%					
Scads	121.1	0	17.35	41.4	41.4
Oil sardine	291.8	172.2	17.13	40.89	82.29
Average dissimilarity Cyclone & Post cyclone - 69.66%					
Oil sardine	172.2	0	50.23	72.11	72.11
Penaeid prawns	32.5	52.1	5.72	8.21	80.32
Average dissimilarity Pre-cyclone & Post cyclone - 87.28%					
Oil sardine	291.8	0	51.97	59.54	59.54
Scads	121.1	0	21.57	24.71	84.25

Table 5.14a - Results of SIMPER test on resources caught by OBGN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 75.59%					
Indian mackerel	297.1	55.8	13.29	17.58	17.58
Ribbon Fishes	230.6	0	12.7	16.8	34.39
Auxis. spp	246.8	58.3	10.38	13.74	48.12
E. affinis	196.4	36.6	8.8	11.64	59.77
Average dissimilarity Cyclone & Post cyclone - 61.28%					
Indian mackerel	55.8	197.1	11.44	18.67	18.67
Other carangids	41.5	178.8	11.12	18.14	36.81
Other tunnies	5.6	132.8	10.3	16.81	53.61
E. affinis	36.6	99.4	5.08	8.3	61.91
Average dissimilarity Pre-cyclone & Post cyclone - 43.32%					
Ribbon Fishes	230.6	14	8.47	19.56	19.56
Auxis. spp	246.8	81.8	6.45	14.9	34.45
Indian mackerel	297.1	197.1	3.91	9.03	43.48
E. affinis	196.4	99.4	3.79	8.76	52.24
Other carangids	102.7	178.8	2.98	6.87	59.11
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 87.8%					
K. pelamis	64.4	0	10.34	11.78	11.78
E. affinis	69.8	6.9	10.1	11.51	23.29
Oil sardine	73.6	12	9.89	11.27	34.55
Indian mackerel	66.6	5.8	9.76	11.12	45.67
Auxis. spp	64.1	4.5	9.57	10.9	56.58
Average dissimilarity Cyclone & Post cyclone - 89.11%					
Oil sardine	12	118.7	15.74	17.66	17.66
E. affinis	6.9	93	12.7	14.25	31.92
K. pelamis	0	81.6	12.04	13.51	45.42
Indian mackerel	5.8	79.9	10.93	12.27	57.69
Average dissimilarity Pre-cyclone & Post cyclone - 25.52%					
Oil sardine	73.6	118.7	3.68	14.44	14.44
Auxis. spp	64.1	27.7	2.97	11.65	26.09
Other sardines	6.2	42.1	2.93	11.49	37.58
E. affinis	69.8	93	1.9	7.43	45.01
Bill Fishes	32.2	53.7	1.76	6.88	51.89

Table 5.14b- Results of SIMPER test on resources caught by OBGN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 77.25%					
Oil sardine	132.3	1	38.39	49.7	49.7
E. affinis	22.7	0	6.64	8.59	58.29
Average dissimilarity Cyclone & Post cyclone - 64.86%					
K. pelamis	0	54.3	17.54	27.04	27.04
Oil sardine	1	32.2	10.08	15.54	42.58
Indian mackerel	32.9	47.4	4.68	7.22	49.8
Bill Fishes	0	13.4	4.33	6.67	56.47
Average dissimilarity Pre-cyclone & Post cyclone - 46.62%					
Oil sardine	132.3	32.2	19.22	41.23	41.23
K. pelamis	13	54.3	7.93	17.01	58.24
ALAPPUZHA					
Average dissimilarity Pre-cyclone & Cyclone - 73.36%					
Oil sardine	291.8	81.7	13.44	18.32	18.32
Other carangids	210.9	8.1	12.98	17.69	36.01
Indian mackerel	288.8	91.4	12.63	17.22	53.23
Average dissimilarity Cyclone & Post cyclone - 73.58%					
Oil sardine	81.7	575.2	31.75	43.15	43.15
Indian mackerel	91.4	236.4	9.33	12.68	55.83
Average dissimilarity Pre-cyclone & Post cyclone - 37.13%					
Oil sardine	291.8	575.2	10.67	28.74	28.74
Other carangids	210.9	96.1	4.32	11.64	40.38
Penaeid prawns	0	80.4	3.03	8.15	48.53
Other clupeids	14	85.3	2.68	7.23	55.76

Table 5.15a - Results of SIMPER test on resources caught by OBHL in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 91.05%					
Auxis. Spp	175.8	5.1	28.81	31.64	31.64
E. affinis	60.3	6.4	9.1	9.99	41.63
Ribbon Fishes	44	0	7.43	8.16	49.79
Other carangids	44.2	3.3	6.9	7.58	57.37
Average dissimilarity Cyclone & Post cyclone - 81.51%					
Sharks	0	39.4	12.92	15.85	15.85
Other carangids	3.3	42.4	12.82	15.73	31.58
Auxis. Spp	5.1	37.2	10.52	12.91	44.49
Rock cods	2	23.2	6.95	8.53	53.02
Average dissimilarity Pre-cyclone & Post cyclone - 52.59%					
Auxis. Spp	175.8	37.2	16.48	31.34	31.34
Sharks	0	39.4	4.68	8.91	40.24
E. affinis	60.3	21	4.67	8.89	49.13
Ribbon Fishes	44	4.9	4.65	8.84	57.97
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 73.01%					
E. affinis	28.9	1.8	29.98	41.06	41.06
K. pelamis	21.4	0	23.67	32.42	73.48
Average dissimilarity Cyclone & Post cyclone - 87.87%					
E. affinis	1.8	70.7	28.62	32.58	32.58
K. pelamis	0	47.4	19.69	22.41	54.99
Average dissimilarity Pre-cyclone & Post cyclone - 51.84%					
E. affinis	28.9	70.7	13.85	26.71	26.71
K. pelamis	21.4	47.4	8.61	16.61	43.32
Half Beaks&Full Beaks	0.1	12	3.94	7.6	50.93

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Table 5.15b - Results of SIMPER test on resources caught by OBHL in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 59.55%					
Cuttlefish	8.9	3.5	12.13	20.38	20.38
Squids	3.7	0.1	8.09	13.58	33.96
S. commersoni	6	2.6	7.64	12.83	46.79
Indian mackerel	0.4	3.5	6.97	11.7	58.49
Average dissimilarity Cyclone & Post cyclone - 52.57%					
Half Beaks&Full Beaks	0.3	5.3	12.22	23.26	23.26
S. commersoni	2.6	5.5	7.09	13.49	36.74
Other carangids	2.1	4.8	6.6	12.56	49.3
Indian mackerel	3.5	1.1	5.87	11.16	60.47
Average dissimilarity Pre-cyclone & Post cyclone - 32.34%					
Half Beaks&Full Beaks	0.8	5.3	7.43	22.96	22.96
Cuttlefish	8.9	4.9	6.6	20.41	43.37
Squids	3.7	0	6.11	18.88	62.24
ALAPPUZHA					
Average dissimilarity Pre-cyclone & Cyclone - 82.6%					
S. commersoni	23.9	0	22.36	27.07	27.07
E. affinis	22.2	0	20.77	25.14	52.21
Other tunnies	20.9	4	15.81	19.14	71.35
Average dissimilarity Cyclone & Post cyclone - 66%					
S. commersoni	0	16	29.25	44.32	44.32
Other tunnies	4	17.6	24.86	37.67	81.99
Average dissimilarity Pre-cyclone & Post cyclone - 42.1%					
E. affinis	22.2	0	15.52	36.88	36.88
Horse Mackerel	8.4	0	5.87	13.95	50.83
S. commersoni	23.9	16	5.52	13.12	63.95

Table 5.16 - Results of SIMPER test on resources caught by OBTN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 33.33%					
Croakers	4.5	8	17.16	51.47	51.47
Big-Jawed Jumper	0	1.5	7.35	22.06	73.53
Average dissimilarity Cyclone & Post cyclone - 42.61%					
Croakers	8	19.1	23.77	55.78	55.78
E. affinis	3.3	9.5	13.28	31.16	86.93
Average dissimilarity Pre-cyclone & Post cyclone - 66.25%					
Croakers	4.5	19.1	36.23	54.68	54.68
E. affinis	2.3	9.5	17.87	26.97	81.65
ALAPPUZHA					
Average dissimilarity Pre-cyclone & Cyclone - 21.25%					
Cuttlefish	2.77	0	10.22	48.08	48.08
Crabs	3.42	2.12	4.78	22.51	70.59
Average dissimilarity Cyclone & Post cyclone - 48.4%					
Penaeid prawns	6.14	16.3	22.29	46.05	46.05
Soles	2.72	7.33	10.11	20.89	66.94
Average dissimilarity Pre-cyclone & Post cyclone - 49.98%					
Penaeid prawns	5.92	16.3	21.63	43.29	43.29
Soles	2.65	7.33	9.77	19.54	62.82

Table 5.17 - Results of SIMPER test on resources caught by OBRS in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 96.64%					
Stolephorus	196.5	2.8	40.71	42.13	42.13
Oil sardine	101.1	0	21.25	21.99	64.11
Average dissimilarity Cyclone & Post cyclone - 92.3%					
Stolephorus	2.8	143.6	64.53	69.91	69.91
Other sardines	0.9	12.9	5.5	5.96	75.87
Average dissimilarity Pre-cyclone & Post cyclone - 42.73%					
Oil sardine	101.1	10.5	13.38	31.31	31.31
Indian mackerel	74.8	9.3	9.67	22.63	53.94
Stolephorus	196.5	143.6	7.81	18.28	72.22
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 59.31%					
Stolephorus	572.4	107.6	27.52	46.4	46.4
Oil sardine	275.1	90.7	10.92	18.41	64.8
Average dissimilarity Cyclone & Post cyclone - 30.32%					
Other sardines	124.8	3.8	17.47	57.62	57.62
Other perches	0	38.1	5.5	18.14	75.76
Average dissimilarity Pre-cyclone & Post cyclone - 67.66%					
Stolephorus	572.4	104	28.68	42.39	42.39
Oil sardine	275.1	92.6	11.17	16.52	58.9
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 65.85%					
Oil sardine	333.6	18.7	30.93	46.97	46.97
Penaeid prawns	19.2	90.1	6.96	10.58	57.55
Soles	51.3	1.1	4.93	7.49	65.04
Average dissimilarity Cyclone & Post cyclone - 53.05%					
Oil sardine	18.7	106.7	12.55	23.66	23.66
Penaeid prawns	90.1	13.9	10.87	20.49	44.15
Stolephorus	2.5	73	10.06	18.96	63.11
Average dissimilarity Pre-cyclone & Post cyclone - 45.89%					
Oil sardine	333.6	106.7	21.88	47.68	47.68
Stolephorus	23.3	73	4.79	10.44	58.12
Soles	51.3	1.8	4.77	10.4	68.52
ALAPPUZHA					
Average dissimilarity Pre-cyclone & Cyclone - 89.61%					
Oil sardine	1886.3	61.4	36.1	40.29	40.29
Other carangids	978.4	0	19.36	21.6	61.9
Average dissimilarity Cyclone & Post cyclone - 77.51%					
Oil sardine	61.4	520.1	30.81	39.75	39.75
Indian mackerel	0	167.8	11.27	14.54	54.29
Other carangids	0	146.4	9.83	12.69	66.98
Average dissimilarity Pre-cyclone & Post cyclone - 63.83%					
Oil sardine	1886.3	520.1	22.7	35.57	35.57
Other carangids	978.4	146.4	13.83	21.66	57.23
Other sardines	508.6	33.6	7.89	12.37	69.59

Table 5.18 - Results of SIMPER test on resources caught by NM in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 66.63%					
Stolephorus	31	3.8	16.69	25.05	25.05
Silverbellies	19.9	0.3	12.02	18.05	43.09
Crabs	17.3	0.5	10.31	15.47	58.56
Average dissimilarity Cyclone & Post cyclone - 79.65%					
Bivalves	0	152.8	47.25	59.32	59.32
Silverbellies	0.3	40.6	12.46	15.64	74.96
Average dissimilarity Pre-cyclone & Post cyclone - 67.43%					
Bivalves	0	152.8	38.1	56.51	56.51
Stolephorus	31	6.5	6.11	9.06	65.57
KOLLAM					
Average dissimilarity Pre-cyclone & Cyclone - 100%					
Crabs	10.2	0	21.29	21.29	21.29
Croakers	6.3	0	13.15	13.15	34.45
Cuttlefish	5	0	10.44	10.44	44.89
Lizard Fishes	3.6	0	7.52	7.52	52.4
Average dissimilarity Cyclone & Post cyclone - 100%					
Croakers	0	9.5	21.94	21.94	21.94
Cuttlefish	0	8.3	19.17	19.17	41.11
Other sardines	0	8.3	19.17	19.17	60.28
Average dissimilarity Pre-cyclone & Post cyclone - 42.32%					
Crabs	10.2	4.8	5.92	13.99	13.99
Other sardines	3.1	8.3	5.7	13.47	27.46
Cuttlefish	5	8.3	3.62	8.55	36.01
Barracudas	3.2	0	3.51	8.29	44.3
Croakers	6.3	9.5	3.51	8.29	52.59
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 74.17%					
Catfishes	7.1	0	26.2	35.32	35.32
Croakers	2.9	0	10.7	14.43	49.75
Thryssa	2.8	0.5	8.49	11.44	61.19
Average dissimilarity Cyclone & Post cyclone - 76.76%					
Oil sardine	0.3	18.7	49.73	64.79	64.79
Indian mackerel	0.2	3.5	8.92	11.62	76.41
Average dissimilarity Pre-cyclone & Post cyclone - 75.95%					
Oil sardine	0.1	18.7	37.27	49.08	49.08
Catfishes	7.1	0	14.23	18.73	67.81
ALAPPUZHA					
Average dissimilarity Pre-cyclone & Cyclone - 32.53%					
Indian mackerel	7.7	54.1	4.22	12.97	12.97
Penaeid prawns	17.7	63.3	4.15	12.74	25.71
Oil sardine	262.7	219.4	3.94	12.1	37.81
Other carangids	50.4	21.9	2.59	7.97	45.78
Silverbellies	13.4	41.6	2.56	7.88	53.66
Average dissimilarity Cyclone & Post cyclone - 36.91%					
Oil sardine	219.4	506.2	19.38	52.52	52.52
Indian mackerel	54.1	108.2	3.66	9.91	62.42
Average dissimilarity Pre-cyclone & Post cyclone - 39.96%					
Oil sardine	262.7	506.2	15.99	40	40
Indian mackerel	7.7	108.2	6.6	16.51	56.51

Table 5.19 - Results of SIMPER test on resources caught by OBBS in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
THIRUVANANTHAPURAM					
Average dissimilarity Pre-cyclone & Cyclone - 80.59%					
Auxis. spp	631.1	0	25.69	31.88	31.88
Oil sardine	413.5	38.5	15.27	18.94	50.82
Crabs	186.7	0	7.6	9.43	60.25
Average dissimilarity Cyclone & Post cyclone - 68.99%					
Lobsters	7.1	491.8	27.48	39.83	39.83
Oil sardine	38.5	235.6	11.17	16.2	56.03
Average dissimilarity Pre-cyclone & Post cyclone - 56.64%					
Auxis. spp	631.1	0	17.27	30.49	30.49
Lobsters	40	491.8	12.36	21.83	52.31
Oil sardine	413.5	235.6	4.87	8.59	60.91

Table 5.20 - Results of SIMPER test on resources caught by MGN in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 97.99%					
Other tunnies	122.2	0.5	17.97	18.34	18.34
Bill Fishes	111.3	3	15.99	16.32	34.65
Other carangids	104.8	0	15.47	15.79	50.44
Rock cods	85.7	0	12.65	12.91	63.36
Average dissimilarity Cyclone & Post cyclone - 97.95%					
K. pelamis	1.2	320.4	48	49	49
Other tunnies	0.5	115.1	17.23	17.59	66.6
Average dissimilarity Pre-cyclone & Post cyclone - 45.59%					
K. pelamis	30.3	320.4	21.83	47.89	47.89
Other carangids	104.8	29.9	5.64	12.37	60.26

Table 5.21 - Results of SIMPER test on resources caught by MHL in the cyclone affected districts of Kerala (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
ERNAKULAM					
Average dissimilarity Pre-cyclone & Cyclone - 70.11%					
Ribbon Fishes	246.5	14	23.09	32.93	32.93
Squids	198.8	0	19.74	28.15	61.08
Average dissimilarity Cyclone & Post cyclone - 66.14%					
Bill Fishes	23.1	161.4	15.8	23.89	23.89
K. pelamis	18.8	114	10.88	16.44	40.33
Other tunnies	62.3	156.5	10.76	16.27	56.6
Average dissimilarity Pre-cyclone & Post cyclone - 73.08%					
Ribbon Fishes	246.5	0	16.34	22.35	22.35
Squids	198.8	0	13.18	18.03	40.38
Cuttlefish	142.5	0	9.44	12.92	53.31

5.4 Impact of Ockhi on the marine species assemblage of commercial fishing grounds off Tamil Nadu

The results of the SIMPER analysis indicated that there was wide variation in the intensity of impact across districts and the gears used (Fig 5.14; Table 5.22). The highest dissimilarity (90.1%) was observed in the in the MDTN catch especially during the cyclone and post cyclone period. The species assemblage along the Kanyakumari coast before and during the cyclone period was also dissimilar (88.31%). The least dissimilarity was in the OBGN and MTN fishery resources along Tuticorin coast. Detailed results of the gear-wise analysis are given below.

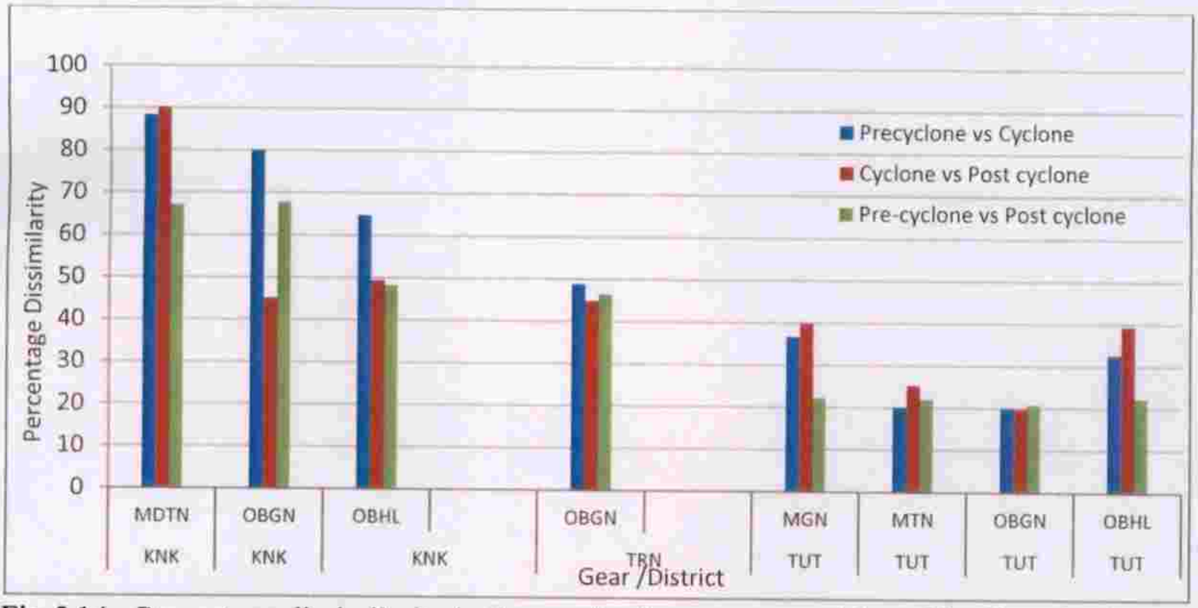

Fig 5.14 - Percentage dissimilarity in the species / group composition of landings by different gears operated in the 2017 cyclone Ockhi affected districts of Tamil Nadu

Table 5.22- Percentage dissimilarity in the species / group composition of landings by different gears operated in the 2017 cyclone Ockhi affected districts of Tamil Nadu

District	Gear	Pre-cyclone vs Cyclone	Cyclone vs Post cyclone	Pre-cyclone vs Post cyclone
Kanyakumari	MDTN	88.31	90.1	67.18
Kanyakumari	OBGN	80.03	45.18	67.77
Thirunelveli	OBGN	48.89	44.92	46.47
Tuticorin	OBGN	20.03	19.9	20.96
Kanyakumari	OBHL	64.75	49.45	48.31
Tuticorin	OBHL	32.69	39.46	22.38
Tuticorin	MGN	36.78	39.93	22.28
Tuticorin	MTN	20.19	25.27	22.1

5.4.1 Variations in resource assemblages in the MDTN operated areas off Tamil Nadu

Kanyakumari MDTN: The marine resources obtained in the MDTN catches were highly different. The percentage dissimilarity between the pre-cyclone and cyclone period was very high (88.31%) and the main resources which contributed to the difference are oil sardine and Indian mackerel which had formed the major component of the catch during pre-cyclone period. These were completely absent during cyclone and they contributed 12.2% and 9.15% of the total dissimilarity percentage (Table 5.23). Several species like wolf herring, perches and threadfin breams which had formed an important part of the pre-cyclone period were absent during the cyclone period.

The species assemblage during the cyclone and post cyclone was also highly dissimilar (90.10%). Croakers, Indian mackerel and scads which were present in the catch during the post cyclone period were completely absent during the cyclone and they contributed the maximum 8.93, 8.85 and 7.76 percentage of the dissimilarity between the assemblages (Table 5.23).

The species assemblage of the pre-cyclone and post cyclone period also showed high variation, but was much less (67.18%). The oil sardine resources which were one of the major contributors of the catch during the pre-cyclone period did not occur in the catch during the post cyclone period, thus contributing to 15.06% of the total dissimilarity. Other major resources which were absent in the post cyclone assemblages were Threadfin breams, wolf herring, squids and *Thryssa* contributing to 5.1, 4.1, 3.3 and 3.1 respectively. Other details are given in Table 5.23.

5.4.2 Variations in resource assemblages in the OBGN operated areas off Tamil Nadu

The species assemblage in the OBGN fishing area differed between the pre-cyclone, cyclone and post cyclone period. The maximum dissimilarity was observed in the Kanyakumari district followed by Thirunelveli. There was only very low dissimilarity at Tuticorin (Table 5.25). Details are given below.

Kanyakumari OBGN: In the Kanyakumari district, the dissimilarity was high (80.03%) when the pre-cyclone and cyclone assemblages are compared. This improved and the dissimilarity was 45.18% between the cyclone and post cyclone period. However, when we compare the pre-cyclone and post cyclone period there was 67.77% dissimilarity. The Indian oil sardine, big jawed jumper and ribbon fishes were abundant during the pre-cyclone period but these completely disappeared during the cyclone period thereby contributing to a dissimilarity of 9.55, 8.66 and 7.44 percentage of the total dissimilarity. Similarly Indian mackerel which was the most dominant fish in OBGN during the pre-cyclone period was available, but the quantity was considerably less thereby making a contribution of 8.64% of the total dissimilarity (Table 5.25).

The dissimilarity between cyclone and post cyclone assemblages was comparatively lower (45.18%). The occurrence of the tuna, *E. affinis* in the catch, though in low quantities, during post cyclone period and its absence during the cyclone period contributed to 16.35% of the dissimilarity. Oil sardine had formed the major part of the assemblage during the pre-cyclone period. Though this species occurred in the catch during post cyclone, their reduction in abundance lead to a dissimilarity of 9.39%. The absence of big jawed jumper and ribbon fishes in the post cyclone period contributed to 9.22 and 7.92 percent of the dissimilarity (Table 5.25).

Thirunelveli OBGN: The dissimilarity in the resource assemblages of OBGN fishing area in the Thirunelveli district area was nearly 50% (48.89%) between the pre-cyclone and cyclone period. It reduced and became 45.18% during the cyclone and post cyclone period and was 46.47% between the pre and post cyclone period. The drastic decline in other sardine resources during the cyclone period contributed to 21.02% of the dissimilarity between the cyclone and pre-cyclone period. Similarly the increase in mackerel catch during the cyclone period also led to a contribution of 17.36% of the total dissimilarity (Table 5.25).

Other sardine which was negligible during the cyclone became abundant during the post cyclone period; thus contributing to 18.19% of the total dissimilarity. Similarly, there was high catch of tuna *E .affinis* during the post cyclone period and its absence during the cyclone led to a contribution of 14.35%. The dissimilarity between pre-cyclone and post cyclone was 46.47% and this was mainly contributed by other sardine (18.19%) and *E. affinis* (14.35%) (Table 5.25).

Tuticorin OBGN: The marine resource assemblage in the OBGN fishing area off Tuticorin was not very dissimilar during the pre-cyclone, cyclone and post cyclone period. The dissimilarity percentage was less than 21% in all the three instances (Table.5.27). Half beaks and full beaks contributed to the highest 8.44% of the total dissimilarity between pre-cyclone and cyclone period. In the comparison between cyclone and post cyclone, the maximum dissimilarity was due to oil sardine (32.19%). This resource was absent during cyclone period but occurred during post cyclone. The resource assemblage during the pre-cyclone and post cyclone was almost similar and the dissimilarity was mainly due to the presence of oil sardine (26.66%) during the post cyclone period.

5.4.2 Variations in resource assemblages in the OBHL operated areas off Tamil Nadu

The dissimilarity in the resource assemblage in the OBHL are of the Ockhi hit districts of Tamil Nadu showed variation and the percentage dissimilarity was high in Kanyakumari district than in Tuticorin. Details are presented in Table 5.26 and Fig 5.14.

Kanyakumari OBHL: The percentage dissimilarity between the cyclone and pre-cyclone period was high (64.75%) which reduced to 49.45 % when the comparison was between cyclone period with post cyclone. However, the percentage dissimilarity between the pre-cyclone and post cyclone period was 48.31%. Details are presented in Table 5.26 and Fig 5.14.

The main difference in the resource assemblage between pre-cyclone and cyclone was the absence of *S. guttatus* during the cyclone period which contributed to 15.77% of the dissimilarity. The low catch of pig face breams and *S. commersoni* contributed to 12.2 % and 11.3% of the dissimilarity. The major resources which were responsible for the dissimilarity of the assemblage between cyclone and post cyclone were Pig face breams (15.18%), half beaks and full beaks (10.85%) and miscellaneous resources (17.01%). The dissimilarity in resource assemblage between pre and post cyclone was mainly by *S. guttatus, S. commersoni* and rays contributing to 16.48, 13.45 and 8.3 percentage respectively (Table 5.26).

Tuticorin OBHL: The marine resource assemblage of the OBHL area off Tuticorin showed a dissimilarity of 32.69% when the pre-cyclone catch was compared with the catch obtained during the cyclone period. The dissimilarity increased and became 39.46 between the cyclone and post cyclone comparison. However, the dissimilarity between the marine resource assemblages of pre-cyclone period with that of post cyclone was only 22.38%. Details are presented in Table 5.26 and Fig 5.14.

The resources which were responsible for the dissimilarity during the pre-cyclone and cyclone period were pig face breams (14.36%), cuttle fish (6.35%) and other carangids (6.20%). The differences between cyclone and post cyclone period was the higher abundance of half and full beak followed by complete absence of wolf herring during the cyclone period. These contributed to 7.94 % and 6.56% respectively. The three major resources which showed variation in catch between the pre and post cyclonee were half beaks and full beaks (7.96%), fishery of pig face breams (6.35%) and the absence of sharks during the post cycle party (6.31%). Details are presented in Table 5.26 and Fig 5.14.

5.4.4 Variations in resource assemblages in the MGN and MTN operated areas off Tamil Nadu

Tuticorin MGN: The marine resource assemblage showed a dissimilarity percentage of 36.7 when the pre-cyclone and cyclone catches were compared. This increased to 39.93% in the comparison between cyclone and post cyclone assemblages. However the dissimilarity was low, 22.28% between the pre and post cyclone period resources (Table 5.24).

Absence of four resources viz. *K. pelamis*, bill fishes, sharks and *Acanthocybium* during the cyclone period and their presence during pre-cyclone period was responsible for 20.4, 16.15, 10.20 and 6.82 percentage of the dissimilarity. Similarly absence of *K. pelamis*, bill fishes and sharks during the cyclone period in contrast to their presence during post cyclone period have contributed to 16.3, 13.15 and 10.96 percent of the dissimilarity. Also the low catch of *E. affinis* during post cyclone period contributed to 14.76% of the total dissimilarity of cyclone and post cyclone species assemblage. *E. affinis* and *Auxis* spp were responsible for 15.03 and 12.35 percentage of the dissimilarity between pre-cyclone and post cyclone period (Table 5.24).

Tuticorin MTN: The resource assemblage in the MTN area was almost similar during the cyclone and pre-cyclone period with 20.19% dissimilarity. This increased to 25.27% when the cyclone and post cyclone resources were compared. Again the dissimilarity was low, 22.1% when the pre-cyclone and post cyclone resource assemblages were compared (Table 5.27).

Table 5.23 - Results of SIMPER test on resources caught by MDTN in the cyclone affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage Contribution	Cumulative percentage
KANYAKUMARI					
Average Dissimilarity Pre-cyclone & Cyclone - 88.31%					
Oil sardine	46.78	0	12.25	13.87	13.87
Indian mackerel	35.04	0	9.18	10.39	24.26
Miscellaneous	28.48	6.88	5.66	6.4	30.67
Wolf herring	19.02	0	4.98	5.64	36.31
Other perches	18.84	0	4.93	5.59	41.9
Average Dissimilarity Pre-cyclone & Post-cyclone - 67.18%					
Oil sardine	46.78	0	10.12	15.06	15.06
Miscellaneous	28.48	1.45	5.84	8.7	23.76
Indian mackerel	35.04	10.1	5.39	8.03	31.79
Threadfin breams	23.59	0	5.1	7.59	39.38
Wolf herring	19.02	0	4.11	6.12	45.5
Squids	18.65	0	4.03	6	51.5
Average Dissimilarity Cyclone & Post-cyclone - 90.1%					
Croakers	0	10.2	8.04	8.93	8.93
Indian mackerel	0	10.1	7.97	8.85	17.77
Scads	0	8.86	6.99	7.76	25.53
Rock cods	1.52	9.75	6.5	7.21	32.74
Other carangids	0	7.14	5.63	6.25	38.99
Threadfin breams	6.6	0	5.21	5.78	44.77

Table 5.24 - Results of SIMPER test on resources caught by MGN in the cyclone affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
TUTICORIN					
Average Dissimilarity Pre-cyclone & Cyclone - 36.78%					
K. pelamis	5.83	0	7.51	20.41	20.41
Bill Fishes	4.62	0	5.94	16.15	36.56
Sharks	2.92	0	3.75	10.2	46.77
Acanthocybium spp.	1.95	0	2.51	6.82	53.59
Average Dissimilarity Pre-cyclone & Post-cyclone - 22.28%					
E. affinis	4.9	1.9	3.35	15.03	15.03
Auxis. spp	5.61	3.15	2.75	12.35	27.39
S. commersoni	4.12	2.24	2.11	9.45	36.84
Other tunnies	7.5	5.65	2.07	9.29	46.13
K. pelamis	5.83	4.07	1.96	8.8	54.93
Average Dissimilarity Cyclone & Post-cyclone - 39.93%					
K. pelamis	0	4.07	6.51	16.3	16.3
E. affinis	5.59	1.9	5.89	14.76	31.06
Bill Fishes	0	3.29	5.25	13.15	44.21
Sharks	0	2.74	4.37	10.96	55.16

Table 5.25- Results of SIMPER test on resources caught by OBGN in the cyclone affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
KANYAKUMARI					
Average Dissimilarity Pre-cyclone & Cyclone -80.03%					
Oil sardine	11.12	0	7.67	9.59	9.59
Big-Jawed Jumper	10.04	0	6.93	8.66	18.24
Indian mackerel	11.63	1.61	6.91	8.64	26.88
Ribbon Fishes	8.63	0	5.95	7.44	34.32
Other sardines	8.34	1.76	4.54	5.67	39.99
Average Dissimilarity Pre-cyclone & Post-cyclone - 67.77%					
Oil sardine	11.12	0.89	6.36	9.39	9.39
Big-Jawed Jumper	10.04	0	6.25	9.22	18.61
Indian mackerel	11.63	1.97	6.01	8.86	27.47
Ribbon Fishes	8.63	0	5.37	7.92	35.39
Crabs	7.05	0.63	3.99	5.89	41.28
Average Dissimilarity Cyclone & Post-cyclone -45.18%					
E. affinis	0	3.46	7.39	16.35	16.35
Leather-jackets	0.32	2.41	4.46	9.87	26.22
Other clupeids	0	1.67	3.57	7.9	34.12
Half Beaks&Full Beaks	1	2.3	2.78	6.15	40.26
Scads	0.89	2.05	2.46	5.45	45.71
THIRUNELVELI					
Average Dissimilarity Pre-cyclone & Cyclone - 48.89%					
Other sardines	13.96	1.1	10.27	21.02	21.02
Indian mackerel	1.64	12.27	8.49	17.36	38.37
Cuttlefish	5.51	1.14	3.49	7.14	45.52
Croakers	2.66	6.94	3.41	6.97	52.49
Average Dissimilarity Pre-cyclone & Post-cyclone - 46.47%					
Other sardines	13.96	28.61	8.45	18.19	18.19
E. affinis	0	11.55	6.67	14.35	32.53
Half Beaks&Full Beaks	0	4.51	2.6	5.6	38.13
Croakers	2.66	6.9	2.44	5.26	43.39
Ribbon Fishes	1.48	5.04	2.05	4.42	47.81
Average Dissimilarity Cyclone & Post-cyclone - 44.92%					
Other sardines	1.1	28.61	15.21	33.87	33.87
E. affinis	0	11.55	6.39	14.22	48.08
Indian mackerel	12.27	4.27	4.43	9.86	57.94
TUTICORIN					
Average Dissimilarity Pre-cyclone & Cyclone - 20.03%					
Half Beaks &Full Beaks	11.06	4.06	1.69	8.44	8.44
Other sardines	21.73	27.24	1.33	6.65	15.08
Thryssa	6.45	1.76	1.13	5.66	20.74
Auxis. spp	6.36	2.3	0.98	4.89	25.63
Pig-face breams	10.19	6.2	0.96	4.8	30.43
Average Dissimilarity Pre-cyclone & Post-cyclone - 20.96%					
Oil sardine	0	26.06	5.59	26.66	26.66
Silverbellies	6.16	12.16	1.29	6.14	32.8
Stolephorus	6.64	2.45	0.9	4.29	37.09
Auxis. spp	6.36	2.35	0.86	4.1	41.19
E. affinis	7.28	3.27	0.86	4.1	45.3
Average Dissimilarity Cyclone & Post-cyclone - 19.9%					
Oil sardine	0	26.06	6.41	32.19	32.19
Other sardines	27.24	22.81	1.09	5.48	37.66
Silverbellies	8.43	12.16	0.92	4.6	42.26
Half Beaks &Full Beaks	4.06	7.36	0.81	4.08	46.34
Barracudas	5.23	8.26	0.74	3.73	50.07

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Table 5.26 - Results of SIMPER test on resources caught by OBHL in the cyclone affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
KANYAKUMARI					
Average Dissimilarity Pre-cyclone & Cyclone - 64.75%					
S. guttatus	7.22	0	10.21	15.77	15.77
Pig-face breams	8.17	2.59	7.9	12.2	27.98
S. commersoni	5.89	0.71	7.33	11.33	39.31
Rays	3.63	0	5.14	7.94	47.25
Cuttlefish	3.54	0.32	4.56	7.04	54.28
Average Dissimilarity Pre-cyclone & Post-cyclone - 48.31%					
S. guttatus	7.22	0	7.96	16.48	16.48
S. commersoni	5.89	0	6.5	13.45	29.93
Rays	3.63	0	4.01	8.3	38.23
Other carangids	3.71	0.55	3.49	7.23	45.46
Miscellaneous	1.22	4.32	3.42	7.08	52.54
Average Dissimilarity Cyclone & Post-cyclone - 49.45%					
Miscellaneous	0.55	4.32	8.41	17.01	17.01
Pig-face breams	2.59	5.96	7.51	15.18	32.19
Half Beaks &Full Beaks	0	2.41	5.36	10.85	43.04
Snappers	2.05	4.23	4.86	9.83	52.87
TUTICORIN					
Average Dissimilarity Pre-cyclone & Cyclone - 32.69%					
Pig-face breams	11.12	3.92	4.69	14.36	14.36
Cuttlefish	6.52	9.7	2.07	6.35	20.71
Other carangids	6.28	3.18	2.03	6.2	26.9
Barracudas	5.04	2.17	1.87	5.73	32.63
Other tunnies	3.18	0.32	1.87	5.71	38.34
Rock cods	7.84	5.03	1.83	5.61	43.95
Average Dissimilarity Pre-cyclone & Post-cyclone - 22.38%					
Half Beaks &Full Beaks	2.63	6.31	1.78	7.96	7.96
Pig-face breams	11.12	8.19	1.42	6.35	14.31
Sharks	2.92	0	1.41	6.31	20.62
Bill Fishes	0	2.63	1.27	5.68	26.3
Catfishes	0.95	3.54	1.25	5.59	31.9
Other perches	4.7	7.26	1.24	5.53	37.43
Average Dissimilarity Cyclone & Post-cyclone - 39.46%					
Half Beaks &Full Beaks	0.89	6.31	3.13	7.94	7.94
Wolf herring	0	4.47	2.59	6.56	14.51
Pig-face breams	3.92	8.19	2.47	6.25	20.76
Other perches	3.03	7.26	2.45	6.2	26.96
E. affinis	0	3.7	2.14	5.43	32.39
Other carangids	3.18	6.69	2.04	5.16	37.55

Table 5.27 - Results of SIMPER test on resources caught by MTN in the cyclone affected districts of Tamil Nadu (Only top 5 or resources which contribute up to 50% cumulate percentage dissimilarity have been listed					
Species	Group 1 Av. Abundance	Group 2 Av. Abundance	Av. Dissimilarity	Percentage contribution	Cumulative percentage
TUTICORIN					
Average Dissimilarity Pre-cyclone & Cyclone - 20.19%					
Silverbellies	14.75	8.5	2.05	10.13	10.13
Indian mackerel	9.75	4.25	1.8	8.91	19.04
Other sardines	12.61	8.69	1.28	6.34	25.38
Other clupeids	5.76	2.32	1.13	5.58	30.95
Other perches	7.4	10.33	0.96	4.75	35.71
Average Dissimilarity Pre-cyclone & Post-cyclone - 22.1%					
Indian mackerel	9.75	0	2.99	13.55	13.55
Squids	5.63	12.6	2.14	9.69	23.24
Indian mackerel	0	5.19	1.59	7.21	30.45
Stolephorus	6.71	3	1.14	5.16	35.61
Miscellaneous	4.62	8.12	1.08	4.88	40.49
Average Dissimilarity Cyclone & Post-cyclone - 25.27%					
Squids	5.72	12.6	2.37	9.4	9.4
Indian mackerel	4.25	5.19	1.79	7.08	16.48
Miscellaneous	3.75	8.12	1.51	5.96	22.44
Silverbellies	8.5	12.86	1.5	5.94	28.39

5.5 Environmental changes during the month of Ockhi along Kerala coast

During the month of Cyclone Ockhi, SST slightly decreased in comparison with the previous months (Fig 5.15). Chlorophyll-a concentration, rainfall and salinity increased from normal (10 year average of each month). Chlorophyll concentration increased by 27% (0.42 to 0.54 mg m^{-3}) (Fig 5.16). Monthly rainfall 67% increased (Fig 5.17). During December, salinity slightly increased from 34.18 to 34.87 ppt (+0.67) (Fig 5.18). During and after the cyclone months, magnitude of the surface current considerably increased (0.08 to 0.25 ms^{-1}). The current direction had changed slightly (Fig 5.20). During December and January, downwelling and upwelling occurred along the Kerala coast (Fig 5.19).Total catch was extremely low (-11322 tonnes). But catch showed a sudden rise in the months after the cyclone (Fig 5.21). Landings of oil sardine, Indian mackerel, other sardines and scads fell in December and peaked in January (Fig 5.22, 5.23, 5.24 and 5.25). During and after the months of cyclone, catch variation of penaeid prawns was less (Fig 5.27). CPUE (Catch per unit effort) of OBBS (Out Board Boat Seine), OBGN (Out Board Gill Net), OBHL (Out Board Hook and Line), OBRS (Out Board Ring Seine) and OBTN (Out Board Trawl Net) gears decreased (Fig 5.29, 5.30, 5.31, 5.32 and 5.33). After the cyclone, CPUE of NM (Non-Motorized), OBBS, OBGN, OBHL and OBRS gears tremendously increased (Fig 5.28, 5.29, 5.30, 5.31 and 5.33).

Thiruvananthapuram Coast

SST slightly decreased (Fig 5.15) in December. Compared to normal, the concentration of chlorophyll-*a* increased (Fig 5.16). LTA (Local Temperature Anomaly) was positive (0.05) indicating upwelling in the Thiruvananthapuram coast. And it intensified in January (Fig 5.19).Salinity was very high (33.2 to 34.7 ppt) (Fig 5.18). Current speed increased from 0.05 to 0.12 ms^{-1} (Fig 5.20). In December, rainfall increased from normal (+88.5 cm) (Fig 5.17). Compared to previous month catch, total catch in the cyclonic month showed a sudden drop (-3637 tonnes) (Fig 5.21). Oil sardine, Indian mackerel, scads and other sardines landings decreased and in January catch emerged in to peak (Fig 5.22, 5.23, 5.24 and 5.25). CPUE of NM, OBBS, OBGN, OBHL, OBRS gears decreased in December and improved in January (Fig 5.28, 5.29, 5.30, 5.31 and 5.33).

Kollam Coast

Compared to normal, there was no variation in SST. However, the SST showed a decline compared to the pre-cyclone SST (Fig 5.15). Chlorophyll-*a* concentration increased 31% from normal (Fig 5.16). Salinity and rainfall (+204cm) were considerably high (Fig 5.17 and 5.18). The value of LTA fell in December (0.05) and peaked in January (0.46) (Fig 5.19). In 2017 December, total catch was very low (-2394 tonnes) (Fig 5.21). Monthly Landings of oil sardine (-802 tonnes), Indian mackerel (-157 tonnes), *Thryssa* (-46 tonnes) and other sardines (-315 tonnes) were reduced. In January the catch didn't improve (Fig 5.22, 5.23, 5.24 and 5.26). CPUE of NM, OBGN, OBHL and OBRS gears declined (Fig 5.28, 5.30, 5.31 and 5.33). In post-cyclonic periods, CPUE of OBTN, OBGN and OBHL gears were raised, even the major fish landings fell (Fig 5.30, 5.31 and 5.32).

Ernakulam Coast

Compared to pre-cyclone period, SST decreased in December (Fig 5.15). Chlorophyll-a concentration increased 34% compared to the normal (Fig 5.16). Rainfall and LTA values decreased (Fig 5.17 and 5.19). Current magnitude increased from 0.08 to 0.23 ms^{-1} (Fig 5.20). In January upwelling occurred in the Ernakulum coast. The catch of oil sardine (-321 tonnes) and *Thryssa* (-1 tonnes) were very low (Fig 5.22 and 5.26). But the croakers (+29 tonnes) and penaeid prawn (+95 tonnes) landings showed a peak (Fig 5.27). CPUE of NM, OBGN, OBHL, OBRS gears decreased in December (Fig 5.28, 5.30, 5.31 and 5.33). But it was very high for OBTN (Fig 5.32).

Alappuzha Coast

Compared to previous months, SST showed declining trend (Fig 5.15). Chlorophyll-a concentration 25% increased from normal (Fig 5.16). Monthly rainfall increased 23%from normal (Fig 5.17). LTA was negative (-0.23). This indicates a downwelling on the coast of Alappuzha in December (Fig 5.19). The magnitude of current increased to $0.35ms^{-1}$). In December, current direction varied from normal (Fig 5.20). Total catch decreased from 5131 to 1062 tonnes (-4069) (Fig 5.21). Oil sardine landing on the coast of Alappuzha was peak in December. In 2017 December, oil sardine landing subsided (Fig 5.22). The landing of Indian mackerel (-222 tonnes) and *Thryssa* (-61 tonnes) declined tremendously (Fig 5.23 and 5.26). But the penaeid prawn landing increased from 36 to 101 tonnes (Fig 5.27). In post-cyclonic months, CPUE of NM, OBGN, OBHL and OBRS were peaked (Fig 5.28, 5.30, 5.31 and 5.33).

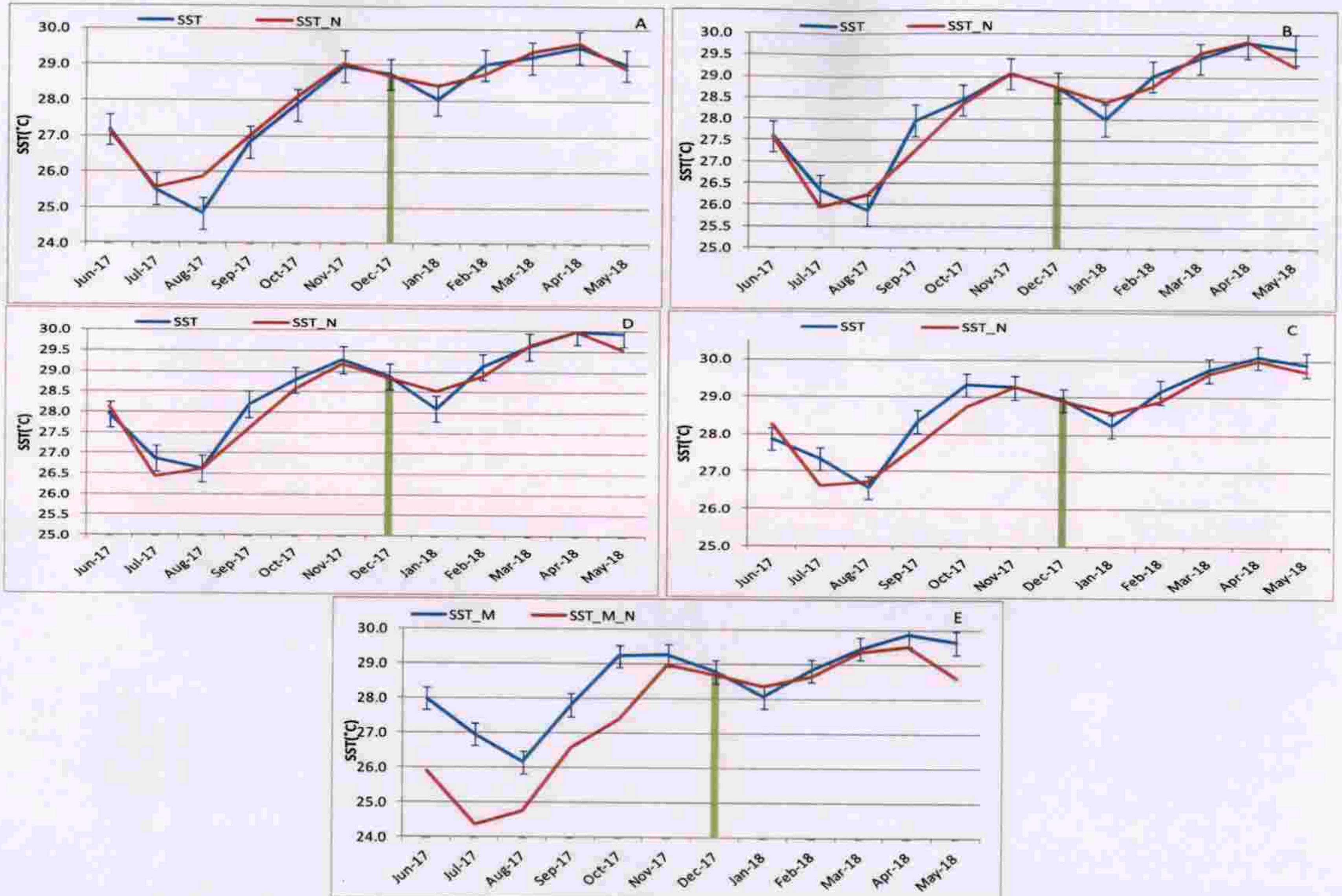

Fig 5.15 - Monthly mean SST (Sea surface temperature) and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; SST_M: Monthly mean SST, SST_M_N: Month wise 10 year average Sea Surface Temperature

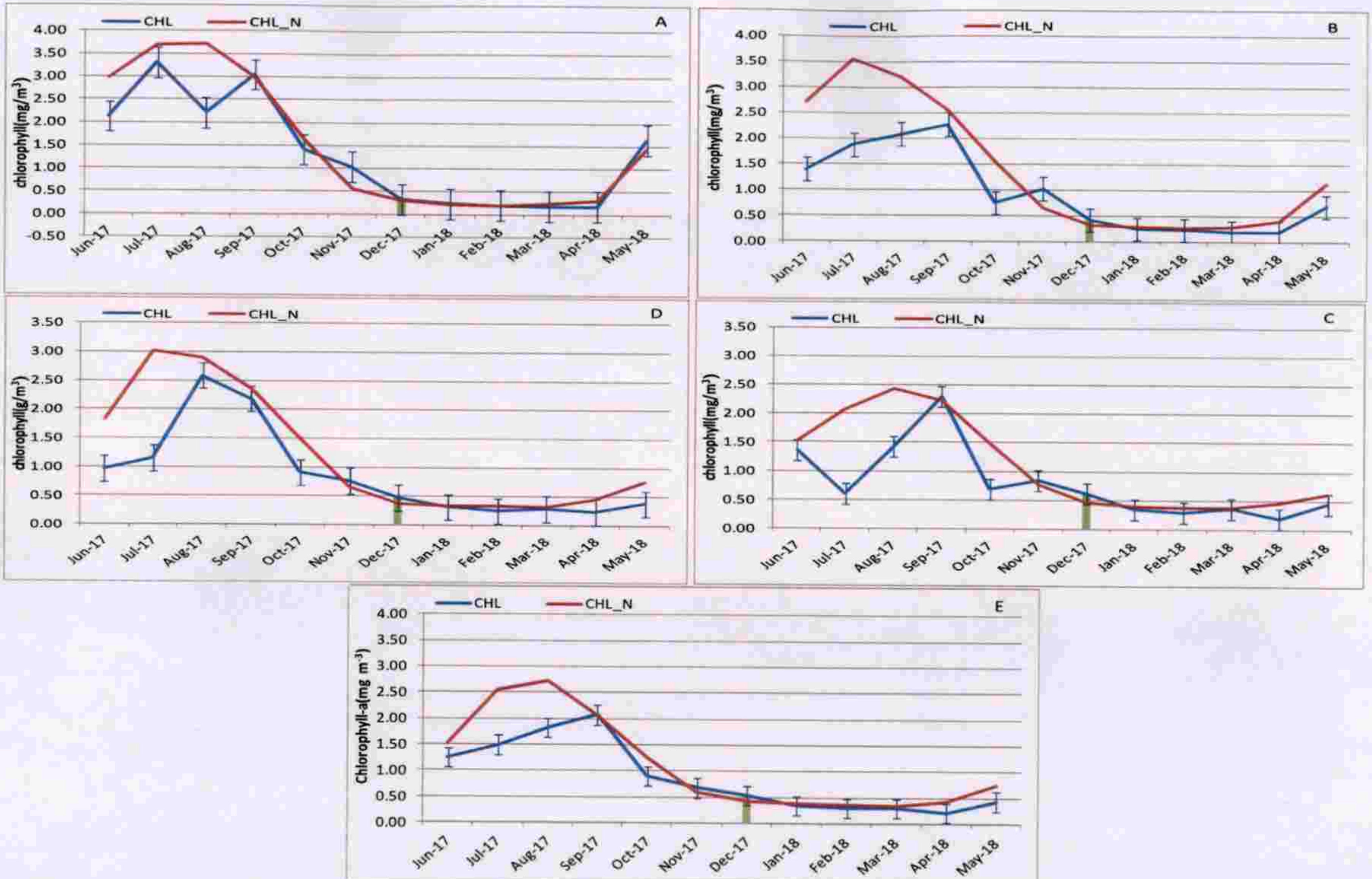

Fig 5.16 - Monthly mean Chlorophyll-*a* concentration and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; CHL: Monthly mean Chlorophyll-*a* concentration, CHL_N: Month wise 10 year average Chlorophyll concentration

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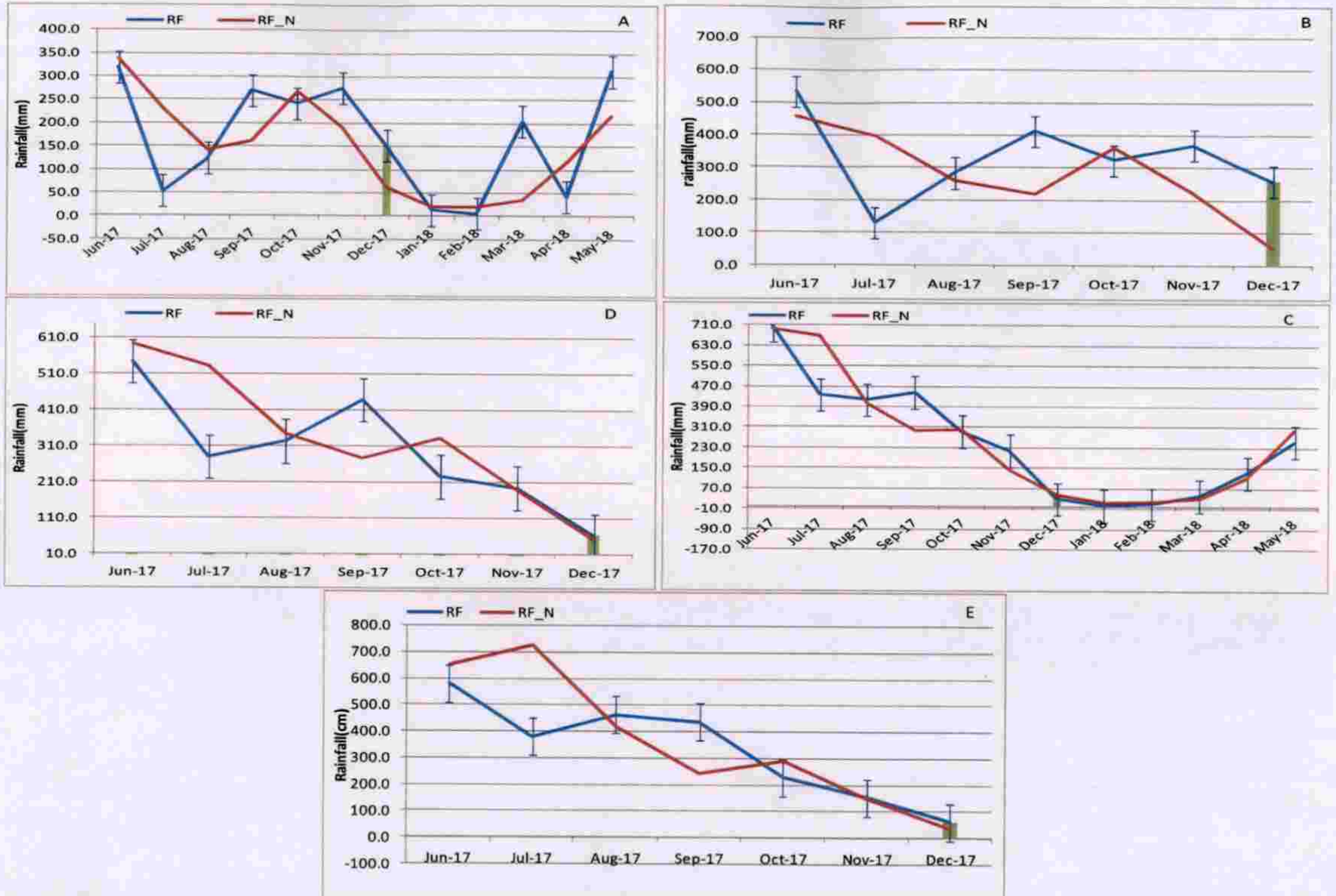

Fig 5.17 - Monthly rainfall and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; RF: Monthly rainfall, RF_N: Month wise 10 year average rainfall

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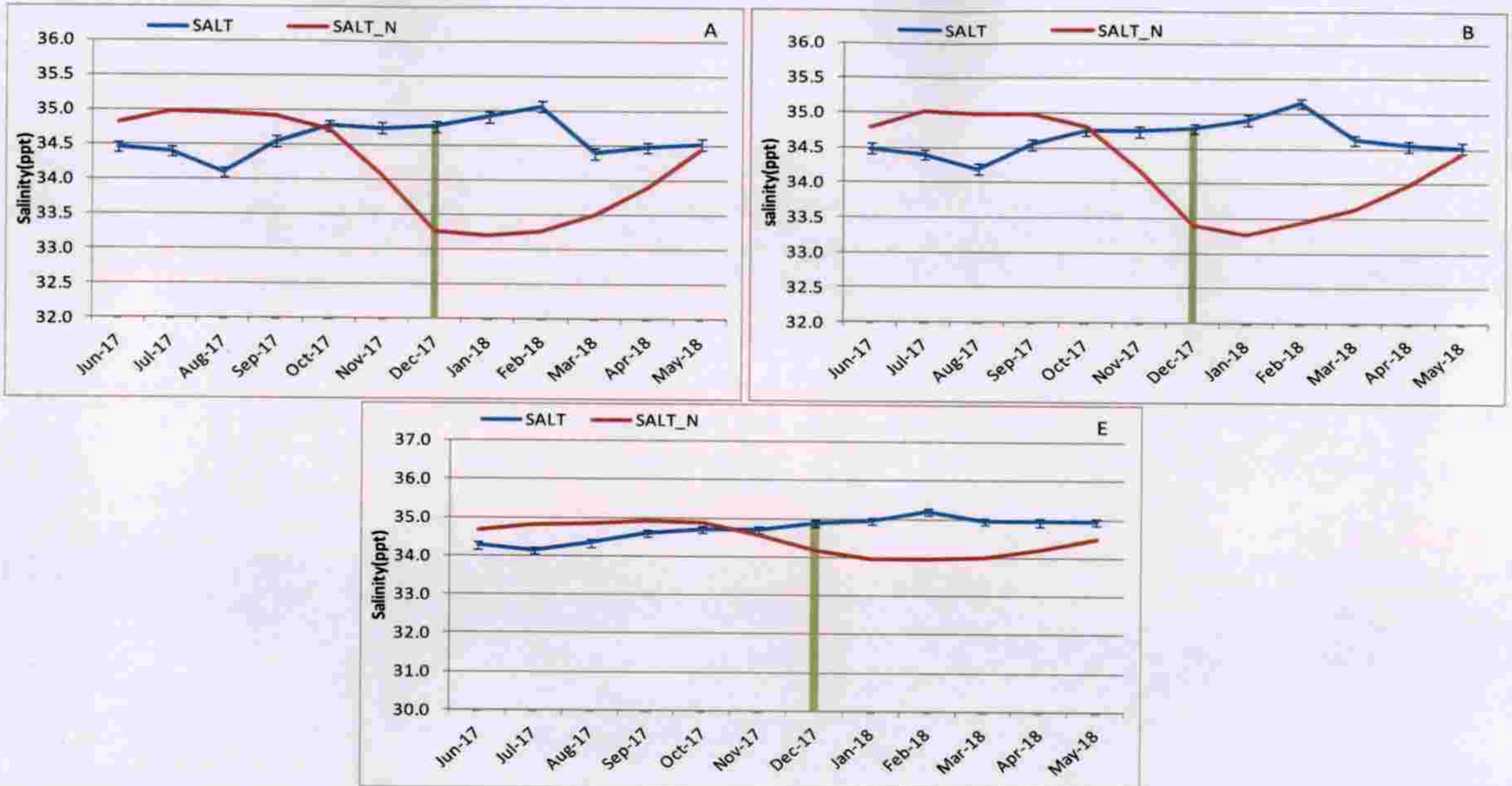

Fig 5.18 - Monthly mean salinity and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; SALT: Monthly mean salinity, SALT_N: Month wise 10 year average sea surface salinity

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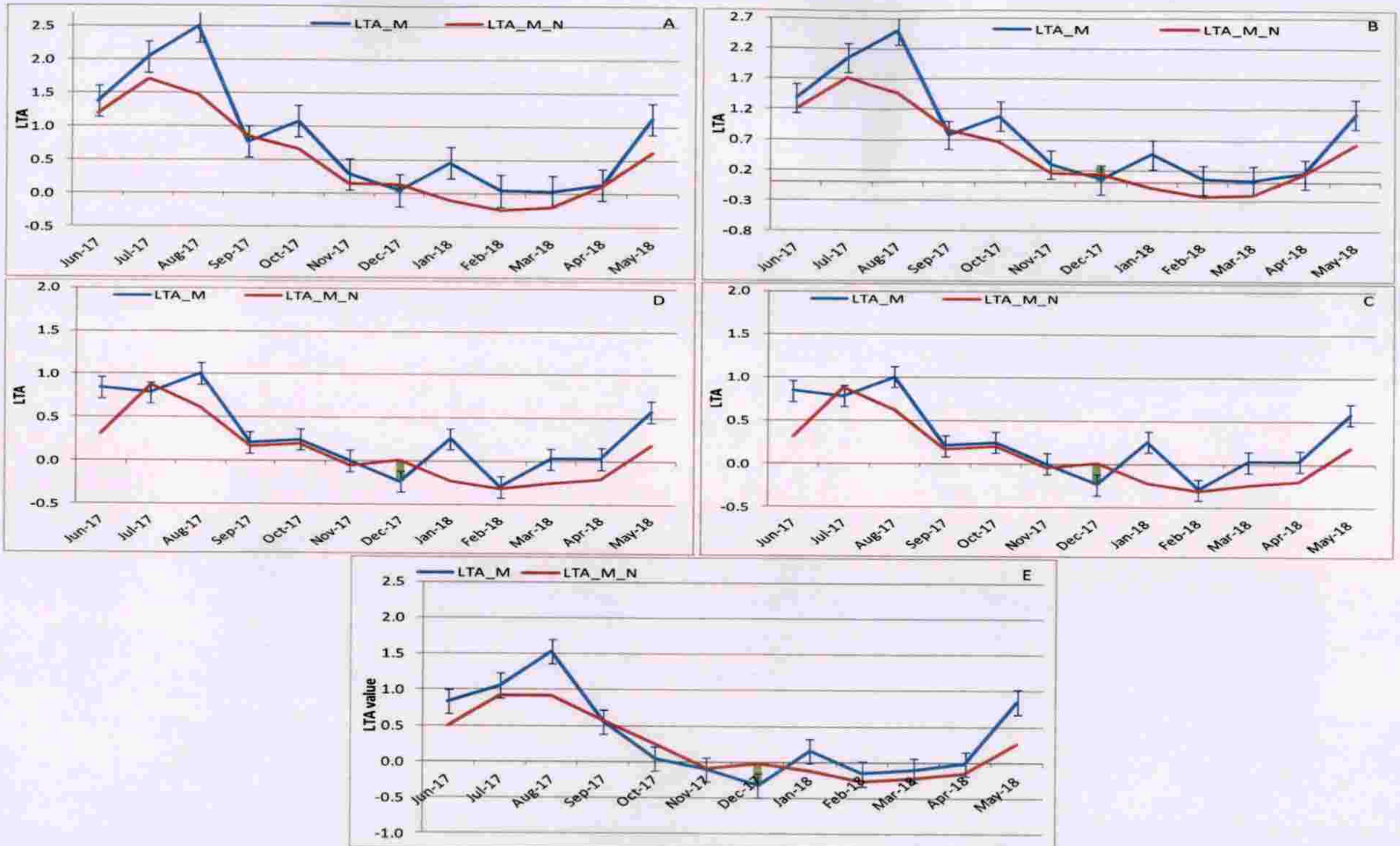

Fig 5.19 - Monthly mean LTA (Local temperature anomaly) value and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; LTA_M: Monthly mean LTA, LTA_M_N: Month wise 10 year average LTA Value

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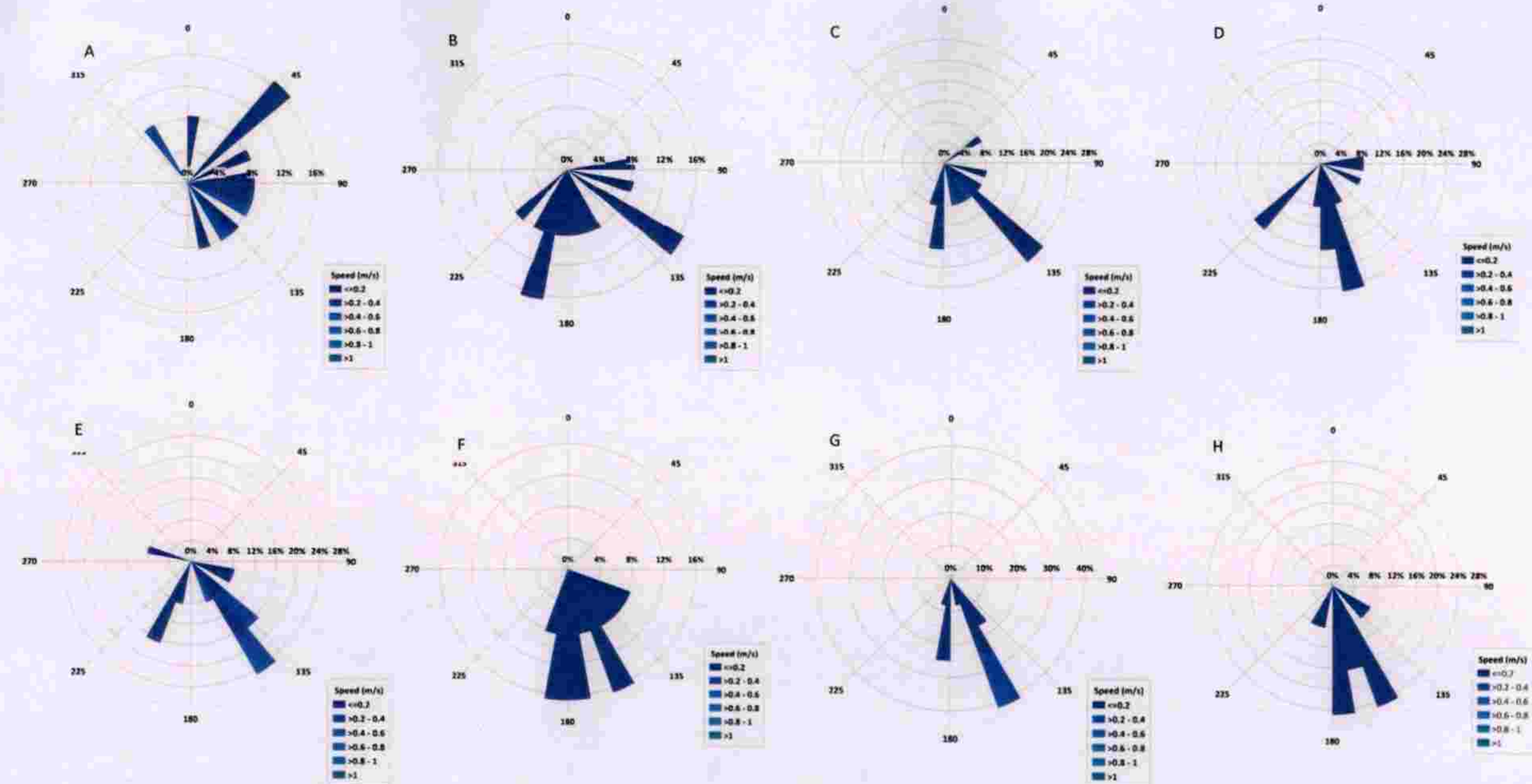

Fig 5.20 - Polar diagram showing monthly mean sea surface current velocity and direction from June 2017 to May 2018; A) Thiruvananthapuram B) Month wise 10 year average current speed and direction in Thiruvananthapuram coast C) Ernakulam D) Month wise 10 year average Current speed and direction in Ernakulam coast E) Alappuzha F) Month wise 10 year average current speed and direction in Alappuzha coast G) Kerala H) Month wise 10 year average current speed and direction in Kerala coast [Green bar indicate the time of occurrence of cyclone Ockhi]

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Fig 5.21 - Monthly total catch and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; TOT: Monthly total catch, TOT_N: Month wise 10 year average total catch

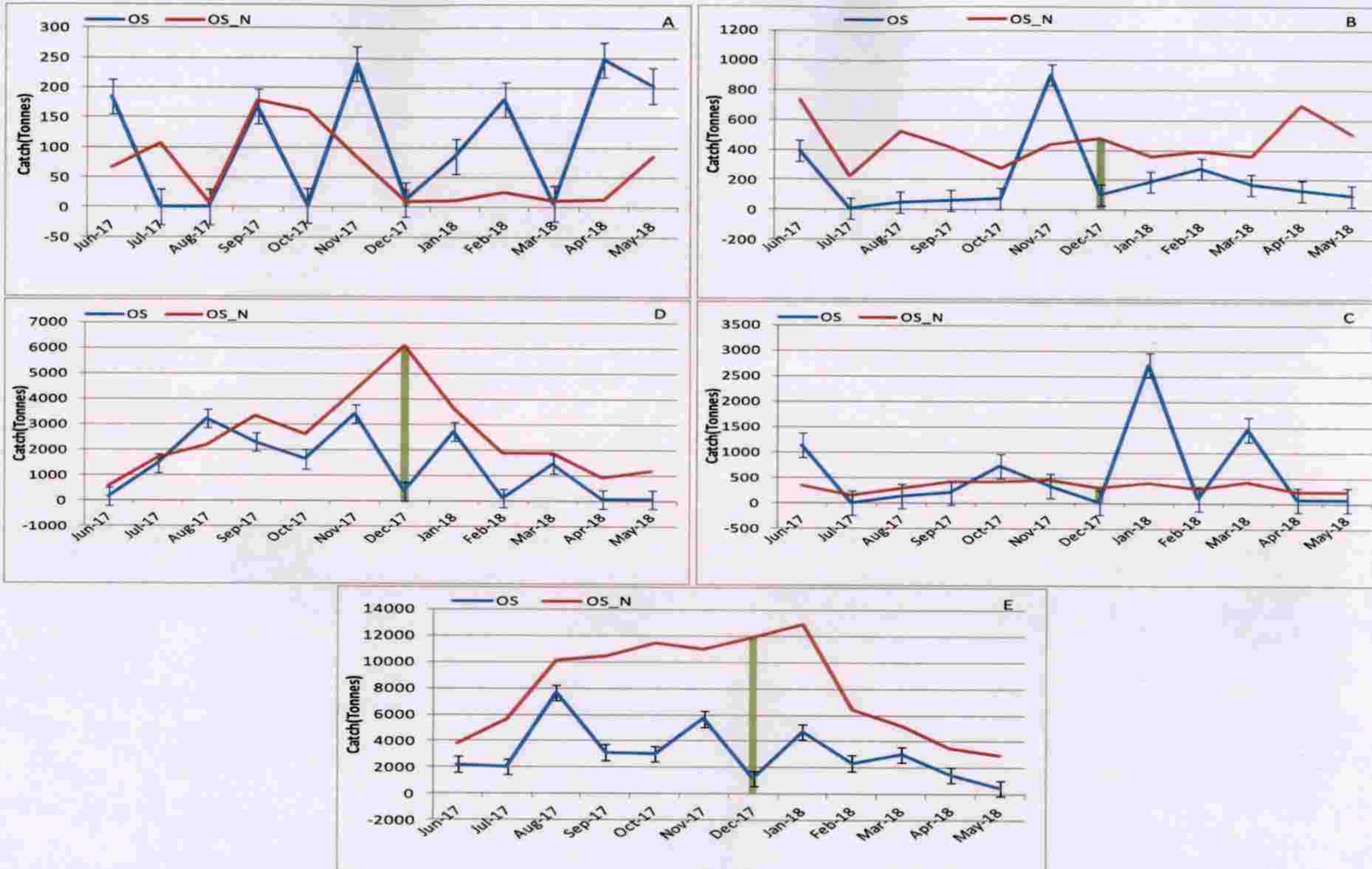

Fig 5.22 - Monthly oil sardine catch and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OS: Monthly oil sardine catch, OS_N: Month wise 10 year average oil sardine landing

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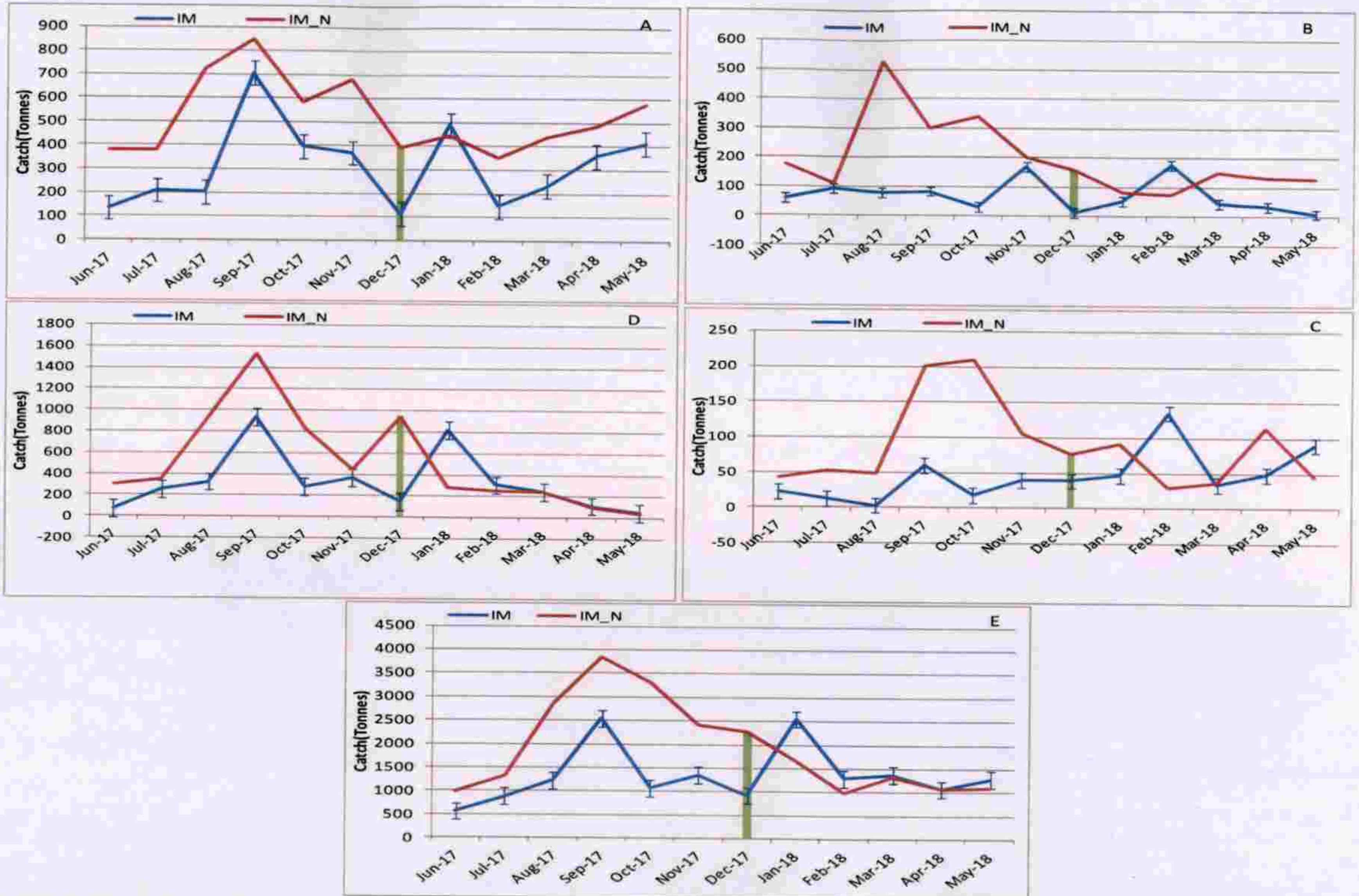

Fig 5.23 - Monthly Indian mackerel catch and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; IM: Monthly Indian mackerel catch, IM_N: Month wise 10 year average Indian Mackerel landing

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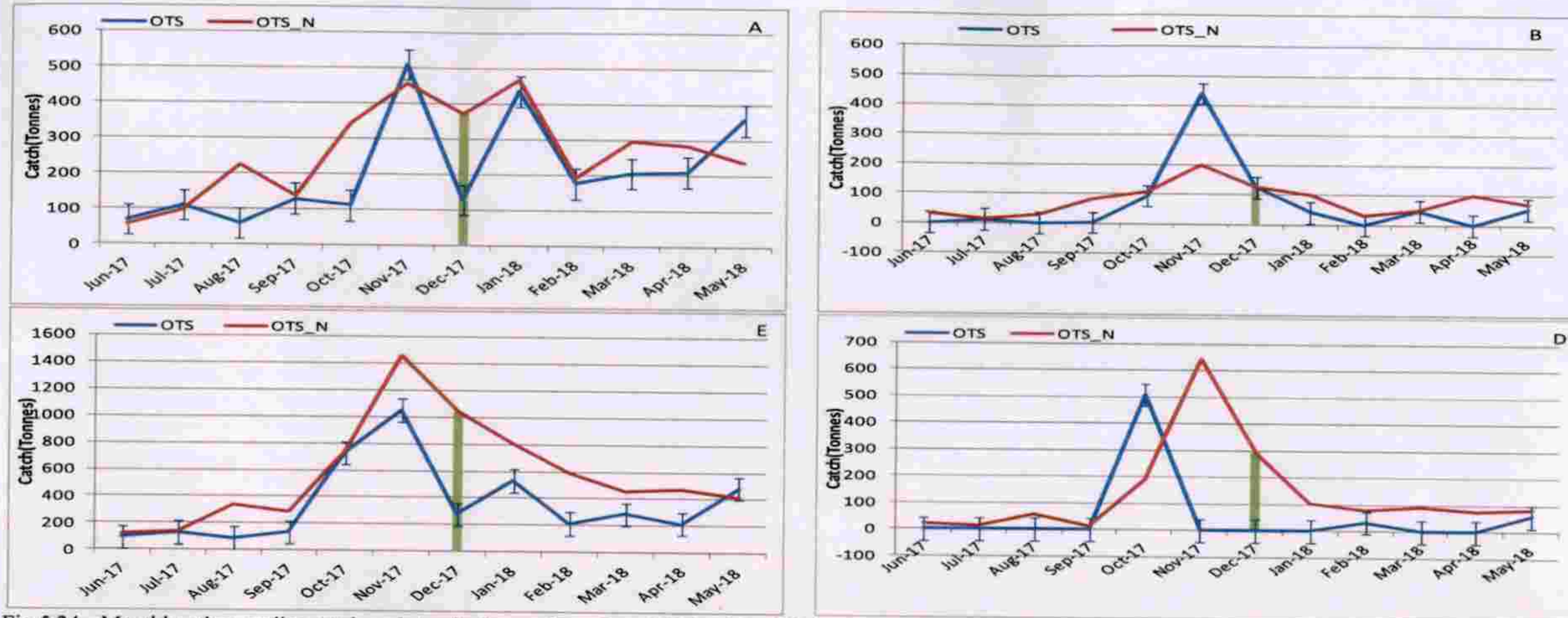

Fig 5.24 - Monthly other sardine catch and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OTS: Monthly other sardine catch, OTS_N: Month wise 10 year average other sardine landing

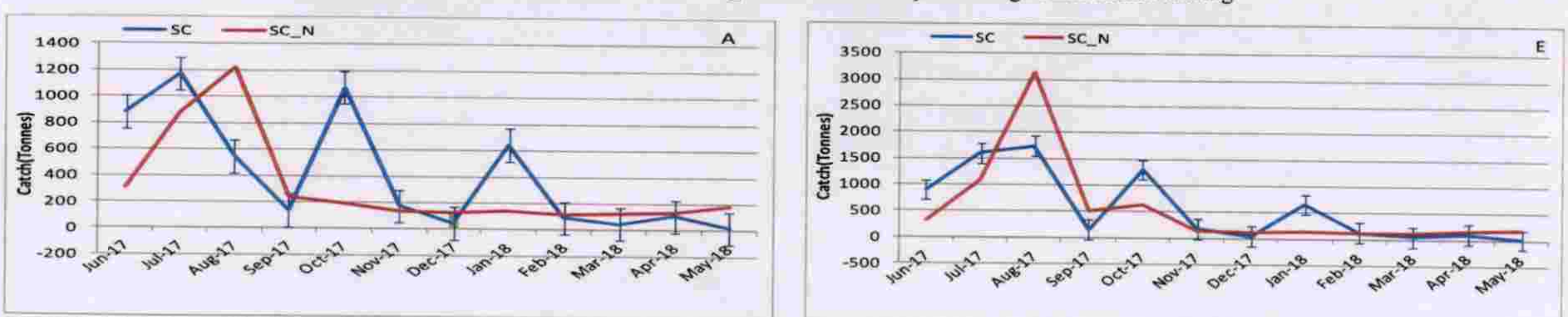

Fig 5.25 - Monthly scad landing and standard error from June 2017 to May 2018; A) Thiruvananthapuram E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; SC: Monthly scad fishery, SC_N: Month wise 10 year average scad landing

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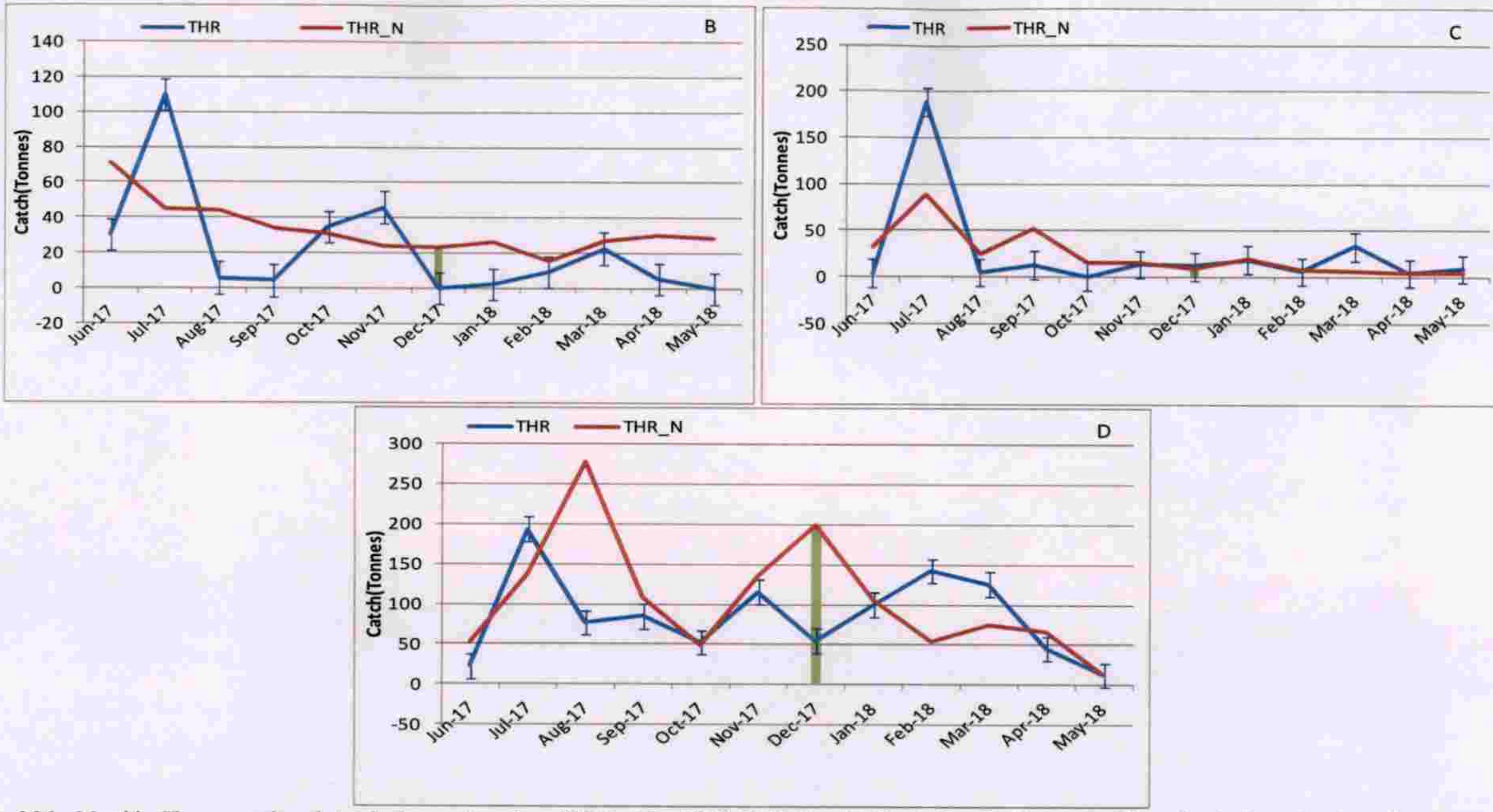

Fig 5.26 - Monthly *Thryssa* catch and standard error from June 2017 to May 2018; B) Kollam C) Ernakulam D) Alappuzha [Green bar indicate the time of occurrence of cyclone Ockhi]; THR: Monthly *Thryssa* catch, THR_N: Month wise 10 year average *Thryssa* landing

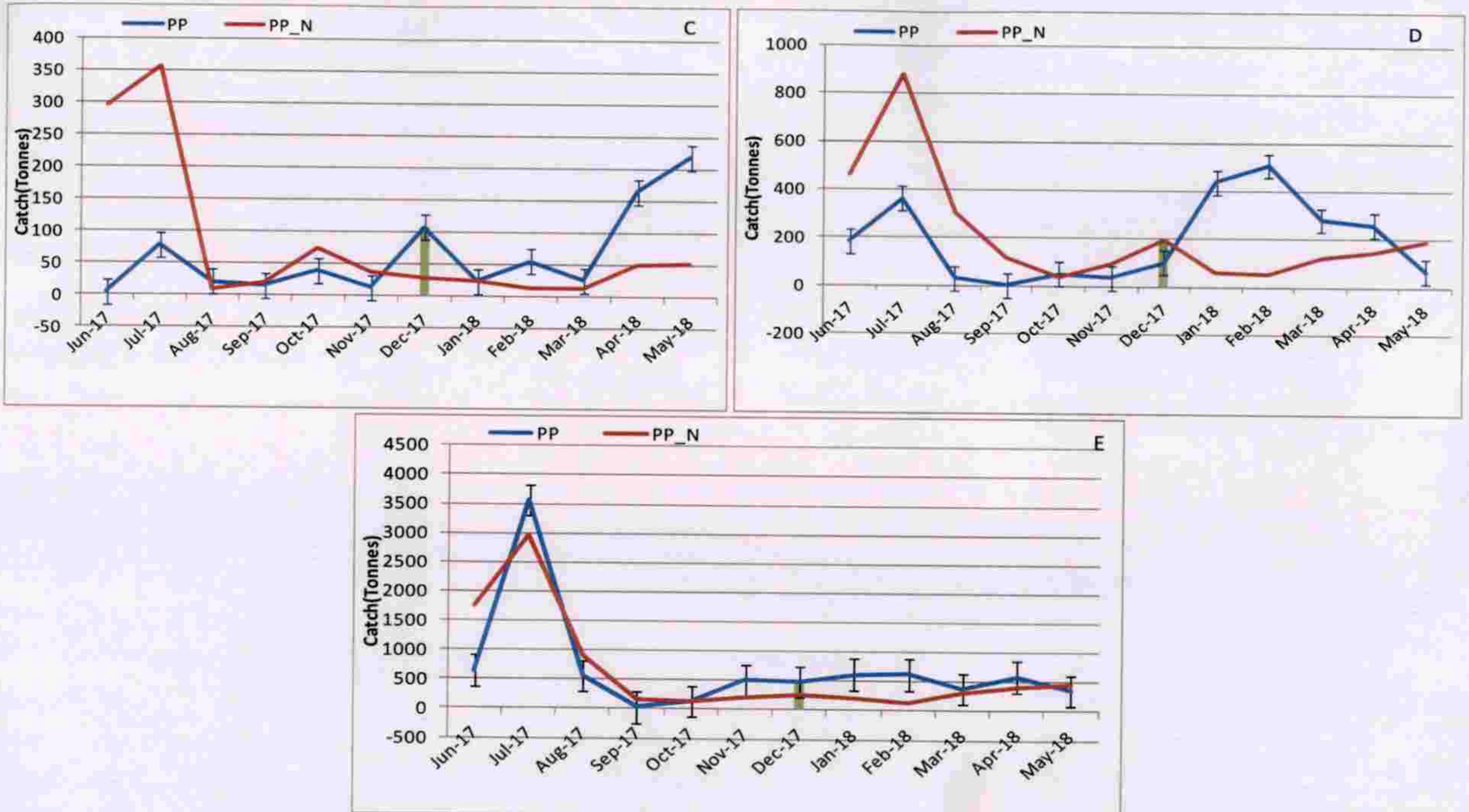

Fig 5.27 - Monthly Penaeid prawn catch and standard error from June 2017 to May 2018; C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; PP: Monthly Penaeid prawn catch, PP_N: Month wise 10 year average Penaeid prawn landing

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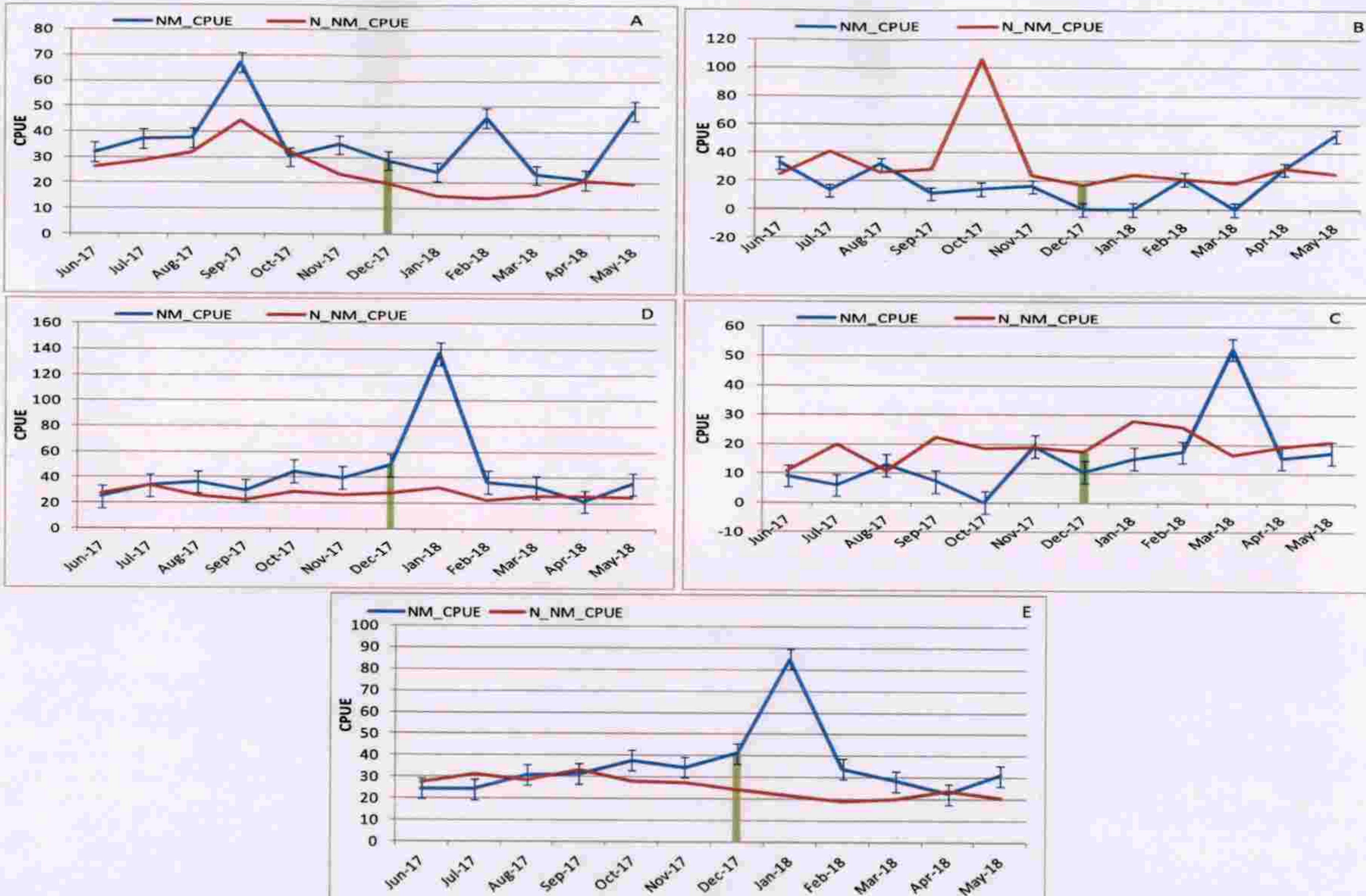

Fig 5.28 - Monthly CPUE (Catch per unit effort) of Non motorised (NM) crafts and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; NM_CPUE: N_NM_CPUE: Month wise 10 year average CPUE of NM

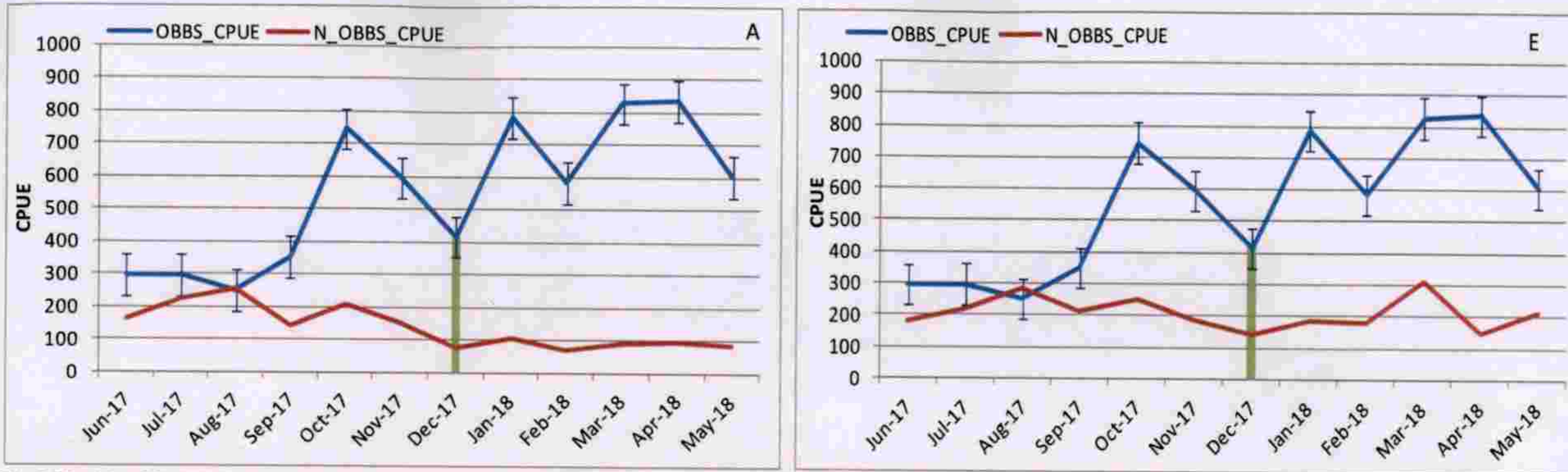

Fig 5.29 - Monthly CPUE (Catch per unit effort) of Out board boat seine (OBBS) and standard error from June 2017 to May 2018; A) Thiruvananthapuram E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OBBS_CPUE: Monthly CPUE of OBBS, N_OBBS_CPUE: Month wise 10 year average CPUE of OBBS

Fig 5.30 - Monthly CPUE (Catch per unit effort) of Out board gill net (OBGN) and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OBGN_CPUE: Monthly CPUE of OBGN, N_OBGN_CPUE: Month wise 10 year average CPUE of OBGN

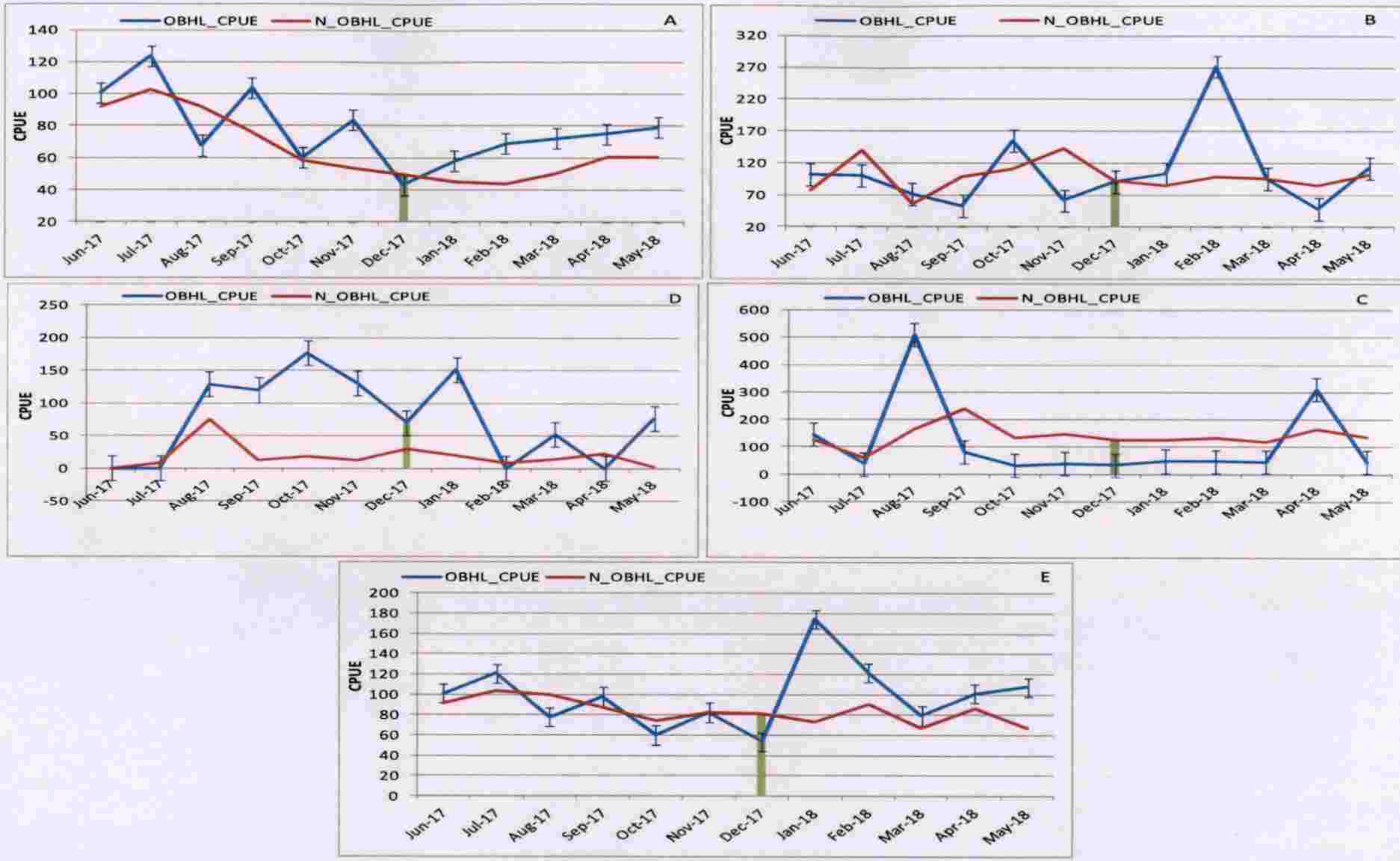

Fig 5.31 - Monthly CPUE (Catch per unit effort) of Out board hook and line (OBHL) and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OBHL_CPUE: Monthly CPUE of OBHL, N_OBHL_CPUE: Month wise 10 year average CPUE of OBHL

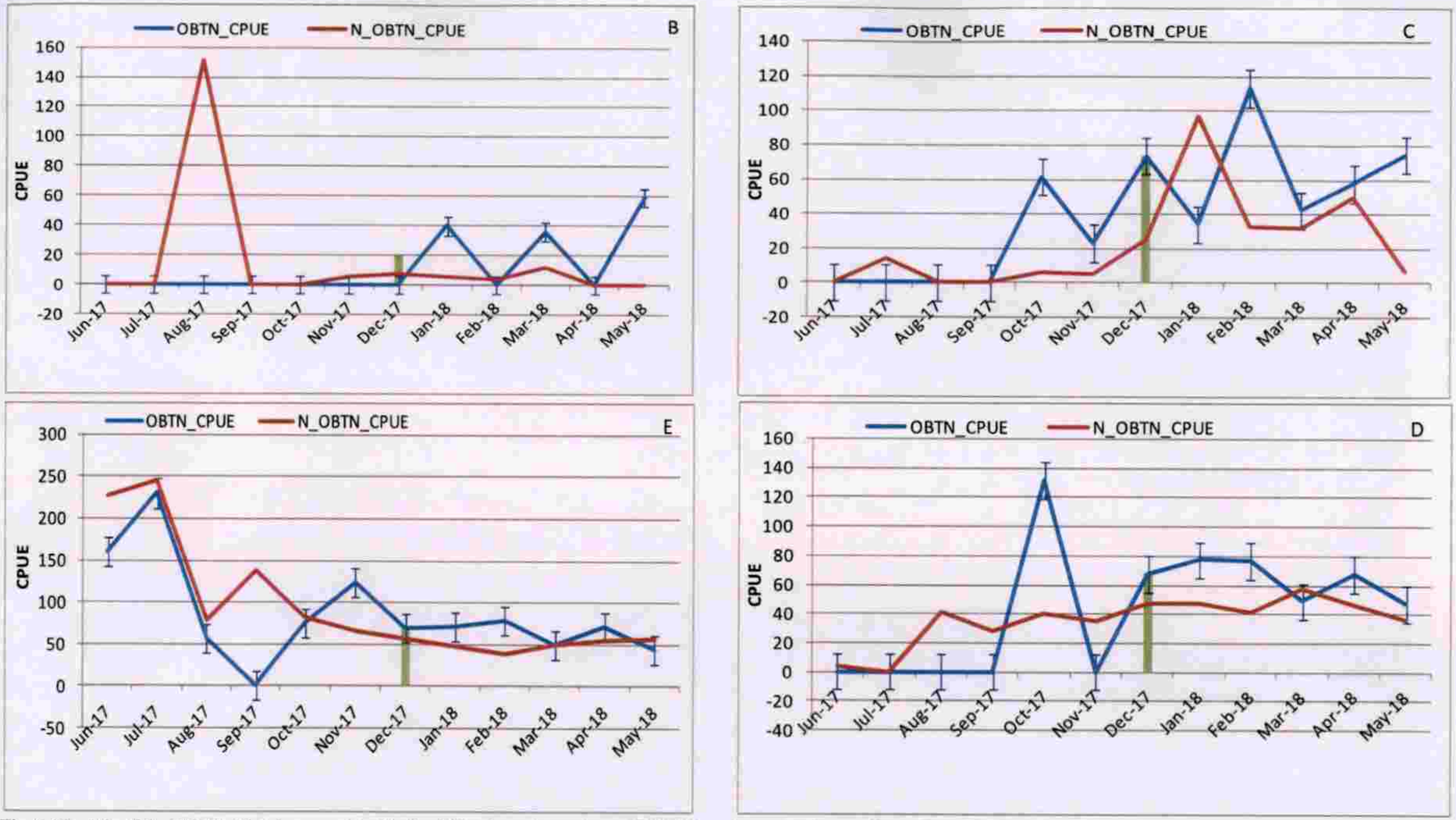

Fig 5.32 - Monthly CPUE (Catch per unit effort) of Out board trawl net (OBTN) and standard error from June 2017 to May 2018; B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OBTN_CPUE: Monthly CPUE of OBTN, N_OBTN_CPUE: Month wise 10 year average CPUE of OBTN

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Fig 5.33 - Monthly CPUE (Catch per unit effort) of Out board ring seine (OBRS) and standard error from June 2017 to May 2018; A) Thiruvananthapuram B) Kollam C) Ernakulam D) Alappuzha E) Kerala [Green bar indicate the time of occurrence of cyclone Ockhi]; OBRS_CPUE: Monthly CPUE of OBRS, N_OBRS_CPUE: Month wise 10 year average CPUE of OBRS

5.6 Environmental Changes during the Month of Cyclone Ockhi along Tamil Nadu Coast

Kanyakumari Coast

SST slightly decreased during December, 2017 (Fig 5.34). Compared to normal, chlorophyll concentration increased 21.6% (Fig 5.35) and the Rainfall had peaked (+152.7mm) (Fig 5.36). Salinity slightly increased (Fig 5.39). LTA was positive (+0.51) (Fig 5.37). Current velocity decreased 82% from normal. There was also a variation in current direction (Fig 5.38). Total catch was extremely low (-425 tonnes) (Fig 5.40). Landings of other sardines decreased (Fig 5.41). In January, catch didn't show a recovery. Compared to pre-cyclone months, CPUE of NM and OBSS gears decreased, But the CPUE of OBGN and OBHL gears increased (Fig 5.46, 5.47, 5.48 and 5.49).

Tuticorin Coast

Compared to pre-cyclone month, SST slightly decreased (Fig 5.34). Compared to normal, Chlorophyll concentration doesn't change. But it slightly increased from the pre-cyclone month value (Fig 5.35). Rainfall considerably increased (+77.7mm) (Fig 5.36). LTA value was negative. Downwelling took place on the Tuticorin coast in December (Fig 5.37). Total catch decreased in December and peaked in January (Fig 5.40). Catch and CPUE were generally low in December. Landings of oil sardine, crab, other sardine and *Thryssa* hiked in January (Fig 5.41, 5.42, 5.44 and 5.45). CPUE of OBGN, OBSS and OBBN gears increased during the month of cyclone Ockhi (Fig 5.47, 5.49 and 5.50).

Thirunelveli Coast

Compared to pre-cyclone month, SST decreased (Fig 5.34). There was no change in Chlorophyll concentration (Fig 5.35). In December, rainfall decreased (Fig 5.36). LTA was negative; indicating a downwelling on the Thirunelveli coast in the month of Ockhi (Fig 5.37). The current speed was very low (Fig 5.38). Total catch sharply declined in the cyclone month and the catch recovered in January (Fig 5.40). Other sardine and *Thryssa*'s landings declined in December. At the same time, there was an increase in croakers catch (Fig 5.41, 5.42 and 5.43). CPUE is less in December. But in 2017 December, there was an anomalous decrease in CPUE.

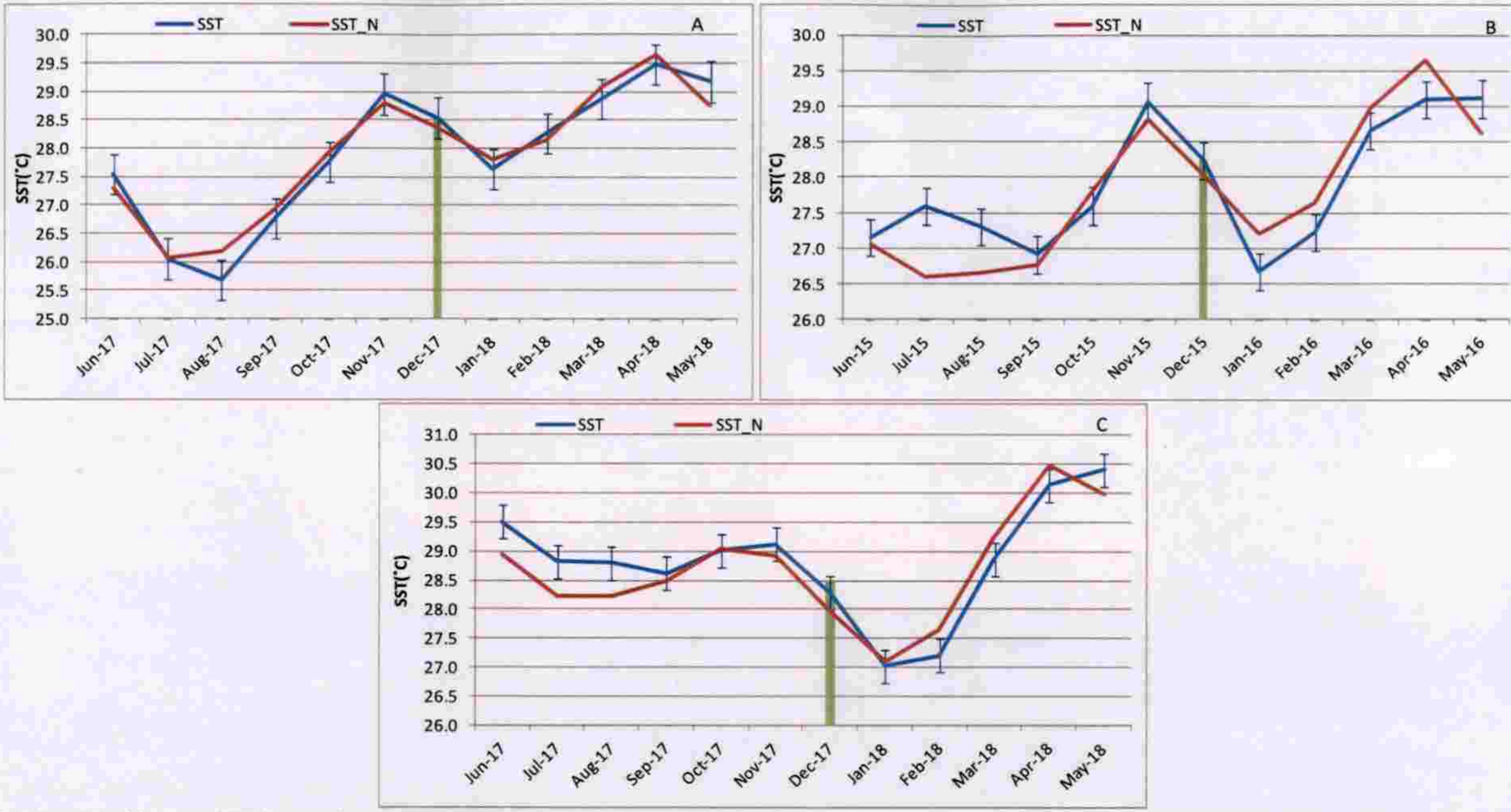

Fig 5.34 - Monthly mean SST (Sea surface temperature) and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; SST_M: Monthly mean SST, SST_M_N: Month wise 10 year average SST

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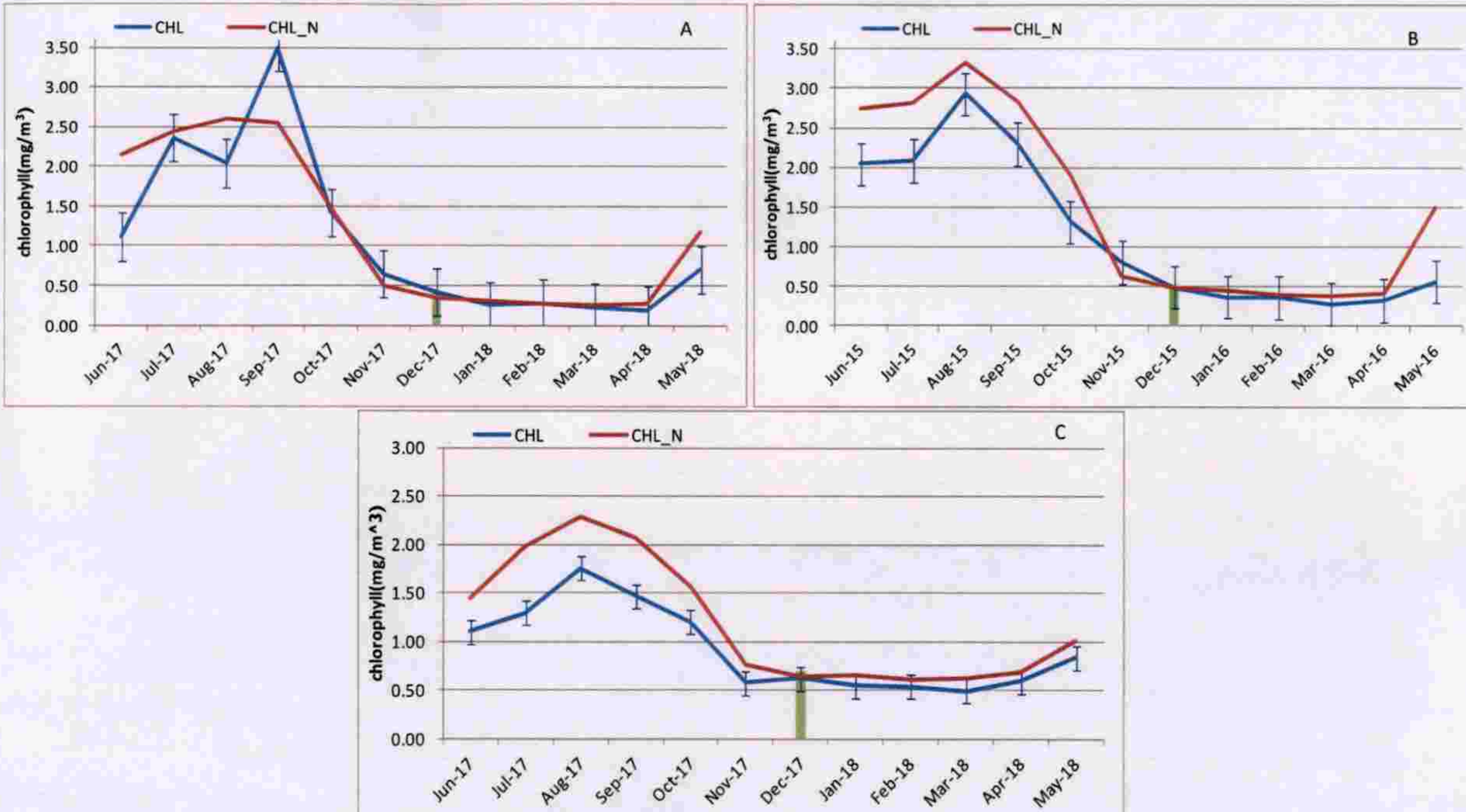

Fig 5.35 - Monthly mean Chlorophyll concentration and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; CHL: Monthly mean Chlorophyll concentration, CHL_N: Month wise 10 year average Chlorophyll concentration

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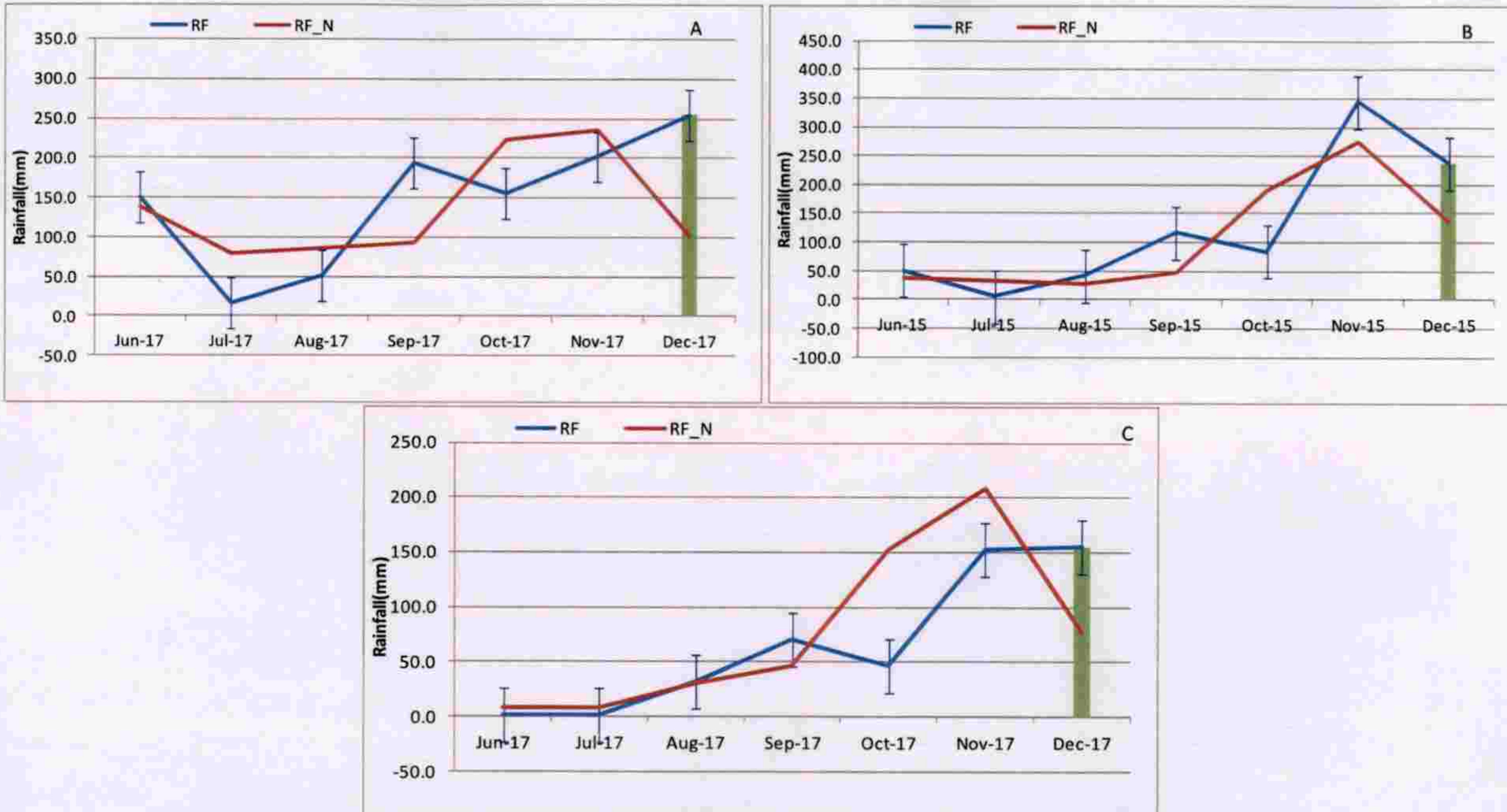

Fig 5.36 - Monthly Rainfall and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; RF: Monthly Rainfall, RF_N: Month wise 10 year average Rainfall

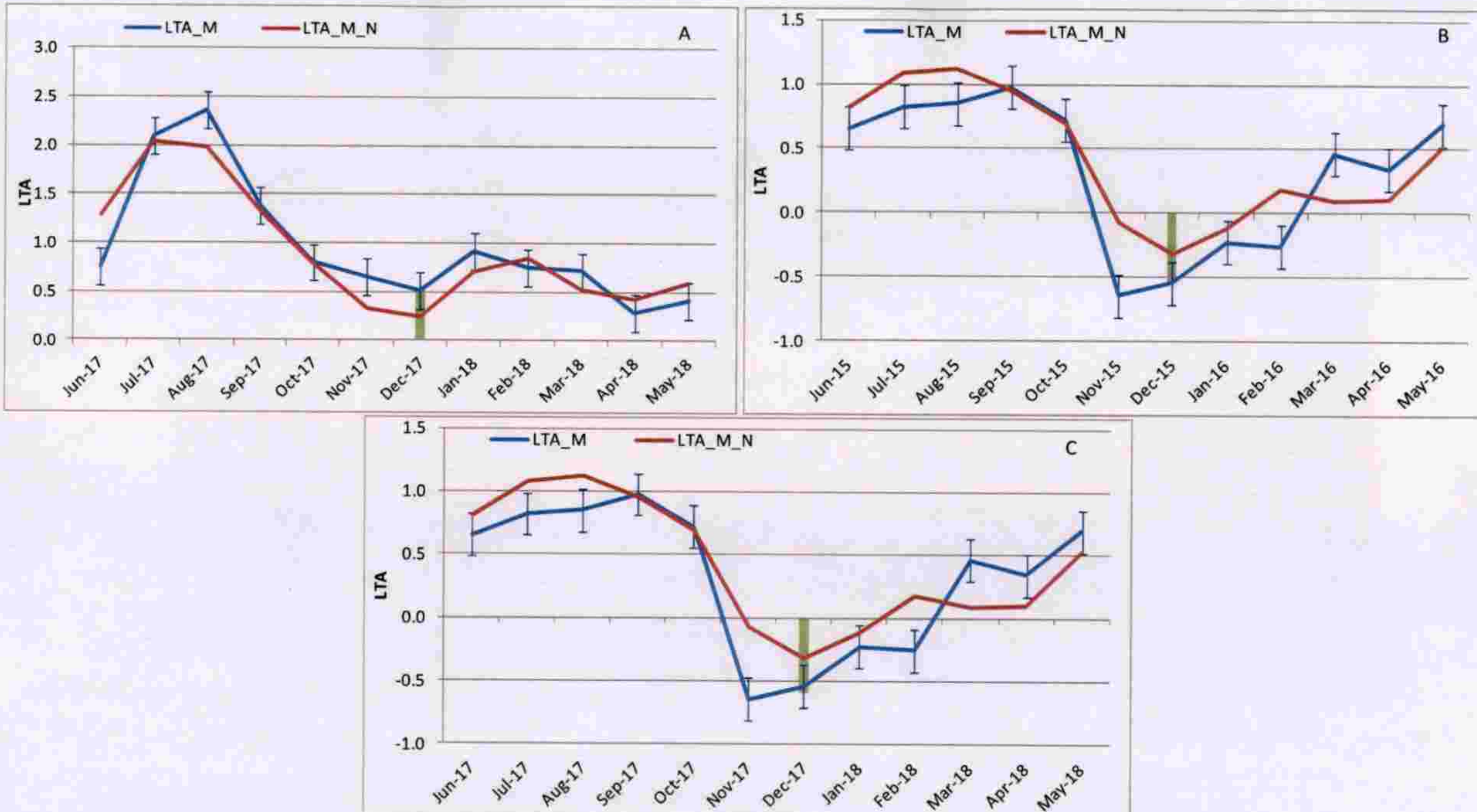

Fig 5.37 - Monthly mean LTA (Local temperature anomaly) and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; LTA: Monthly mean LTA, LTA_M_N: Month wise 10 year average LTA value

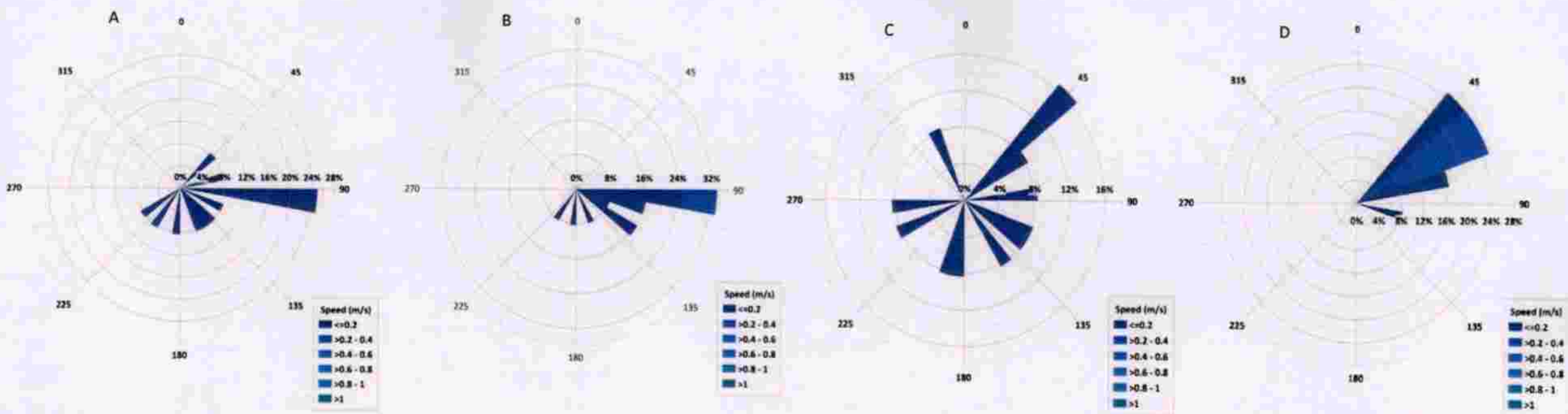

Fig 5.38 - Polar diagram showing monthly mean Current speed and direction from June 2017 to May 2018; A) Kanyakumari B) Month wise 10 year average Kanyakumari Current speed and direction C) Thirunelveli D) Month wise 10 year average Thirunelveli current speed and direction [Green bar indicate the time of occurrence of cyclone Ockhi]

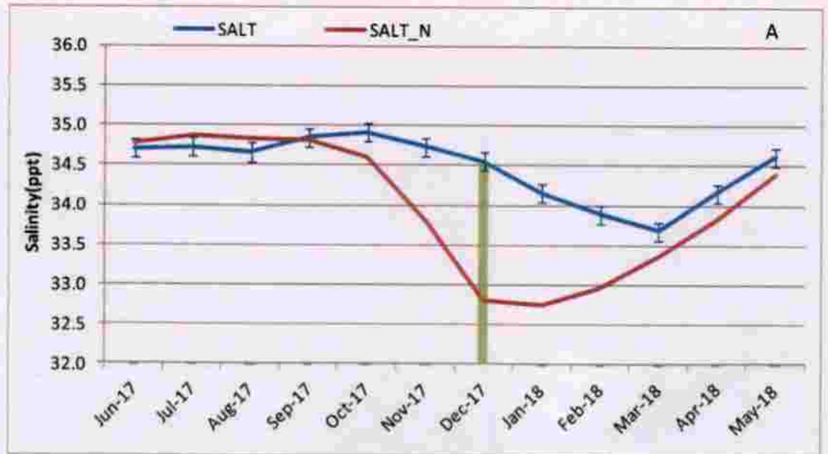

Fig 5.39 - Monthly mean sea surface salinity and standard error from June 2017 to May 2018; A) Kanyakumari [Green bar indicate the time of occurrence of cyclone Ockhi]; SALT: Monthly mean sea surface salinity, SALT_N: Month wise 10 year average sea surface salinity

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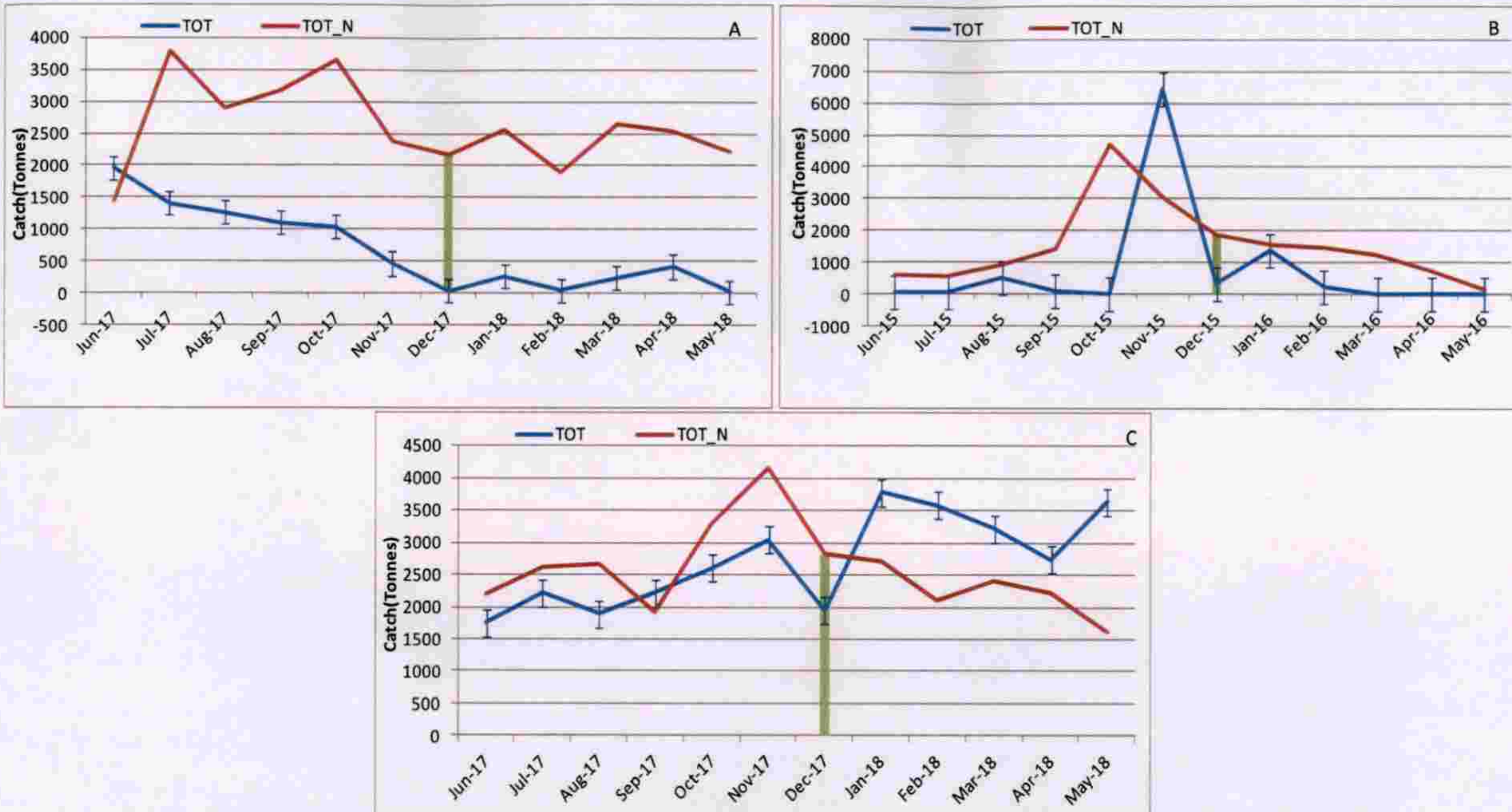


Fig 5.40 - Monthly total catch and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; TOT: Monthly Total catch, TOT_N: Month wise 10 year average total catch

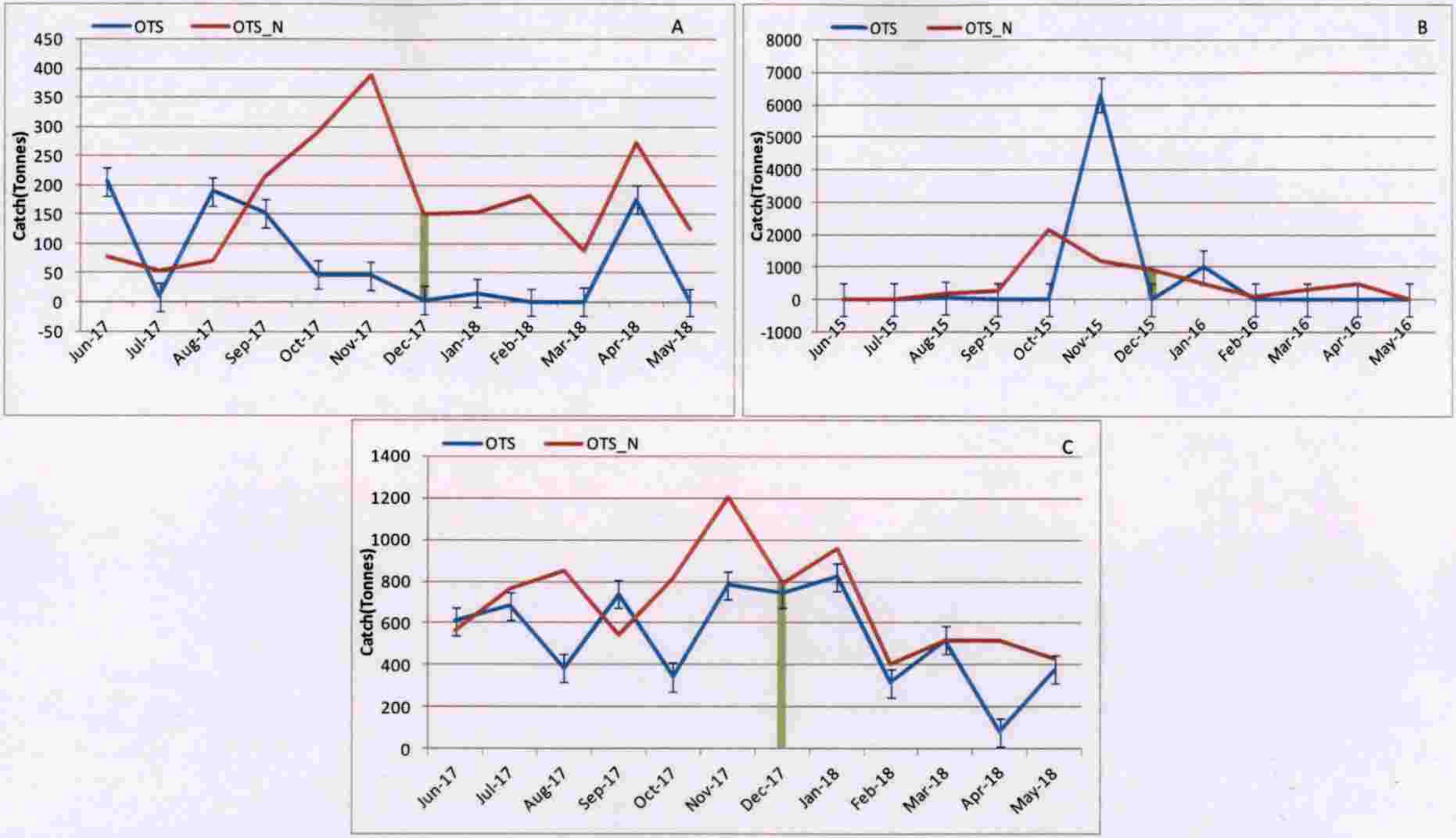


Fig 5.41 - Monthly other sardine catch and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OTS: Monthly other sardine catch, OTS_N: Month wise 10 year average other sardine landing

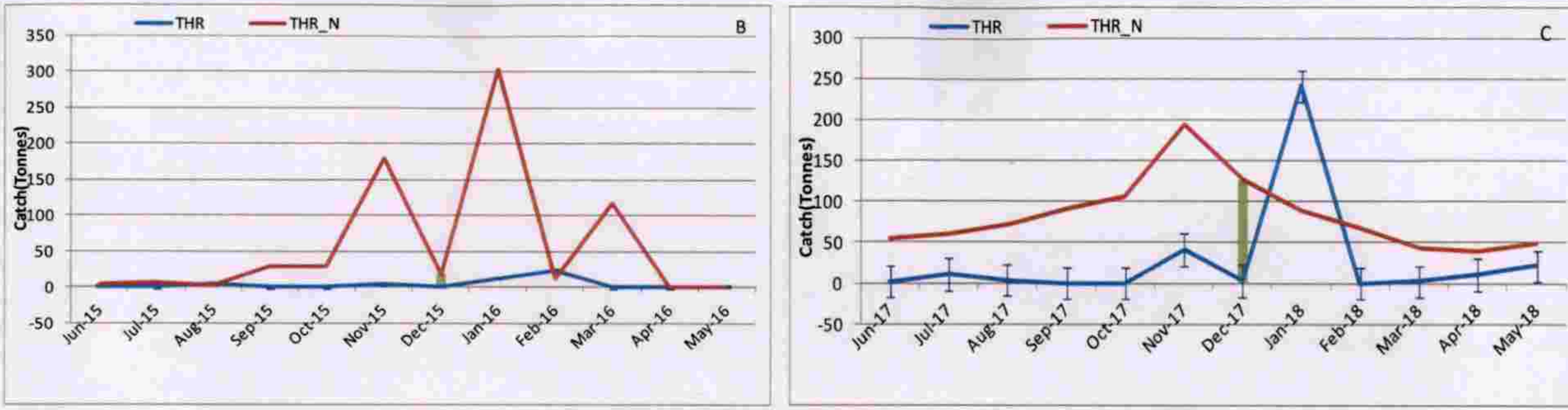


Fig 5.42 - Monthly *Thryssa* catch and standard error from June 2017 to May 2018; B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; THR: Monthly *Thryssa* catch, THR_N: Month wise 10 year average *Thryssa* landing

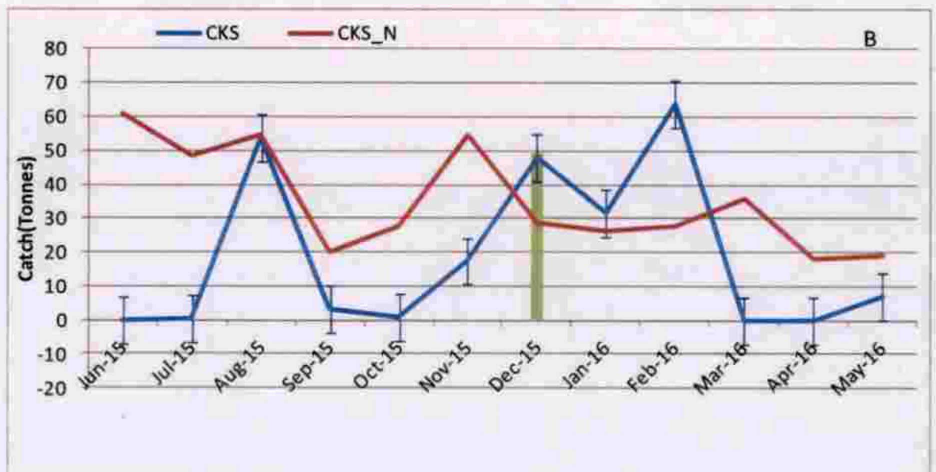


Fig 5.43 - Monthly croaker fishery and standard error from June 2017 to May 2018; B) Thirunelveli [Green bar indicate the time of occurrence of cyclone Ockhi]; CKS: Monthly croaker fishery, CKS_N: Month wise 10 year average croker landing

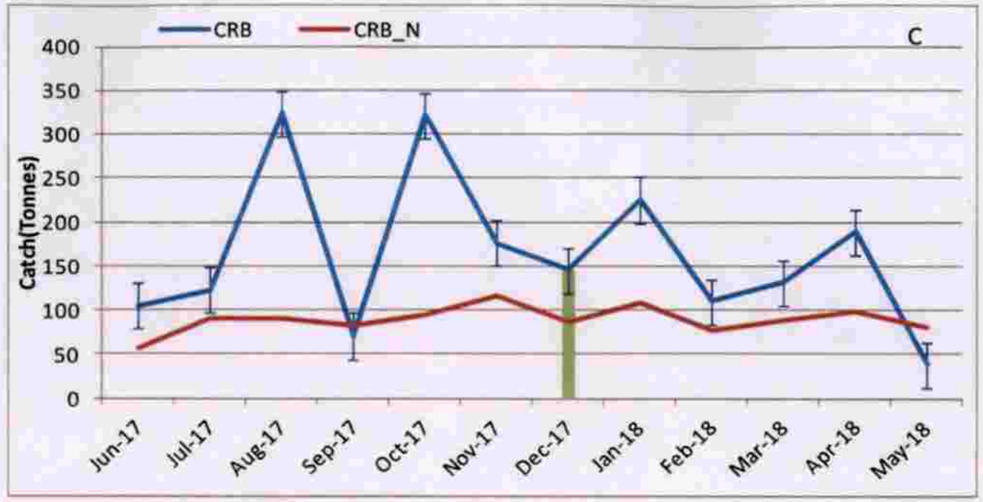


Fig 5.44 - Monthly crab landing and standard error from June 2017 to May 2018 C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; CRB: Monthly crab landing, CRB_N: Month wise 10 year average crab catch

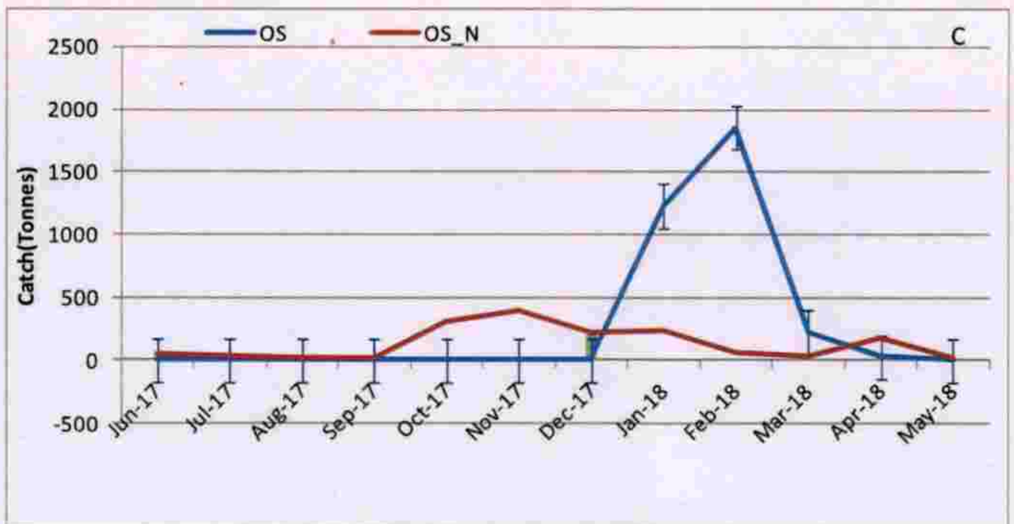


Fig 5.45 - Monthly oil sardine catch and standard error from June 2017 to May 2018; C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OS: Monthly oil sardine catch, OS_N: Month wise 10 year average oil sardine catch

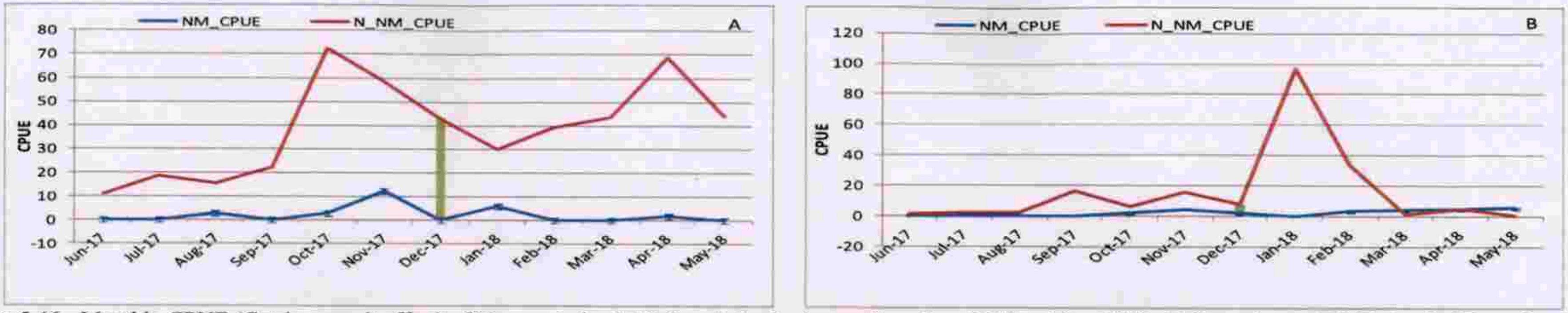


Fig 5.46 - Monthly CPUE (Catch per unit effort) of Non motorized (NM) and standard error from June 2017 to May 2018; A) Kanyakumari C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; NM_CPUE: Monthly CPUE of NM, N_NM_CPUE: Month wise 10 year average CPUE of NM

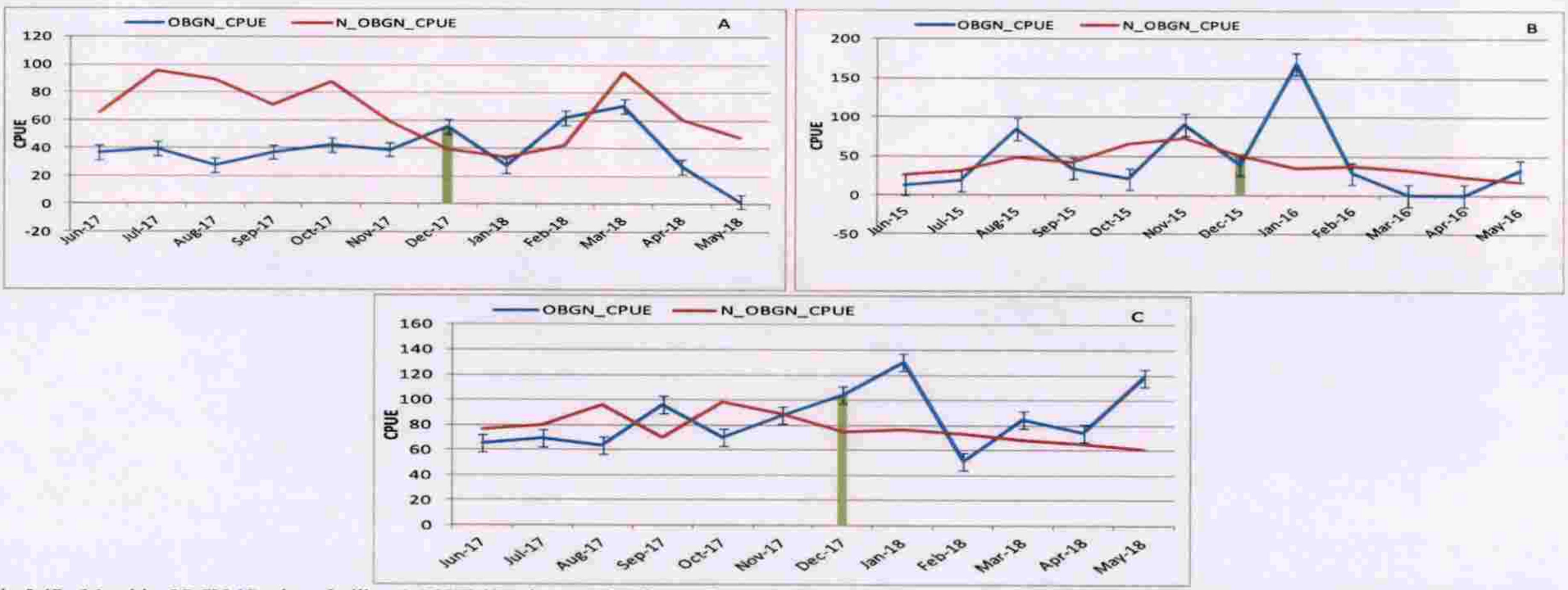
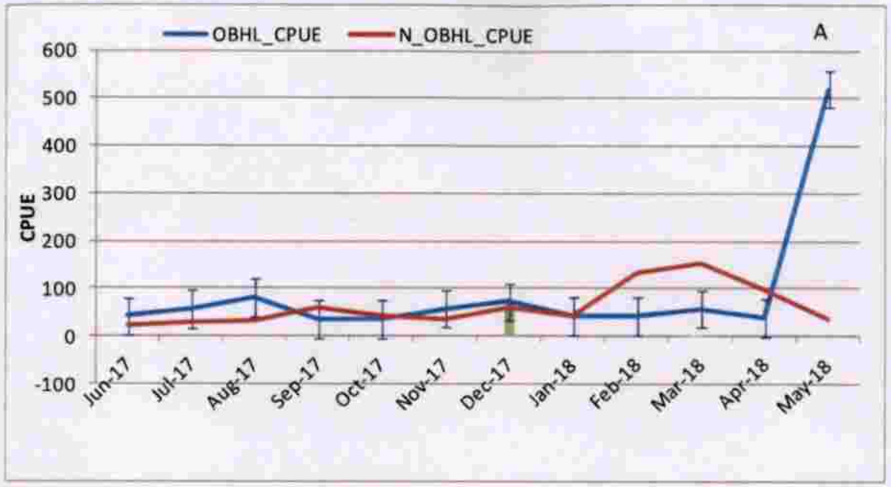


Fig 5.47 - Monthly OBGN (Out board gill net) CPUE (Catch per unit effort) and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OBGN_CPUE: Monthly OBGN CPUE, N_OBGN_CPUE: Month wise 10 year average CPUE of OBGN



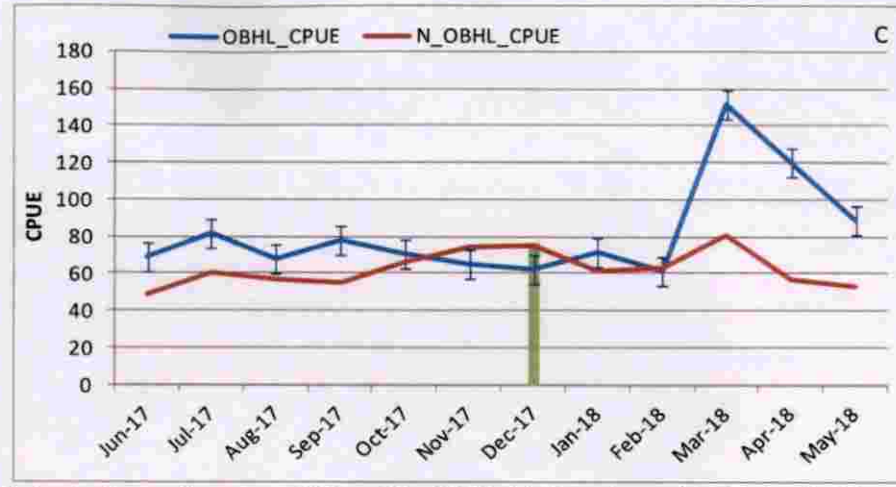
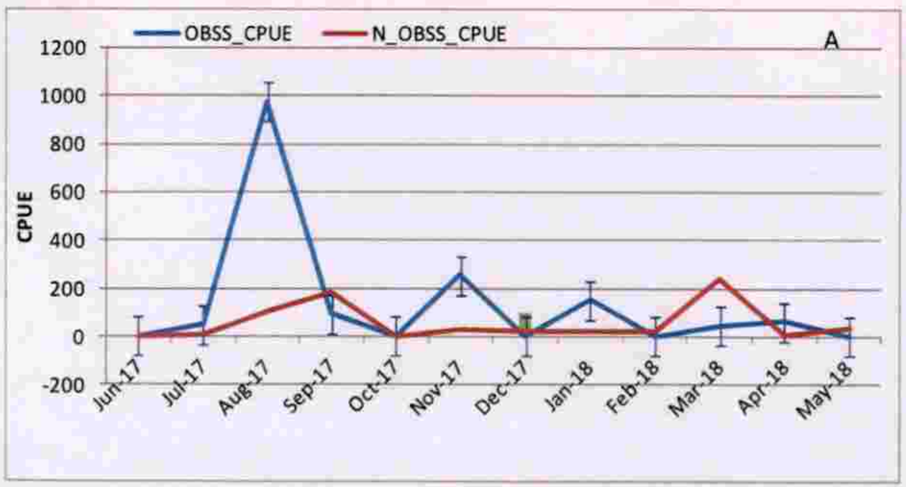


Fig 5.48 - Monthly OBHL (Out board hook and line) CPUE (Catch per unit effort) and standard error from June 2017 to May 2018; A) Kanyakumari C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OBHL_CPUE: Monthly OBHL CPUE, N_OBHL_CPUE: Month wise 10 year average CPUE of OBHL



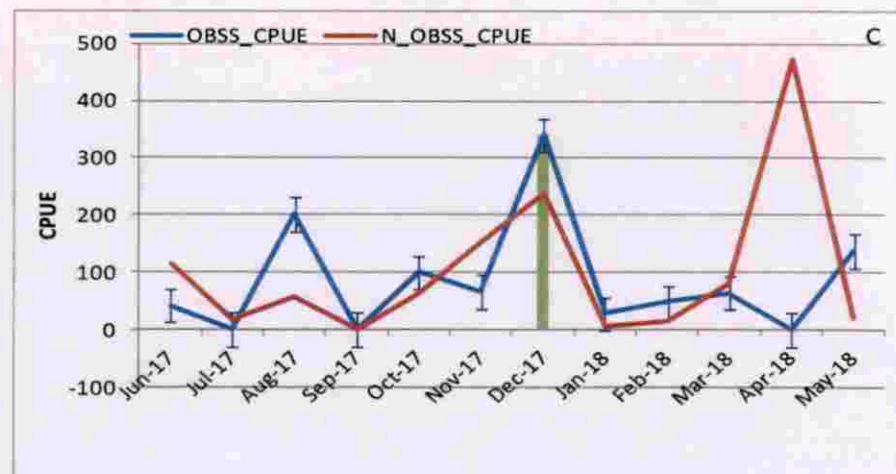


Fig 5.49 - Monthly OBSS (Out board shore seine) CPUE (Catch per unit effort) and standard error from June 2017 to May 2018; A) Kanyakumari C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OBSS_CPUE: Monthly OBSS CPUE, N_OBSS_CPUE: Month wise 10 year average CPUE of OBSS

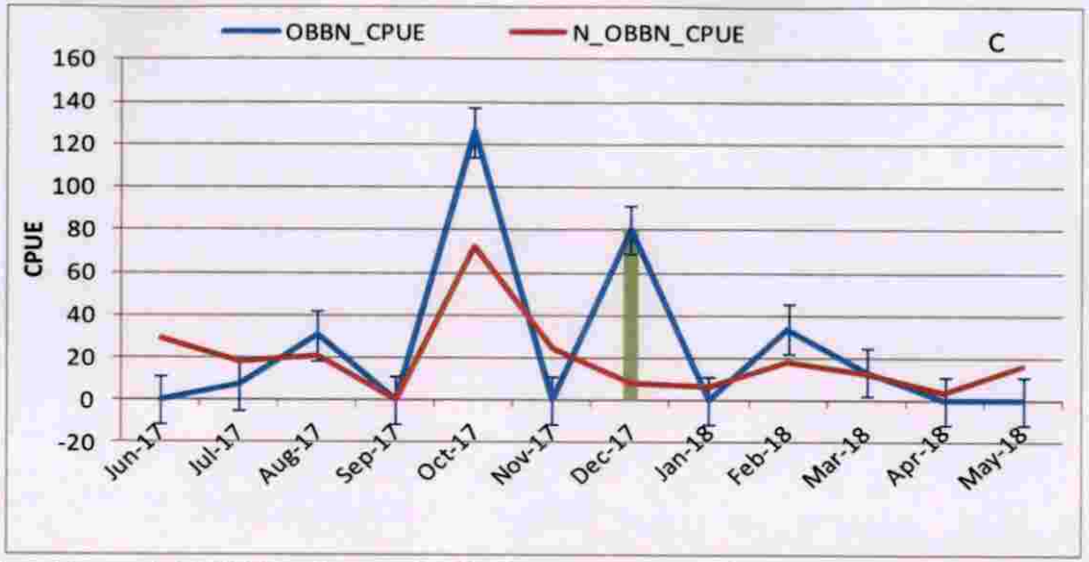


Fig 5.50 - Monthly OBBN (Out board bag net) CPUE (Catch per unit effort) and standard error from June 2017 to May 2018; A) Kanyakumari B) Thirunelveli C) Tuticorin [Green bar indicate the time of occurrence of cyclone Ockhi]; OBBN_CPUE: Monthly OBBN CPUE, N_OBBN_CPUE: Month wise 10 year average CPUE of OBBN

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5.7 Socio-economic Impact of Cyclone Ockhi on Fishermen

5.7.1 Economic loss in Kerala

In Kerala, the marine fisheries sector is very vibrant and provides employment for a total fisher population of 6, 10,165 (CMFRI 2011). The number of fisher population has been found to vary in coastal districts (Fig 5.51) with highest (24%) in Thiruvananthapuram (146326).

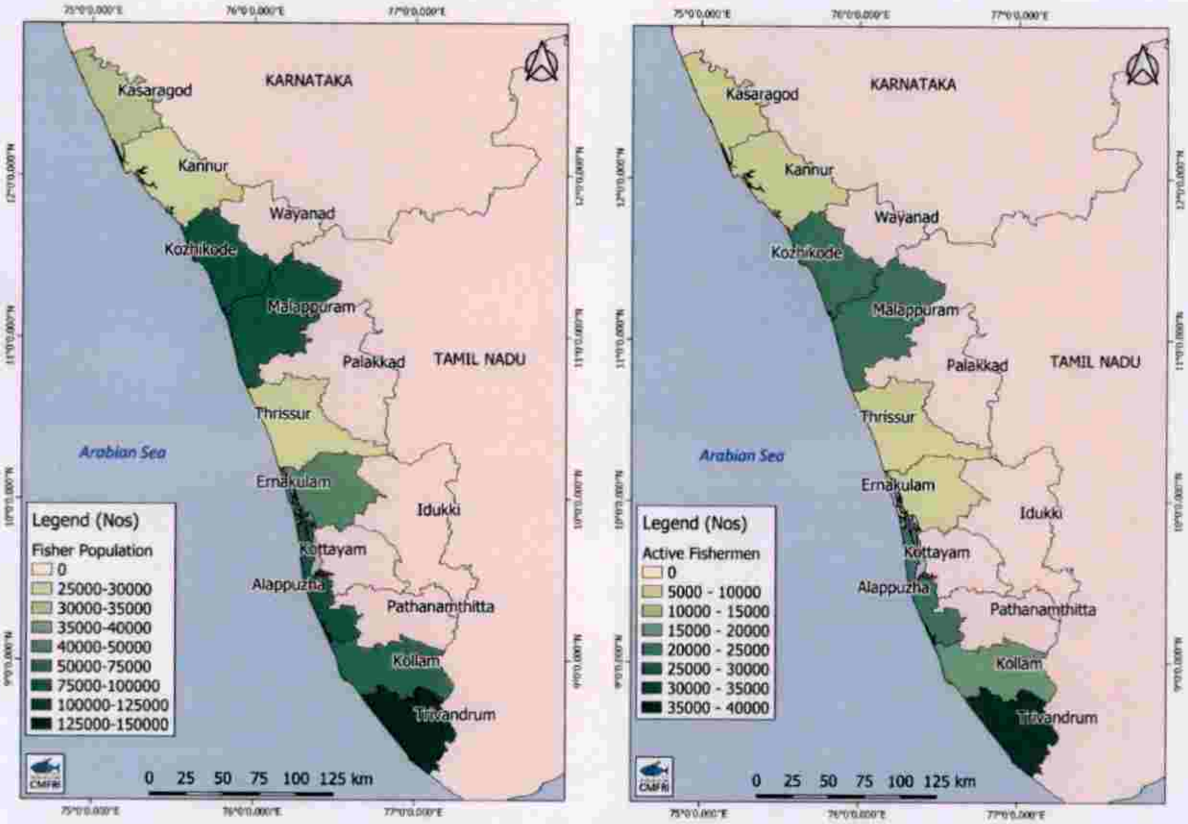

Fig 5.51 - Marine fishermen population and active fisherfolks in coastal districts of Kerala

During cyclone Ockhi the fishermen were not able to go for fishing for several days mainly due to rough weather, cyclone alert and fishing ban. In the present study, the loss in mandays and revenue in the coastal districts of Kerala and Tamil Nadu was estimated from the loss in fishing days due to Ockhi.

The number of days when fishing was not conducted (loss in fishing days) due to Ockhi warning and other aspects related to this cyclone was higher in Thiruvananthapuram (20 days). And in other districts it varied between seven to ten days in December, 2018.

Loss in mandays

The number of crew or fishers in a fishing craft varied depending on the type of craft. Average crew size is maximum in MRS (Mechanized Ring seines) and lowest in traditional crafts like NM (Non-motorized) crafts. In Thiruvananthapuram and Alappuzha districts motorized crafts are dominated. Mechanized crafts are predominant in the Ernakulam, Kollam and Kozhikode districts. Based on the number of fishing days lost, the number of crafts employed for fishing and the crew for each craft, the mandays lost for fishers directly engaged in fishing activity for different districts of Kerala and Tamil Nadu due to cyclone Ockhi was calculated.

In general, an estimated 3,21,495 mandays of fishers directly engaged in marine fishing activity was lost in Kerala due to cyclone Ockhi and the maximum loss (30.5%; 97,871 mandays) was in Thiruvananthapuram district followed by Kollam (15%; 48,330 mandays) (Table 5.28). Sector-wise highest loss 162634 (50.6%) was in the motorized sector, followed by mechanized sector, 139309 (43.3) and the least 19552 (6.1%) in the non-motorized sector.

Table 5.28 - Details of estimated loss in mandays due to cyclone Ockhi in different coastal districts of Kerala and in three major fishing sectors

	Mechanized Sector			Motorised Sector				Traditional		
District	MDTN	MGN	MRS	OBRS	OBGN	OBHL	OBTN	NM	Total loss in mandays	Percentage
Thiruvananthapuram			6431	3900	58300	23100		6240	97971	30.5
Kollam	15611		19707	4255	5205	1301		2251	48330	15.0
Ernakulam	8877	650	7008	5676	1916	762	114	380	25383	7.9
Alappuzha				14203	7719	694	216	9503	32335	10.1
Thrissur	4055		6936	6589	4823	4510	2488	1178	30579	9.5
Malappuram	2510		20570	184	3835		167		27266	8.5
Kozhikode	10123		17175	753	6233	790	431		35505	11.0
Kannur	3713	73	15870	439	3600	112	319		24126	7.5
Total	44889	723	93697	35999	91631	31269	3735	19552	321495	100
Percentage	13.96	0.22	29.14	11.20	28.50	9.73	1.16	6.08	100.00	
Sector wise total mandays	139309			162634				19552		
Sector wise percentage	43.3			50.6				6.1		

Loss in Revenue

The economic analysis indicated that mechanized gill net (MGN) sector has greater gross revenue (₹1,97,500) and net operating income (₹89,559) per trip. Operating cost was high for Mechanized gill net (MGN) nearly ₹1,07,941 per trip. Traditional crafts like NM (Non-motorized) crafts have the least Gross revenue and net profit.

Total loss in catch in Kerala due to loss in fishing days during cyclone Ockhi was estimated to be 257.3 tonnes. Among coastal districts, reduction in catch due to loss in fishing days was higher at Ernakulam (57.54 tonnes) and Malappuram (45.08 tonnes) districts. In Kerala, total economic loss due to loss in fishing days was estimated to be 107.29 crores which is in addition to the physical damage caused by Cyclone Ockhi to fishing crafts and gears (Table 5.28). Based on the economic loss, Kollam (₹ 22.98 crores), Thiruvananthapuram (₹ 16.84 crores) and Kozhikode (₹ 15.6 crores) districts were found to be more impacted by Ockhi and comparatively less economic loss was at Kannur (₹ 8.89 crores), Malappuram (₹ 8.95 crores) and Alappuzha (₹ 9.07 crores) districts. The estimated equipment (craft, gear and other accessories) losses were 9 crores (The Times of India, 2018). The total loss in the marine fisheries sector (loss in fishing days and from craft and gear damage) were 116.29 crores.

Table 5.29 - Details of estimated loss in revenue (in crores) and craft and gear damages due to cyclone Ockhi in different coastal districts of Kerala and in three major fishing sectors

	Mechanized sector			Motorised sector				Traditional		
District	MDTN	MGN	MRS	OBRS	OBGN	OBHL	OBTN	NM	Total loss	Percentage
Thiruvanathapuram			1.86	2.08	9.72	2.97		0.21	16.84	15.7
Kollam	13.95		5.71	2.2	0.87	0.17		0.08	22.98	21.4
Ernakulam	7.93	0.92	2.03	2.94	0.32	0.1	0.01	0.01	14.26	13.3
Alappuzha				7.35	1.29	0.09	0.02	0.32	9.07	8.5
Thrissur	3.62		2.01	3.41	0.8	0.58	0.23	0.04	10.69	10.0
Malappuram	2.24		5.96	0.1	0.64		0.02		8.96	8.4
Kozhikode	9.05		4.98	0.39	1.04	0.1	0.04		15.6	14.5
Kannur	3.32	0.1	4.6	0.23	0.6	0.01	0.03		8.89	8.3
Total loss in revenue (in crores)	40.11	1.02	27.15	18.7	15.28	4.02	0.35	0.66	107.29	
Percentage	37.4	1.0	25.3	17.4	14.2	3.7	0.3	0.6		
Sector wise total	68.3			38.4				0.7		
Sector wise %	63.6			35.7				0.6		
loss due to craft and gear damage (crores)	9.0									
Total loss in crores (including loss in fishing days and craft and gear damage)	116.29									

Among the different gears, MDTN had the highest loss (Rs 40.11 crore; 37.4%) followed by MRS (Rs 27.15crore; 25.3%). The gear-wise and district wise loss is presented in Table 5.29

and in Fig 5.52 & Fig 5.53. Mechanized sector had the highest loss, Rs 68.3crores (63.6%), followed by motorised sector, Rs 38.4 crores (35.7%) and the least was Rs 0.7 crores (0.6%) by the traditional non-motorized sector.

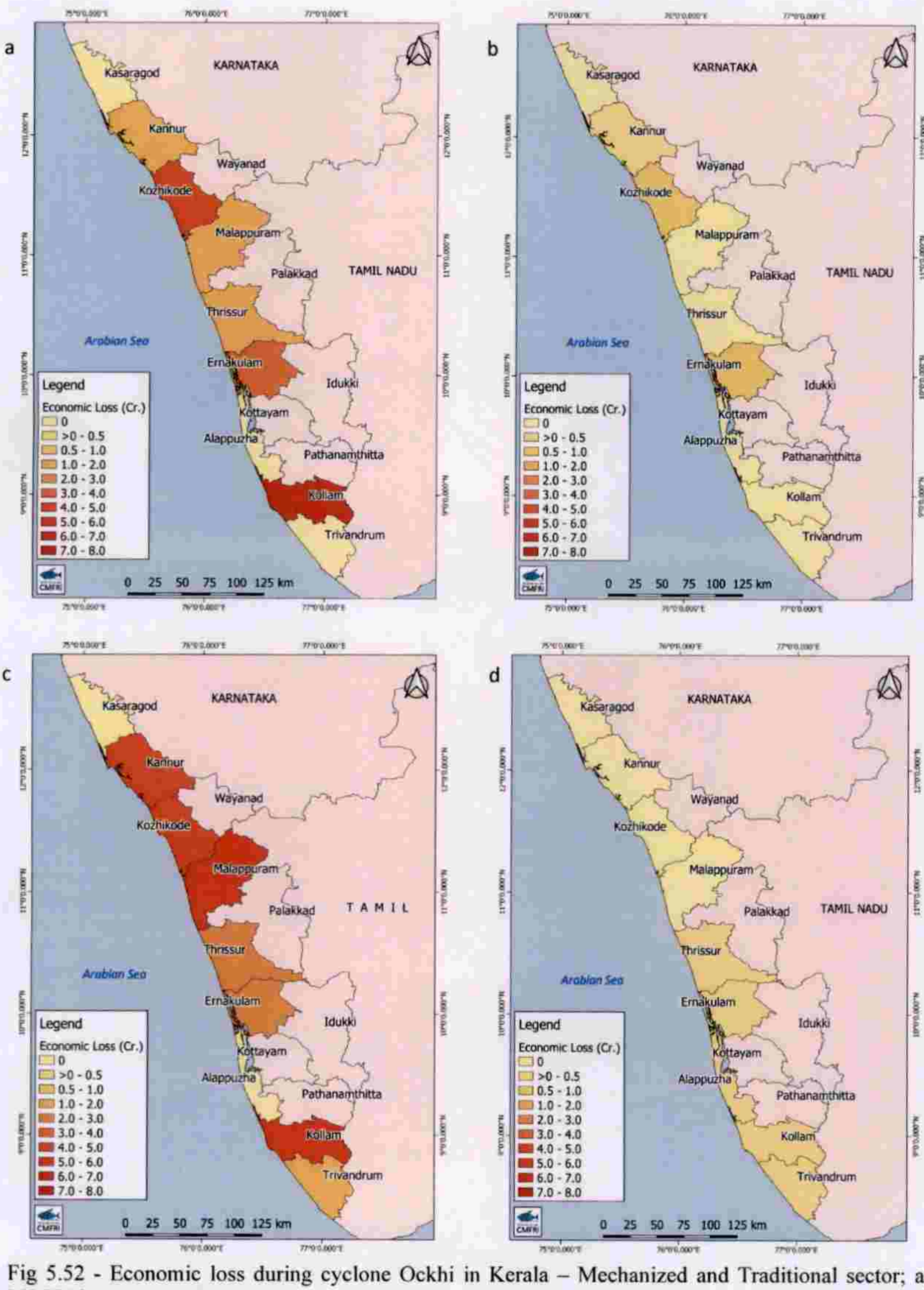

Fig 5.52 - Economic loss during cyclone Ockhi in Kerala – Mechanized and Traditional sector; a) MDTN b) MGN c) MRS d) NM

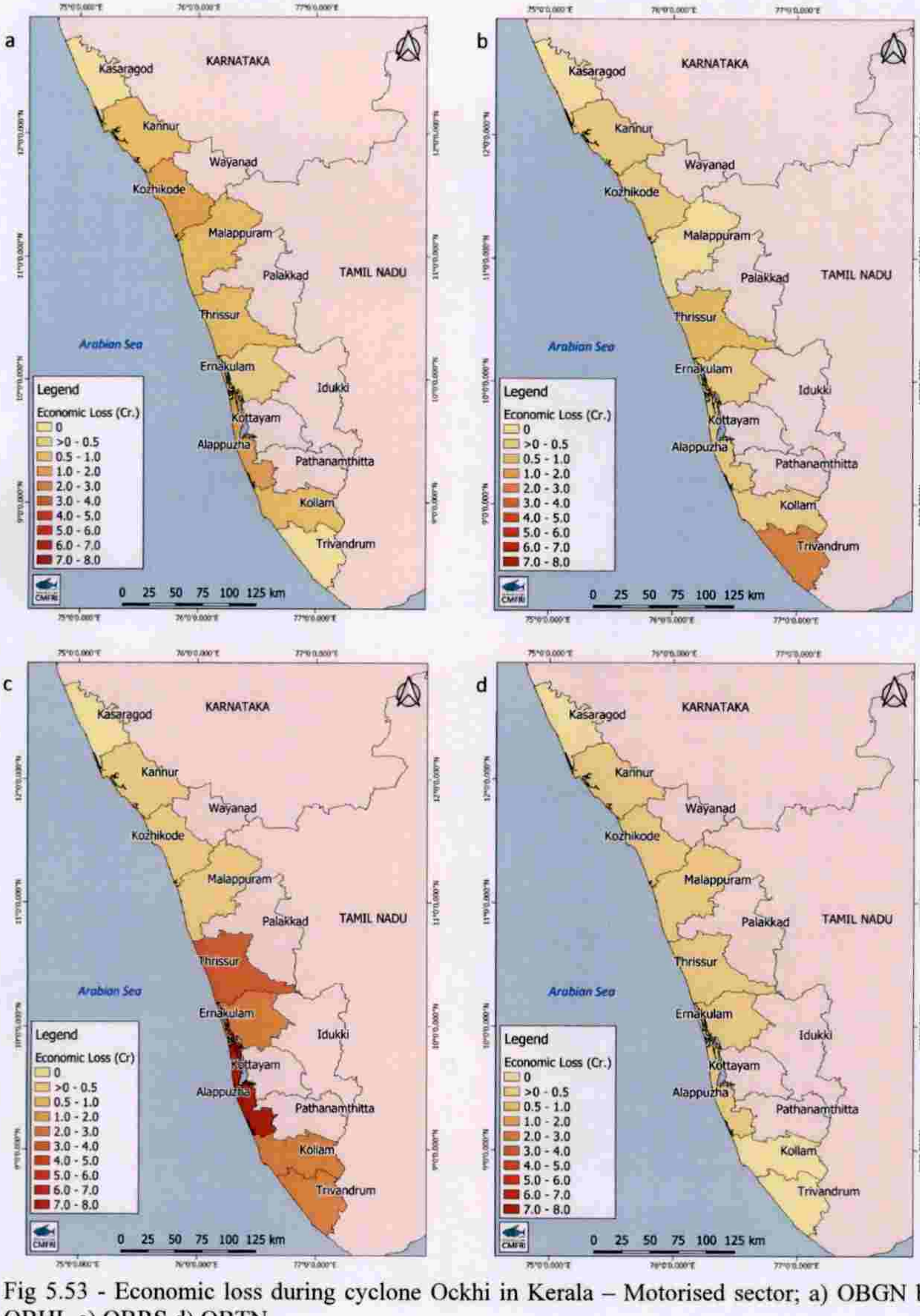

Fig 5.53 - Economic loss during cyclone Ockhi in Kerala – Motorised sector; a) OBGN b) OBHL c) OBRS d) OBTN

5.7.2 Economic loss in Tamil Nadu

In Tamil Nadu, the total fishermen families has been indicated as 201855 with a population of 795708 (CMFRI, 2011). Ramanathapuram district has about the 23.7% of total fisher population. The fishermen populations are comparatively less in the Villupuram and Thiruvarur coastal districts. Entire Tamil Nadu coast is divided in to Coromondal, Palk Bay and Gulf of Mannar regions based on their difference in ecosystem, fishing ground and fishing pattern. Coromondal coast is more populated with 37% of fishermen families (Fig 5.54). The various districts in Coromondal coast are Thiruvallur, Chennai, Kancheepuram, Villupuram, Cuddalore, Nagapattinam while in Palk Bay region there are four districts *viz.* Thiruvarur, Thanjavur, Pudukottai, Ramanathapuram. Cyclone Ockhi affected Tamil Nadu districts are Tuticorin, Thirunelveli and Kanyakumari districts in Gulf of Mannar coast.

In Tamil Nadu, the loss in fishing days in Kanyakumari and Thirunelveli districts were 20 and 14 days respectively. There was no loss in fishing days at Tuticorin district. The loss in mandays was estimated as 106250 (Table 5.30). The highest mandays lost was for the OBGN sector of Kanyakumari, 75515 mandays (71%) followed by OBHL sector of the same district 13095 mandays (12.3%). With a loss of Rs 8.9 crore, (70% of the total loss) the MDTN sector of Kanyakumari was the worst affected by not being able to fish due to cyclone Ockhi.

When compared to other districts, total loss in catch and revenue were greater in Kanyakumari district (Fig). Based on the economic loss, Kanyakumari district (₹12.27 crores) is the most impacted district by the cyclone Ockhi in Tamil Nadu state. In Tamil Nadu, estimated loss in revenue due to loss in fishing days was 12.57 crores. Economic loss due to craft and gear damage was 23.6 crores (OPIOC, 2018). Thus the total economic loss in Tamil Nadu due to cyclone Ockhi was 36.17 crores.

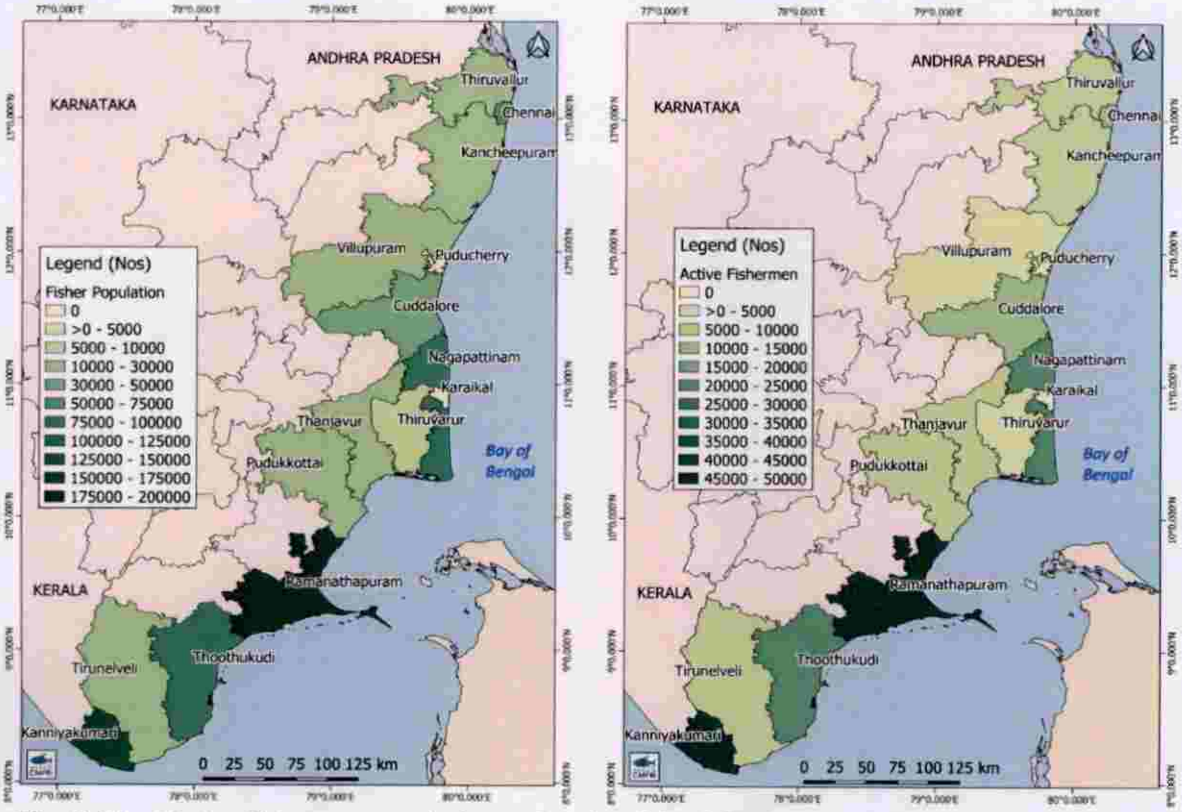

Fig 5.54 - Marine fishermen population and active fisherfolks in coastal districts of Tamil Nadu

Table 5.30 Details of craft and gear damage, loss in revenue and mandays for important marine craft – gear combination in the cyclone Ockhi affected districts of Tamil Nadu

		Mechanized sector	Motorised sector		
	INDICATORS	KANYAKUMARI	KANYAKUMARI		THIRUNELVELI
Sl. No		MDTN	OBGN	OBHL	OBGN
1	No. of Crafts	36	539	131	92
2	Average Catch(in Kg)	8612	39	43	48
3	Crew size	12	7	5	7
4	Average operating cost (in ₹)	85320	1349	1784	1349
5	Average gross revenue (in ₹)	124251	2424	2875	2424
6	Average net operating income (in ₹)	38931	1075	1091	1075
7	Loss in fishing days	20	20	20	14
8	Loss in catch per trip (in tonnes) (7*2)	172.24	0.79	0.86	0.68
9	Loss in revenue per Boat (in lakhs) (7*5)	24.85	0.48	0.58	0.34
10	Total loss in revenue due to the loss in fishing days (in crores)(9*1)	8.90	2.61	0.75	0.31
	Percentage Gear wise loss in revenue	70.8	20.8	6.0	2.5
11	Total loss in mandays (1*3*7)	8594	75515	13095	9046
	% mandays lost	8.1	71.1	12.3	8.5
12	loss due to craft and gear damage (crores)	23.6			
13	Total loss in crores (including loss in fishing days and craft and gear damage)	36.17			

CHAPTER 6

INFLUENCE OF OCEANOGRAPHIC PARAMETERS ON MARINE FISHERY LANDING

The influence of selected environmnetal variatables on the major commercial resources of Kerala and Tamil Nadu across the districts which were impacted due to Ockhi and South India Flood -2015 were analysed and the results obtained is described below.

6.1 KERALA

Total catch and Environmental variables

In Thiruvanathapuram total catch is highly negatively correlated (-0.61) with SST ($p<0.001$) and highly positively correlated (0.61) with DCM ($p <0.001$). Moderate positive correlation with salinity (0.41) and LTA (0.52) ($p<0.001$) and weak positive correlation (0.22) was found between the total catch and chlorophyll Standardized anomaly ($p<0.05$) (Table 6.1).

In Kollam, weak negative correlation (-0.25) was found between the total catch and SST ($p<0.01$). Total catch showed a weak positive significant correlation with salinity (0.2) and DCM (0.25) ($p<0.05$) (Table 6.2).

In Ernakulam, moderate negative correlation (-0.41) was found between the total catch and SST ($p<0.001$), while the DCM showed a moderate positive correlation (0.42) ($p<0.001$). Weak positive correlation (0.31) was observed with the LTA ($p<0.001$) (Table 6.3).

In Alappuzha, total catch had only weak correlation with SST(-0.31) and DCM (0.3). SST showed a negative correlation while DCM showed a positive correlation ($p<0.001$) (Table 6.4).

In Kerala, total catch showed a moderate negative correlation (-0.52) with SST and a moderate positive correlation with chlorphyll (0.45) and DCM (0.51) ($p<0.001$) and weak positive correlation (0.31) with LTA ($p<0.001$). Weak negative correlation with current magnitude and Standardized anomaly (-0.27) and DHM value (-0.24) ($p<0.01$) was also obtained in the analysis (Table 6.5).

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Correlation Analysis

Table 6.1 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Trivandrum district and CPUE of NM, OBBS, OBGN, OBHL, OBRS, OBSS, Total catch and the landings of Indian mackerel, scads, other sardines, *Stolephorous*, squids and oil sardine.

	TOT	NM_CPUE	OBBS_CPUE	OBGN_CPUE	OBHL_CPUE	OBRS_CPUE	OBSS_CPUE	IM	SC	OTS	STL	SQD	OS
SST_M	-0.61***	-0.22*	-0.21*	-0.66***	-0.55***	-0.11	-0.05	-0.13	-0.40***	0.22*	-0.41***	-0.31***	-0.07
CHL_STA	0.22*	-0.21*	-0.13	0.08	0.05	-0.05	0.03	0.35***	-0.04	-0.11	0.04	0.05	-0.07
SALT	0.41***	0.40***	0.29***	0.43***	0.43***	0.01	0.1	0.1	0.21*	-0.14	0.32***	0.29***	0.28**
LTA_M	0.52***	0.22**	0.26**	0.67***	0.59***	0.21*	0.06	0.02	0.39***	-0.18*	0.38***	0.20*	0.06
CUR_M_A	-0.12	0	0.19*	0.04	-0.06	0.46***	-0.04	-0.18*	-0.01	0	0.1	-0.03	-0.07
CUR_D_A	0.12	0.01	-0.14	-0.02	0.03	-0.21*	0.01	0.19*	0.07	-0.05	-0.19*	0.02	0.16
IOD	0.11	0.30***	0.16	0.03	-0.02	0.18*	0.20*	-0.01	0.07	-0.06	0.03	0.11	0.21*
DHM	-0.12	-0.03	0.07	-0.1	-0.05	0	0.06	-0.12	-0.07	0.23**	-0.08	-0.04	-0.08
DCM	0.61***	0.22*	0.21*	0.67***	0.57***	0.11	0.06	0.12	0.41***	-0.21*	0.41***	0.32***	0.06

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL_STA – Chlorophyll concentration standardized anomaly, SALT – Sea surface salinity, LTA_M – Monthly mean Local Temperature Anomaly, CUR_M_A – Current magnitude anomaly, CUR_D_A – Current direction anomaly, IOD – Indian Ocean Dipole Index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBBS_CPUE – Catch per unit effort of Out Board Boat Seine, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, OBSS_CPUE – Catch per unit effort of Out Board Shore seine, IM – Indian mackerel landing, SC – Scads catch, OTS – Other sardines landing, STL – *Stolephorous* catch, SQD – Squid landing, OS – Oil sardine landing

Table 6.2 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Kollam district and CPUE of NM, OBGN, OBRS, Total catch and the landings of Indian mackerel, other sardines and *Thryssa*.

	TOT	NM_CPUE	OBGN_CPUE	OBRS_CPUE	IM	OTS	THR
SST_M	-0.25**	-0.08	-0.14	-0.15	-0.28**	0.24**	-0.22*
CHL_STA	-0.05	0.26**	-0.09	-0.03	0.1	-0.22*	0.04
RF_A	0.01	-0.05	0.23**	0.1	0.03	0.05	-0.22*
SALT	0.20*	0.08	0.26**	0.18*	0.16	-0.08	0.08
IOD	0.15	0.03	0.09	-0.01	-0.04	0.16	0.03
DHM	-0.02	-0.01	0.01	-0.11	-0.04	0.13	-0.07
DCM	0.25**	0.08	0.14	0.14	0.29***	-0.24**	0.22*

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL_STA – Chlorophyll concentration standardized anomaly, RF_A – Rainfall anomaly, SALT – Sea surface salinity, IOD – Indian Ocean Dipole Index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, IM – Indian mackerel landing, OTS – Other sardines landing, THR - *Thryssa* landing

Table 6.3 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Ernakulam district and CPUE of NM, OBGN, OBRS and OBTN, Total catch and the landings of *Stolephorous*, penaeid prawns, croakers and *Thryssa*.

	TOT	NM_CPUE	OBGN_CPUE	OBRS_CPUE	OBTN_CPUE	STL	PP	CKS	THR
SST_M	-0.41***	0.08	-0.14	-0.08	0.14	-0.40***	-0.30***	-0.43***	-0.42***
CHL_STA	0.04	0.05	0.08	0.20*	0	0	0.04	0.01	-0.07
LTA_D	0.31***	-0.19*	0.11	-0.06	-0.25**	0.28**	0.30***	0.34***	0.37***
CUR_M_A	0	-0.15	0.01	-0.05	0.03	0.01	-0.06	-0.11	-0.12
CUR_D	0.05	-0.12	0.17*	0	0.07	-0.03	-0.04	0.12	-0.04
IOD	0.01	0	0	0.02	-0.06	0.03	-0.11	0.11	-0.03
DHM	-0.15	-0.05	-0.11	-0.08	0.07	-0.07	-0.01	-0.09	-0.09
DCM	0.42***	-0.09	0.13	0.07	-0.13	0.41***	0.31***	0.44***	0.43***

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL_STA – Chlorophyll concentration standardized anomaly, LTA_D – Day time Local Temperature Anomaly , CUR_M_A – Current magnitude anomaly, CUR_D – Current direction, IOD – Indian Ocean Dipole Index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, OBTN_CPUE – Catch per unit effort of Out Board Trawl net, STL – *Stolephorous* catch, THR - *Thryssa* landing, PP – Penaeid prawns catch and CKS – Croakers landing

Table 6.4 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Alappuzha district and CPUE of NM, OBGN, OBHL and OBTN, Total catch and the landings of *Stolephorous*, indian mackerel, penaeid prawns and *Thryssa*.

	TOT	NM_CPUE	OBGN_CPUE	OBHL_CPUE	OBTN_CPUE	STL	IM	PP	THR
SST_M	-0.31***	-0.09	-0.17	-0.06	0.25**	-0.28***	-0.18*	-0.44***	-0.19*
SST_M_STA	-0.05	-0.02	0.24**	0.08	0.09	0.09	0	-0.04	0.1
CHL_A	0	0	-0.23**	-0.06	-0.08	0	-0.03	0.12	-0.08
CUR_M_STA	-0.06	0.19*	0	0.28**	0.06	-0.09	0.04	0.01	0.02
CUR_D	-0.05	-0.12	0.04	0	-0.19*	-0.11	-0.03	-0.25**	-0.16
IOD	0.01	-0.24**	0.31***	0.17	0.02	0.06	0.08	-0.06	-0.16
DHM	-0.17*	-0.17*	-0.1	0	-0.02	-0.07	-0.1	-0.08	-0.06
DCM	0.30***	0.07	0.16	0.06	-0.27**	0.29***	0.17*	0.45***	0.19*

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_STA – Sea surface temperature standardized anomaly, CHL_A – Chlorophyll concentration anomaly, CUR_M_STA – Current magnitude standardized anomaly, CUR_D – Current direction, IOD – Indian Ocean Dipole Index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBTN_CPUE – Catch per unit effort of Out Board Trawl net, STL – *Stolephorous* catch, IM – Indian mackerel landing, THR - *Thryssa* landing, PP – Penaeid prawns catch

Table 6.5 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Kerala state and CPUE of NM, OBGN, OBHL, OBRS and OBTN, Total catch and the landings of oil sardine, Stolephorous, indian mackerel, penaeid prawns, other sardines and scads.

	TOT	NM_CPUE	OBGN_CPUE	OBHL_CPUE	OBRS_CPUE	OBTN_CPUE	OS	STL	IM	PP	OTS	SC
SST_M	-0.52***	-0.30***	-0.58***	-0.18*	-0.07	-0.44***	-0.19*	-0.38***	-0.24**	-0.51***	0.22*	-0.38***
CHL	0.45***	0.36***	0.58***	0.16	0.03	0.46***	0.09	0.46***	0.22*	0.52***	-0.27**	0.38***
CHL_STA	-0.01	-0.23**	-0.42***	-0.23**	0.19*	-0.43***	0.21*	-0.31***	0.03	-0.38***	0.08	-0.12
SALT_A	0.06	0.15	0.15	-0.07	0.14	0.20*	-0.02	0.19*	0.01	0.19*	0	0.01
LTA_M	0.31***	0.28**	0.60***	0.21*	-0.04	0.41***	-0.05	0.34***	0.22*	0.50***	-0.23**	0.41***
CUR_M_STA	-0.27**	-0.03	0.08	0.03	-0.25**	-0.01	-0.28***	-0.12	-0.13	-0.01	0.07	-0.04
CUR_D_A	-0.18*	-0.12	-0.04	0.07	-0.22*	0.05	-0.12	-0.11	-0.20*	-0.06	0.03	-0.09
DHM	-0.24**	-0.14	-0.16	0.02	-0.06	-0.1	-0.18*	-0.1	-0.12	-0.08	0.06	-0.07
DCM	0.51***	0.29***	0.58***	0.19*	0.06	0.44***	0.17*	0.39***	0.24**	0.51***	-0.22*	0.39***

* → $p<0.05$; ** → $p<0.01$; *** → $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL – Chlorophyll concentration, CHL_STA – Chlorophyll concentration standardized anomaly, SALT_A – Sea surface salinity anomaly, LTA_M –Monthly mean Local Temperature Anomaly, CUR_M_STA – Current magnitude standardized anomaly, CUR_D_A – Current direction anomaly, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, OBTN_CPUE – Catch per unit effort of Out Board Trawl net, IM – Indian mackerel landing, SC – Scads catch, OTS – Other sardines landing, STL – *Stolephorous* catch, OS – Oil sardine landing, PP- Penaeid prawn catch

Catch per unit effort (CPUE) of Non-motorised (NM) vessels and Environmental parameters

In Thiruvanathapuram, moderate positive correlation (0.40) was found between the CPUE of NM crafts and salinity ($p<0.001$). Weak positive correlation with LTA (0.22) ($p<0.01$), IOD (0.3) ($p<0.001$) and DCM (0.22) ($p<0.05$). Weak negative correlation (-0.21) with SST and Chlorophyll Standardized Anomaly ($p<0.05$) (Table 6.1).

In Kollam, CPUE of NM showed a weak positive correlation (0.26) with Chlorophyll Standardized Anomaly ($p<0.01$) (Table 6.2).

In Alappuzha, weak negative correlation (-0.24) was found between the CPUE of NM and IOD ($p<0.01$) (Table 6.3).

Overall in Kerala, NM-CPUE indicated a weak negative correlation with SST (-0.3) and Chlorophyll Standardized Anomaly (-0.23) and the correlation was significant ($p<0.01$). Chlorophyll (0.36), LTA (0.28) and DCM (0.29) showed a weak positive correlation ($p<0.001$) with NM-CPUE (Table 6.5).

Catch per unit effort of OBBS and Environmental variables

In Thiruvanathapuram, salinity (0.29), LTA (0.26) and DCM (0.21) showed weak positive correlation with CPUE of OBBS and the correlation was significant ($p<0.05$). Apart from this there was a weak negative correlation (-0.21) with SST ($p<0.05$) (Table 6.1).

Catch per unit effort of OBGN and Environmental variables

In Thiruvanathapuram, a highly negative significant ($p<0.001$) correlation (-0.66) was found between the SST and OBGN CPUE while LTA and DCM showed a highly positive correlation (0.67) ($p<0.001$). CPUE of OBGN showed a moderate positive correlation (0.43) with salinity ($p<0.001$) (Table 6.1).

In Kollam, salinity (0.26) and rainfall anomaly (0.23) showed a weak positive correlation ($p<0.001$) with OBGN-CPUE (Table 6.2).

In Alappuzha, CPUE of OBGN showed a weak positive correlation with Standardized Anomaly of SST (0.24) ($p<0.01$) and IOD (0.31) ($p<0.001$). Weak negative correlation(-0.23) with chlorophyll anomaly ($p<0.01$) was also oberved (Table 6.4).

In Kerala, highly positive correlation (0.6) was found between the LTA and OBGN CPUE ($p<0.001$). Chlorophyll and DCM values showed a moderate positive correlation (0.58) ($p<0.001$). SST (-0.58) and chlorophyll Standardized Anomaly (-0.42) showed a moderate negative correlation ($p<0.001$) (Table 6.5).

Catch per unit effort of OBHL and Environmental variables

In Thiruvanathapuram, a moderate negative correlation (-0.55) was found between the SST and OBHL CPUE ($p<0.001$). Salinity (0.43), LTA (0.59) and DCM (0.57) showed a moderate positive correlation ($p<0.001$) with OBHL-CPUE (Table 6.1).

In Alappuzha, CPUE of OBHL showed a weak positive correlation (0.28) with current magnitude Standardized anomaly ($p<0.01$) (Table 6.4).

Overall in Kerala, a weak positive correlation (0.21) was found between the LTA and OBHL CPUE ($p<0.05$). A weak negative correlation(-0.23) was found between chlorophyll Standardized anoamaly and OBHL CPUE ($p<0.01$) (Table 6.5).

Catch per unit effort of OBOTHS and Environmental variables

In Ernakulam, current magnitude anomaly showed a weak positive correlation (0.27) with OBOTHS CPUE.

($p<0.01$). Weak negative correlation (-0.22) was observed with the chlorophyll Standardized Anomaly ($p<0.05$) (Table 6.3).

Catch per unit effort of OBRS and Environmental variables

In Thiruvanathapuram, current magnitude anomaly showed a moderate positive correlation (0.46) with CPUE of OBRS ($p<0.001$). LTA showed a weak positive correlation (0.21) and current direction anomaly showed a weak negative correlation (-0.21) with OBRS-CPUE ($p<0.05$) (Table 6.1).

In Ernakulam, chlorophyll Standardized Anomaly showed a weak negative correlation (0.2) with CPUE of OBRS ($p<0.05$) (Table 6.3).

In Kerala, both the current speed (-0.25) and its direction(-0.22) shows a weak negative correlation and their correlation is significant($p<0.05$) (Table 6.5).

Catch per unit effort of OBSS and Environmental variables

In Thiruvanathapuram, a weak positive correlation (0.2) was found between the IOD and OBSS CPUE ($p<0.05$) (Table 6.1).

Catch per unit effort of OBTN and Environmental variables

In Ernakulam, LTA showed a weak negative correlation (-0.25) with CPUE of OBTN ($p<0.01$) (Table 6.3).

In Alappuzha, a weak negative correlation (-0.27) was found between the DCM and OBTN CPUE ($p<0.01$) while SST showed a weak positive correlation (0.25) (Table 6.4).

In general, in Kerala SST(-0.44) and chlorophyll Standardized Anomaly (-0.43) showed a moderate negative correlation ($p<0.001$). Chlorophyll (0.46), LTA (0.41) and DCM (0.44) showed a moderate positive correlation with OBTN-CPUE ($p<0.001$) (Table 6.5).

Oil sardine fishery and Environmnetal relationship

In Thiruvanathapuram, salinity (0.28) and IOD(0.21) showed a weak significant positive ($p<0.05$) correlation with oil sardine fishery (Table 6.1).

In Kollam, a weak negative correlation (-0.2) was found between the SST Standardized Anomaly and oil sardine landing ($p<0.05$) (Table 6.2).

Overall in Kerala, a weak negative correlation (-0.28) was found between the current magnitude Standardized anomaly and oil sardine fishery ($p<0.001$). Chlorophyll Standardized Anomaly showed a weak positive correlation (0.21) with oil sardine fishery (Table 6.5).

Indian mackerel fishery and Environmental variables

In Thiruvanathapuram, chlorophyll Standardized Anomaly showed a weak positive correlation (0.35) with Indian mackerel landing ($p<0.001$) (Table 6.1).

In Kollam, DCM showed a weak positive correlation (0.29) with Indian mackerel catch. SST showed a weak negative correlation (-0.28) ($p<0.01$) (Table 6.2).

In Kerala, a weak negative correlation (-0.24) was found between SST and Indian mackerel fishery ($p<0.01$). Chlorophyll (0.22), LTA (0.22) and DCM (0.24) showed a weak positive correlation ($p<0.05$) while a negative correlation (-0.2) was observed with current direction anomaly (Table 6.5).

Other sardine fishery and Environmental variables

In Thiruvanathapuram, SST (0.22) and DHM (0.23) showed a weak positive correlation with other sardine landing and the correlation was significant ($p<0.05$). A weak negative correlation (-0.21) was found between DCM and other sardine catch ($p<0.05$) (Table 6.1).

In Kollam, a weak positive correlation was found between SST (0.24) and other sardine fishery ($p<0.001$) while chlorophyll Standardized Anomaly (-0.22) ($p<0.05$) and DCM (-0.24) ($p<0.01$) showed a weak negative correlation (Table 6.2).

In general in Kerala, other sardine catch showed a weak negative correlation with Chlorophyll (-0.27), LTA (-0.23) and DCM (-0.22) ($p<0.05$) and a weak positive correlation (0.22) with SST ($p<0.05$) (Table 6.5).

Stolephorous fishery and Environmental variables

In Thiruvanathapuram, salinity (0.32) and LTA (0.38) showed a weak positive correlation with *Stolephorous* fishery ($p<0.001$) and a moderate positive correlation (0.41) with DCM ($p<0.001$). A moderate negative correlation (-0.41) was found between the SST and *Stolephorous* catch ($p<0.001$) (Table 6.1).

In Ernakulam, a moderate negative correlation (-0.4) was found between SST and *Stolephorous* catch ($p<0.001$) and a moderate positive correlation (0.41) with DCM ($p<0.001$). *Stolephorous* catch showed a weak positive correlation (0.28) with LTA ($p<0.01$) (Table 6.3).

In Alappuzha, a weak negative correlation(-0.28) is found between the SST and stolephorous catch($p<0.001$). DCM shows a weak positive correlation (0.29) with stlephorous landing (Table 6.4).

In general in Kerala, SST (-0.38) and chlorophyll Standardized Anomaly (-0.31) showed a weak negative correlation with *Stolephorous* fishery ($p<0.001$). LTA (0.34) and DCM (0.39) showed a weak positive correlation with *Stolephorous* catch ($p<0.001$). The landing of *Stolephorous* showed a moderate positive correlation ($p<0.001$) with chlorphyll (Table 6.5).

Scad fishery and Environmental variables

In Thiruvanathapuram, a moderate negative correlation (-0.4) was found between SST and scad fishery ($p<0.001$). DCM showed a moderate positive correlation (0.41) with scad fishery

($p<0.001$). The catch of scads showed a weak positive correlation (0.39) with LTA ($p<0.001$) (Table 6.1).

In general in Kerala, a moderate positive correlation (0.41) was found between the LTA and scad fishery ($p<0.001$). SST showed a weak negative correlation (-0.38) with scad fishery ($p<0.001$). There was also a weak positive correlation ($p<0.001$) with chlorphyll (0.38) and DCM (0.39) and scad fishery (Table 6.5).

Squid fishery and Environmental variables

In Thiruvanathapuram, a weak negative correlation (-0.31) was found between SST and squid fishery ($p<0.001$). Salinity (0.29), LTA (0.2) and DCM (0.32) showed a weak positive correlation with squid catch and the correlation is significant ($p<0.05$) (Table 6.1).

***Thryssa* fishery and Environmental variables**

In Kollam, SSTand rainfall anomaly showed a weak negative correlation (-0.22) with *Thryssa* catch and a weak positive correlation (0.22) with DCM (Table 6.2).

In Ernakulam, a moderate negative correlation (-0.42) was found between the SST and *Thryssa* landing ($p<0.001$) and a moderate positive correlation (0.43). There was also a weak positive correlation (0.37) with LTA ($p<0.001$) (Table 6.3).

Penaeid prawn fishery and Environmental variables

In Ernakulam, a weak negative correlation (-0.3) was found between the SST and penaeid prawn landing ($p<0.001$). The penaeid prawn fishery showed a weak positive correlation with LTA (0.3) and DCM (0.31) ($p<0.001$) (Table 6.3).

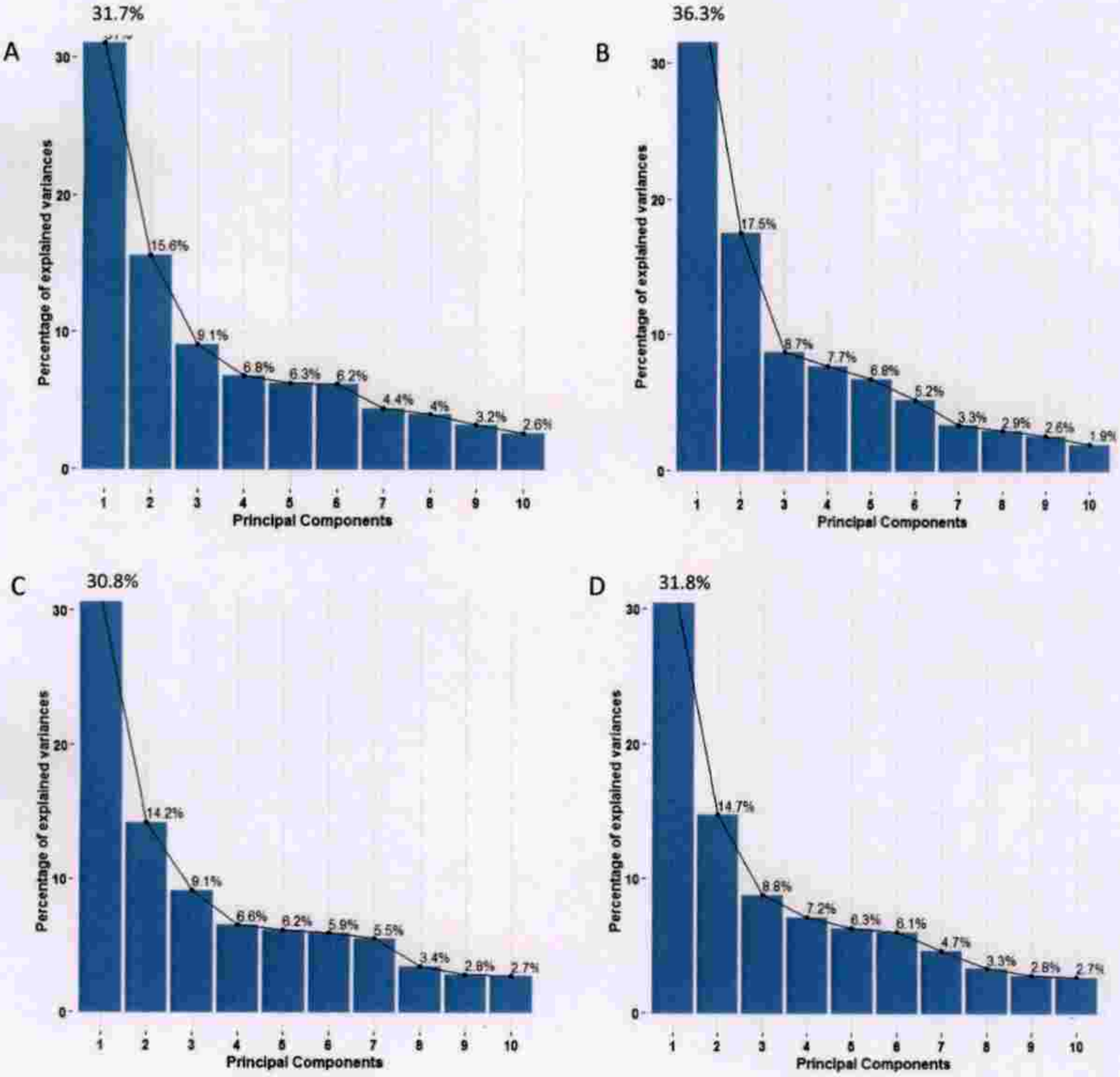
In Alappuzha, a moderate negative correlation(-0.44) was found between the SST and penaeid prawn catch ($p<0.001$) while DCM showed a moderate positive correlation (0.45). The landing of penaeid prawns shows a weak negative correlation (-0.25) with current direction ($p<0.01$) (Table 6.4).

In general in Kerala, a moderate negative correlation (-0.51) was found between the SST and penaeid prawn catch ($p<0.001$). There was also a moderate positive correlation ($p<0.001$) with chlorophyll (0.52), LTA (0.5) and DCM (0.51) ($p<0.001$). Chlorophyll Standardized Anomaly showed a weak negative correlation (-0.38) with penaeid prawn catch ($p<0.001$) (Table 6.5).

Croaker fishery and Environmental variables

In Ernakulam, a moderate negative correlation (-0.43) was found between SST and croaker landing ($p<0.001$) while DCM showed a moderate positive correlation (0.44) with croaker fishery. The landing of croaker showed a weak positive correlation (0.34) LTA ($p<0.001$) (Table 6.3).

PCA ANALYSIS



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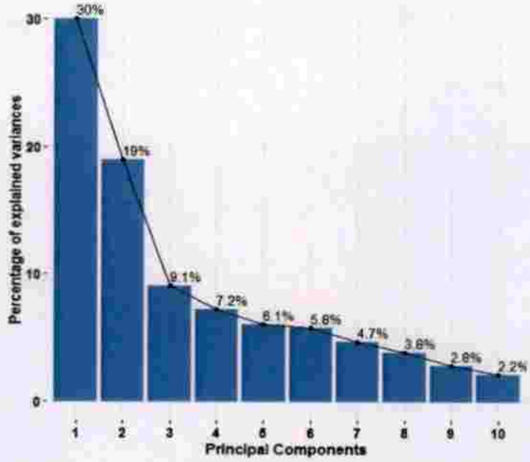


Fig. 6.1: Scree plot of principle components for A)Thiruvanathapuram B)Kollam C)Ernakulam D)Alappuzha E)Kerala

To select a representative MDS (Minimum data set) for assessing the relation between marine fishery catch and oceanographic variables, we first performed Standardized principle component analysis (PCA). Selected parameters for the study were Sea suface temperature (SST), Chlorophyll-a concentration, Sea level anomaly (SLA), salinity, rainfall, surface current velocity and direction, local temperature anomaly (LTA), MEI (Multivariate ENSO Index), IOD (Indian ocean dipole), degree heating month (DHM), degree cooling month (DCM) and their anomalies. Principle components (PCs) receiving high values best represent system attributes. All PC's with eigen value >1.0 were only retined for further analysis. For a particular PC, each variable received a weight or factor loading that represented its contribution to the PC. Only highly weighted variables from each PC were selected for the MDS. According to Andrews *et al.* (2002), highly weighted was that within 10% of the highest factor loading (using the absolute values). When more than one variables were retained within a PC, using the linear correlation found out the redundant variables and were removed from the MDS. In regression model, final MDS indicators were used as independent variables and catch parameters as dependent variables.

Results of the Multiple Linear Regression Modelling using different environmental parameters as regressors and catch parameters as Response Variables

Regression analysis models the relationships between a response variable and one or more predictor variables. R-squared is a goodness-of-fit measure for linear regression models. R-squared is the percentage of the response variable variation that is explained by a linear model. It is always between 0 and 100%.

47% of the total catch variation was explained by this regression model, i.e changes in the selected environment parameters contribute 47% total catch variation. In this, variation in SST and DCM values contribute 25 and 26% of its total variation. The percentage variance explained by the model for the OBGN-CPUE and OBHL-CPUE were 59% and 49% respectively. In OBGN-CPUE, SST contributed 24% to total variance explained by the model. In OBHL-CPUE , 49.63% total variance explained by the regression model 26% was contributed by upwelling index (LTA) (Table 6.6). Using the regression model, 26.5, 16.02, 23.3, 20.98, 18.86, 28.23% of Indian mackerel, oil sardine, other sardine, scads, squid and *Stolephorous* landings could be explained. Total variance explained for the Indian mackeral fishery, 34% was contributed by Chlorophyll Standardized anomaly. Out of the total variance explained by the regression model for oil sardine fishery, 39% was contributed by sea surface salinity. The 23.31% variance explained by the regression model, 57% contributed by DHM-Y values. The 20.98% variance explained by the scad fishery, DCM, SST and LTA contribute 26, 25 and 25% respectively. while for 28.23% of variance explained for the *Stolephorus* landing, 42% contributed by the SST and DCM (Table 6.7).

Table 6.6 - Regression model results of Thiruvanathapuram district using chlorophyll concentration, total catch, CPUE of NM, OBBS, OBGN and OBRS gears as Response (Dependant) variables and SST, LTA, Standardized anomaly of SST, rainfall and Chlorophyll concentration, salinity, DHM, DCM, IOD, current velocity and direction anomalies as covariate (Independent variables).

Response variable	Chlorophyll concentration	CPUE of NM	CPUE of OBBS	CPUE of OBGN	CPUE of OBHL	CPUE of OBRS	Total catch
Variance explained by model	80.12%	34.26%	26.78%	59.76%	49.63%	35.80%	47%
SST_M	0.27	0.06	0.08	0.23	0.21	0.02	0.25
LTA_M	0.24	0.05	0.08	0.24	0.26	0.07	0.16
SST_M_STA	0.02	0.07	0.04	0.07	0.08	0.05	0.02
CHL_STA	---	0.12	0.05	0.00	0.00	0.01	0.05
CUR_M_A	0.00	0.00	0.10	0.00	0.02	0.42	0.05
SALT	0.13	0.22	0.15	0.08	0.11	0.01	0.11
RF_STA	0.02	0.13	0.01	0.01	0.01	0.01	0.02
DHM	0.01	0.01	0.04	0.01	0.02	0.01	0.01
DHM_Y	0.01	0.01	0.23	0.08	0.03	0.11	0.00
CUR_D_A	0.00	0.00	0.05	0.00	0.00	0.10	0.01
IOD	0.00	0.13	0.09	0.01	0.01	0.14	0.02
DCM	0.28	0.06	0.07	0.24	0.23	0.02	0.26
DCM_Y	0.02	0.15	0.01	0.02	0.02	0.03	0.04

Table 6.7 - Regression model results of Thiruvanathapuram district using Indian mackerel, other sardine, scads and *Stolephorous* landing as Response(Dependant)variables and SST, LTA, Standardized anomaly of SST, rainfall and Chlorophyll concentration, salinity, DHM, DCM, IOD, current velocity and direction anomalies as covariate(Independent variables).

Response variable	Indian mackerel catch	Other sardines landing	Scads landing	*Stolephorous* catch
Variance explained by model	26.57%	23.31%	20.98%	28.23%
SST_M	0.03	0.08	0.25	0.21
LTA_M	0.06	0.05	0.25	0.15
SST_M_STA	0.07	0.02	0.02	0.05
CHL_STA	0.34	0.03	0.05	0.00
CUR_M_A	0.10	0.00	0.02	0.01
SALT	0.04	0.03	0.05	0.12
RF_STA	0.01	0.00	0.01	0.01
DHM	0.02	0.09	0.01	0.01
DHM_Y	0.03	0.57	0.02	0.06
CUR_D_A	0.08	0.00	0.01	0.14
IOD	0.00	0.03	0.02	0.01
DCM	0.03	0.07	0.26	0.21
DCM_Y	0.19	0.02	0.01	0.01

Table 6.8 - Multiple linear regression equations for the response variables in the coast of Thiruvananthapuram

Model No:	REGRESSION EQUATION
1	CHL = -4.1 -0.2 * SST_M + 0.49 * LTA_M + 0.2 * SST_M_STA -0.001 * CUR_M_A + 0.29 * SALT -0.03 * RF_STA + 0.45 * DHM -0.05 * DHM_Y + 0.001 * CUR_D_A -0.5 * IOD + 0.5 * DCM + 0.001 * DCM_Y
2	TOT = -20902.8 + 496.7 * SST_M -3.3 * LTA_M + 198 * SST_M_STA + 304.4 * CHL_STA -4.8 * CUR_M_A + 222.4 * SALT + 243.3 * RF_STA -950.8 * DHM + 158.7 * DHM_Y + 1.8 * CUR_D_A + 860.8 * IOD + 1435.9 * DCM + 11.8 * DCM_Y
3	NM_CPUE = 621.3 -24.95 * SST_M + 2.18 * LTA_M + 1.04 * SST_M_STA -3.05 * CHL_STA -0.007 * CUR_M_A + 3.96 * SALT + 3.5 * RF_STA + 23.3 * DHM + 0.6 * DHM_Y + 0.007 * CUR_D_A + 8.5 * IOD -24.3 * DCM + 0.35 * DCM_Y
4	OBBS_CPUE = 12413.8 -465.9 * SST_M + 12.3 * LTA_M + 12.36 * SST_M_STA -17.45 * CHL_STA + 0.4 * CUR_M_A + 43.3 * SALT -2.2 * RF_STA + 380 * DHM + 107.69 * DHM_Y -0.2 * CUR_D_A + 126 * IOD -463 * DCM -1.2 * DCM_Y
5	OBGN_CPUE = 560 -18.5 * SST_M + 15.97 * LTA_M + 10.3 * SST_M_STA + 1.03 * CHL_STA -0.02 * CUR_M_A + 0.85 * SALT + 3.4 * RF_STA -20 * DHM + 15.4 * DHM_Y -0.004 * CUR_D_A + 3.6 * IOD -6.1 * DCM -0.12 * DCM_Y
6	OBHL_CPUE = -1283 + 42.6 * SST_M + 12.7 * LTA_M + 6.9 * SST_M_STA + 0.56 * CHL_STA -0.04 * CUR_M_A + 2.04 * SALT + 1.8 * RF_STA -53.6 * DHM + 4.17 * DHM_Y + 0.015 * CUR_D_A -7.2 * IOD + 49.8 * DCM -0.37 * DCM_Y
7	OBOTHS_CPUE = 46.7 -2.5 * SST_M -1.3 * LTA_M -0.06 * SST_M_STA -0.12 * CHL_STA + 0.004 * CUR_M_A + 0.87 * SALT -0.16 * RF_STA + 1.8 * DHM -0.08 * DHM_Y + 0.002 * CUR_D_A -1.4 * IOD -2.26 * DCM -0.05 * DCM_Y
8	OBRS_CPUE = 5864 -187.9 * SST_M + 58.7 * LTA_M -46.4 * SST_M_STA -15.6 * CHL_STA + 1.22 * CUR_M_A -8.96 * SALT -12.2 * RF_STA +118.4 * DHM + 123.6 * DHM_Y -0.6 * CUR_D_A + 285.3 * IOD -224 * DCM + 2.23 * DCM_Y
9	OBSS_CPUE = 54 -1.7 * SST_M + 0.6 * LTA_M + 2.2 * SST_M_STA + 2.2 * CHL_STA -0.02 * CUR_M_A -0.23 * SALT + 1.5 * RF_STA + 2.06 * DHM + 4.5 * DHM_Y -0.0001 * CUR_D_A + 22 * IOD -0.3 * DCM -0.13 * DCM_Y
10	OBTN_CPUE = -38 -0.34 * SST_M -3.9 * LTA_M -2.7 * SST_M_STA + 0.33 * CHL_STA -0.02 * CUR_M_A + 1.5 * SALT - 0.83 * RF_STA -0.98 * DHM + 0.43 * DHM_Y -0.01 * CUR_D_A + 4.34 * IOD -0.4 * DCM -0.11 * DCM_Y
11	OS = 6627.8 -285.4 * SST_M -1.75 * LTA_M -0.12 * SST_M_STA -10.8 * CHL_STA -0.06 * CUR_M_A + 56 * SALT + 11.9 * RF_STA + 191.96 * DHM -15.2 * DHM_Y + 0.38 * CUR_D_A + 49.1 * IOD -298.5 * DCM + 1.57 * DCM_Y
12	STL = 1474.6 -104.3 * SST_M + 31.25 * LTA_M + 65.35 * SST_M_STA + 8.4 * CHL_STA + 0.29 * CUR_M_A + 49.7 * SALT -1.4 * RF_STA + 179.65 * DHM -131 * DHM_Y -1.14 * CUR_D_A -171.6 * IOD + 16.4 * DCM -3.15 * DCM_Y
13	IM = -13890 + 422 * SST_M -166 * LTA_M -45.6 * SST_M_STA + 106 * CHL_STA -0.7 * CUR_M_A + 52.4 * SALT + 8.07 * RF_STA -417 * DHM -51.9 * DHM_Y + 0.6 * CUR_D_A + 4.2 * IOD + 479 * DCM + 11.8 * DCM_Y
14	SQD = -4378 + 58 * SST_M -162.6 * LTA_M + 23.5 * SST_M_STA + 10.9 * CHL_STA -0.03 * CUR_M_A + 75.7 * SALT + 42.7 * RF_STA + 56.3 * DHM -25 * DHM_Y + 0.004 * CUR_D_A + 38.6 * IOD + 210.6 * DCM + 2.7 * DCM_Y
15	OTS = 14670 -466 * SST_M -65.9 * LTA_M + 1.4 * SST_M_STA -27 * CHL_STA + 0.145 * CUR_M_A -18.3 * SALT + 0.34 * RF_STA + 533 * DHM + 290 * DHM_Y + 0.02 * CUR_D_A + 162.9 * IOD -504.7 * DCM + 2.16 * DCM_Y
16	SC = 5485.6 -138.9 * SST_M + 180 * LTA_M + 20.5 * SST_M_STA -71 * CHL_STA -0.8 * CUR_M_A -39.4 * SALT + 15.07 * RF_STA -56.4 * DHM + 83.6 * DHM_Y + 0.4 * CUR_D_A + 202 * IOD -8.3 * DCM -5.2 * DCM_Y

Kollam Fishery

Coefficient of determination (R^2) value for the total catch and CPUE of OBGN were 17% and 14.49% respectively. The 17.06% variance explained by the regression model for the total catch, 22% contributed by the SST standardized anomaly (Table 6.9). 21.3% and 19.25% of Indian mackerel and other sardine catch could be explain by this regression model. The variance explained by the model for other sardine fishery, 14% contributed by chlorophyll standardized anomaly while 21.3% variance explained for the Indian mackerel fishery 35% contributed by the DHM-Y (Table 6.10).

Table 6.9 - Regression model results of Kollam district using chlorophyll concentration and total catch as Response(Dependant)variables and SST, Salinity, Standardized anomaly of SST, salinity and Chlorophyll-a concentration, rainfall anomaly, DHM, DCM, IOD as covariate (Independent variables).

Response variable	Chlorophyll-a concentration	Total catch
variance explained by model	74.02%	17.06%
SST_M	0.33	0.12
SST_M_STA	0.03	0.22
CHL_STA	---	0.07
SALT	0.22	0.17
SALT_STA	0.03	0.07
RF_A	0.00	0.00
DHM	0.01	0.01
DHM_Y	0.01	0.01
IOD	0.00	0.15
DCM	0.35	0.12
DCM_Y	0.02	0.05

Table 6.10 - Regression model results of Kollam district using other sardines and Indian mackerel as Response(Dependant)variables and SST, Salinity, Standardized anomaly of SST, salinity and Chlorophyll concentration, rainfall anomaly, DHM, DCM, IOD as covariate (Independent variables).

Response variable	Other sardines catch	Indian mackerel landing
variance explained by model	19.25%	21.30%
SST_M	0.14	0.12
SST_M_STA	0.04	0.04
CHL_STA	0.16	0.02
SALT	0.03	0.06
SALT_STA	0.01	0.04
RF_A	0.00	0.00
DHM	0.04	0.02
DHM_Y	0.12	0.35
IOD	0.13	0.01
DCM	0.14	0.13
DCM_Y	0.18	0.21

Table 6.11 - Multiple linear regression equations for the response variables in the coast of Kollam

Model No:	REGRESSION EQUATION
1	CHL = -33.4 + 0.31 * SST_M + 0.15 * SST_M_STA + 0.71 * SALT -0.28 * SALT_STA + 0.001 * RF_A + 0.14 * DHM -0.24 * DHM_Y -0.45 * IOD + 1.08 * DCM -0.56 * DCM_Y
2	TOT = 7268.5 -633 * SST_M -323.5 * SST_M_STA -146.8 * CHL_STA + 377 * SALT -211.3 * SALT_STA -0.17 * RF_A + 1028.5 * DHM + 86.6 * DHM_Y + 803.6 * IOD -632.8 * DCM + 8.5 * DCM_Y
3	OS = -2766 + 67.9 * SST_M -110 * SST_M_STA + 46 * CHL_STA + 35.9 * SALT -15.3 * SALT_STA -0.19 * RF_A + 295.8 * DHM -99.7 * DHM_Y + 149.3 * IOD + 40.5 * DCM + 0.003 * DCM_Y
4	STL = 10123.5 -536.2 * SST_M -84.1 * SST_M_STA -82.2 * CHL_STA + 180.8 * SALT -120.9 * SALT_STA + 0.19 * RF_A + 325 * DHM -9.6 * DHM_Y + 295.3 * IOD -577 * DCM -11.1 * DCM_Y
5	IM = -8886 + 261.6 * SST_M -22.9 * SST_M_STA + 11.3 * CHL_STA + 32.9 * SALT -27.2 * SALT_STA + 0.01 * RF_A -343 * DHM + 168.2 * DHM_Y + 44.5 * IOD + 281.4 * DCM + 6.7 * DCM_Y
6	THR = 203.5 -16.8 * SST_M -2.14 * SST_M_STA + 1.2 * CHL_STA + 9.5 * SALT -7.9 * SALT_STA -0.12 * RF_A + 11.2 * DHM -0.46 * DHM_Y + 5.4 * IOD -15.8 * DCM -0.12 * DCM_Y
7	OTS = 4153 -120.6 * SST_M -5.2 * SST_M_STA -20.8 * CHL_STA -14.9 * SALT + 5.79 * SALT_STA + 0.01 * RF_A + 161.9 * DHM + 58.2 * DHM_Y + 86.9 * IOD -145.9 * DCM + 3.73 * DCM_Y
8	SVB = -234.9 + 15.8 * SST_M -7.06 * SST_M_STA -6.4 * CHL_STA -6.26 * SALT + 4.64 * SALT_STA + 0.04 * RF_A + 34.4 * DHM + 2.42 * DHM_Y + 16.7 * IOD + 23.8 * DCM + 0.5 * DCM_Y
9	NM_CPUE = -1652 + 39.8 * SST_M -5.29 * SST_M_STA + 19.04 * CHL_STA + 14.4 * SALT -7.77 * SALT_STA -0.11 * RF_A -19.8 * DHM -5.07 * DHM_Y + 14.2 * IOD + 34.2 * DCM + 0.91 * DCM_Y
10	OBBS_CPUE = -8419 + 287 * SST_M -11.4 * SST_M_STA + 19.4 * CHL_STA -4.04 * SALT + 1.23 * SALT_STA + 0.16 * RF_A -271.3 * DHM -38.4 * DHM_Y + 105.3 * IOD + 307.2 * DCM -0.98 * DCM_Y
11	OBGN_CPUE = 932.6 -44.4 * SST_M -10.4 * SST_M_STA -12.2 * CHL_STA + 14.2 * SALT + 3.8 * SALT_STA + 0.25 * RF_A + 49.4 * DHM + 6.6 * DHM_Y + 19.3 * IOD -41.5 * DCM + 0.15 * DCM_Y
12	OBHL_CPUE = -489 + 16.3 * SST_M -8.1 * SST_M_STA + 3.57 * CHL_STA + 2.76 * SALT -1.82 * SALT_STA -0.06 * RF_A -10.3 * DHM + 5.23 * DHM_Y + 19.2 * IOD + 9.53 * DCM + 1.27 * DCM_Y
13	OBOTHS_CPUE = 6476.5 -141.5 * SST_M + 29.4 * SST_M_STA -26.1 * CHL_STA -64.6 * SALT + 13.02 * SALT_STA -0.5 * RF_A + 279.9 * DHM -154.9 * DHM_Y -181 * IOD -123.4 * DCM + 10.3 * DCM_Y
14	OBRS_CPUE = 36452 -1269.9 * SST_M -121.6 * SST_M_STA -79.6 * CHL_STA + 68.7 * SALT + 94.9 * SALT_STA + 1.34 * RF_A + 259.3 * DHM + 392.9 * DHM_Y + 189.3 * IOD -1268.8 * DCM -6.58 * DCM_Y
15	OBTN_CPUE = -1799.4 + 66.8 * SST_M -0.15 * SST_M_STA + 9.84 * CHL_STA -6.62 * SALT + 3.67 * SALT_STA + 0.10 * RF_A -49.9 * DHM -0.79 * DHM_Y + 65.2 * IOD + 81.9 * DCM + 0.33 * DCM_Y

Ernakulam Fishery

Using this linear regression model, 23%, 16.9% and 15.6% of total catch, CPUE of OBTN and OBOTHS could be explained. For the total monthly catch,SST and DCM contributed 31 and 33% of total variance explained by the regression. The 15.6% variance explained by the regression model for OBOTHS CPUE, 46% contributed by the current magnitude anomaly (Table 6.12). 28.7%, 25.7% and 24.4% of croaker, *Thryssa* and *Stolephorous* catch could be explained. In the variance explained by regression model for croacker fishery, 27 and 28% contributed by SST and DCM. The 28.72% variance expalined by the regression model for the *Stolephorous* fishery, 32 and 35% contributed by SST and DCM. For the *Thryssa* fishery, SST and DCM values contribute 28 and 29% to 25.69% variance explained by the regression model (Table 6.13).

Table 6.12 - Regression model results of Ernakulam district using chlorophyll concentration and total catch as Response(Dependant)variables and SST, LTA, Standardized anomaly of SST, rainfall and Chlorophyll concentration, DHM, DCM, IOD, current direction and current magnitude anomaly as covariate (Independent variables).

Response variable	Chlorophyll concentration	Total catch
variance explained by model	62.97%	23.80%
SST_M	0.31	0.31
LTA_D	0.19	0.14
SST_M_STA	0.02	0.04
CHL_STA	---	0.00
CUR_M_A	0.01	0.00
RF_STA	0.02	0.02
DHM	0.01	0.06
DHM_Y	0.02	0.03
CUR_D	0.02	0.00
IOD	0.01	0.01
DCM	0.32	0.33
DCM_Y	0.07	0.05

Table 6.13 - Regression model results of Ernakulam district using croakers, *Stolephorous* and *Thryssa* catch as Response(Dependant)variables and SST, LTA, Standardized anomaly of SST, rainfall and Chlorophyll concentration, DHM, DCM, IOD, current direction and current magnitude anomaly as covariate (Independent variables).

Response variable	Croakers landing	*Stolephorous* landing	*Thryssa* catch
variance explained by model	28.72%	24.43%	25.69%
SST_M	0.27	0.32	0.28
LTA_D	0.15	0.11	0.22
SST_M_STA	0.04	0.12	0.03
CHL_STA	0.00	0.00	0.07
CUR_M_A	0.05	0.01	0.05
RF_STA	0.09	0.03	0.01
DHM	0.01	0.03	0.01
DHM_Y	0.02	0.01	0.00
CUR_D	0.04	0.01	0.01
IOD	0.04	0.01	0.01
DCM	0.28	0.35	0.29
DCM_Y	0.01	0.01	0.01

Table 6.14 - Multiple linear regression equations for the response variables in the coast of Ernakulam

MODEL NO:	REGRESSION EQUATION
1	CHL = -66.1 + 2.2 * SST_M + 0.31 * LTA_D -0.1 * SST_M_STA -0.0003 * CUR_M_A + 7.14 * RF_STA -2.09 * DHM + 0.15 * DHM_Y -0.0014 * CUR_D + 0.2 * IOD + 2.7 * DCM + 0.02 * DCM_Y
2	NM_CPUE = 521 -16.6 * SST_M -5.02 * LTA_D -0.2 * SST_M_STA + 0.6 * CHL_STA -0.02 * CUR_M_A -0.5 * RF_STA + 10.8 * DHM -3.96 * DHM_Y -0.02 * CUR_D -0.16 * IOD -16.4 * DCM -0.01 * DCM_Y
3	OBGN_CPUE = 11190 -369.5 * SST_M + 20.3 * LTA_D -5.97 * SST_M_STA + 10.5 * CHL_STA -0.03 * CUR_M_A + 14.5 * RF_STA + 318 * DHM -17.4 * DHM_Y + 27 * CUR_D + 6.8 * IOD -369 * DCM -0.35 * DCM_Y
4	OBHL_CPUE = -1087 + 39.8 * SST_M -43 * LTA_D + 32 * SST_M_STA -10.07 * CHL_STA + 0.2 * CUR_M_A -1.16 * RF_STA + 125 * DHM -89.4 * DHM_Y + 0.1 * CUR_D -168 * IOD + 52.3 * DCM + 5.6 * DCM_Y
5	OBOTHS_CPUE = -54850 + 1826 * SST_M + 86.6 * LTA_D + 65.5 * SST_M_STA -110 * CHL_STA + 1.65 * CUR_M_A -26 * RF_STA -1241 * DHM -67 * DHM_Y + 0.63 * CUR_D -5.29 * IOD + 1884 * DCM + 5.4 * DCM_Y
6	OBRS_CPUE = -5154 + 196 * SST_M -168 * LTA_D -49.5 * SST_M_STA + 106 * CHL_STA -0.21 * CUR_M_A + 11.9 * RF_STA -253 * DHM -92 * DHM_Y + 0.1 * CUR_D + 157.6 * IOD + 252 * DCM -1.9 * DCM_Y
7	OBTN_CPUE = 2858 -94 * SST_M -22.5 * LTA_D -2.96 * SST_M_STA + 3.6 * CHL_STA + 0.01 * CUR_M_A -1.5 * RF_STA + 105.6 * DHM -4.6 * DHM_Y + 0.06 * CUR_D -2.05 * IOD -91.6 * DCM -2.4 * DCM_Y
8	TOT = -94850 + 3173 * SST_M + 126 * LTA_D + 135 * SST_M_STA -4.99 * CHL_STA -0.4 * CUR_M_A -64.5 * RF_STA -3106 * DHM -233 * DHM_Y + 0.12 * CUR_D -229 * IOD + 3515 * DCM + 16.27 * DCM_Y
9	OS = -10500 + 357 * SST_M -96 * LTA_D -31 * SST_M_STA + 1.05 * CHL_STA -0.14 * CUR_M_A -4.3 * RF_STA -387 * DHM -138 * DHM_Y + 0.29 * CUR_D -33.8 * IOD + 364 * DCM + 9.05 * DCM_Y
10	STL = -36070 + 1199 * SST_M + 24.2 * LTA_D + 117 * SST_M_STA -4.02 * CHL_STA + 0.32 * CUR_M_A -38.8 * RF_STA -1182 * DHM -1.75 * DHM_Y -0.34 * CUR_D -70.96 * IOD + 1415 * DCM -0.66 * DCM_Y
11	IM = -26130 + 871 * SST_M -32.7 * LTA_D + 6.4 * SST_M_STA + 24.1 * CHL_STA + 0.05 * CUR_M_A + 7.8 * RF_STA -955 * DHM + 25 * DHM_Y -0.11 * CUR_D + 42.9 * IOD + 873 * DCM + 4.7 * DCM_Y
12	PP = -8770 + 295 * SST_M + 78 * LTA_D + 12.6 * SST_M_STA -3.87 * CHL_STA -430.6 * CUR_M_A -1.01 * RF_STA -174 * DHM -43.5 * DHM_Y -0.08 * CUR_D -96 * IOD + 344 * DCM -2.95 * DCM_Y
13	CKS = -1394 + 45.6 * SST_M + 20 * LTA_D + 10 * SST_M_STA -1.7 * CHL_STA -0.08 * CUR_M_A -12 * RF_STA -8.5 * DHM -19.3 * DHM_Y + 10.3 * CUR_D + 24 * IOD + 75 * DCM + 0.25 * DCM_Y
14	THR = 410.6 -13.3 * SST_M + 15.7 * LTA_D + 4.5 * SST_M_STA -7.6 * CHL_STA -0.05 * CUR_M_A + 2.25 * RF_STA + 8.9 * DHM -4.8 * DHM_Y -0.04 * CUR_D -11.2 * IOD + 1.5 * DCM -0.26 * DCM_Y

Using Regression model, 23.3% and 23.7% of total catch and OBGN CPUE could be explained. The 23.3% variance explained by the regression for total catch, 17% influenced by SST. 23.7% variance explained byregression model for CPUE of OBGN, 23 and 24% influenced by IOD and SST standardized anomaly (Table 6.15). 35.14% of penaeid prawn and 19.5% of *Thryssa* catch could be explained by this multiple linear regression. Out of 35.14% variance explained by penaeid prawn landing, SST and DCM influence 29 and 30% respectively. For the *Thryssa* landing, 19.46% variance could be explained by the regression model, out of which, 17% contributed by IOD index (Table 6.16).

Table 6.15 - Regression model results of Alappuzha district using chlorophyll concentration, total catch and CPUE of OBGN gear as Response(Dependant)variables and SST, Standardized anomaly of SST, rainfall and current velocity, Chlorophyll anomaly, DHM, DCM, IOD, current direction as covariate (Independent variables).

Response variable	Chlorophyll concentration	CPUE of OBGN	Total catch
Variance explained by model	70.55%	23.78%	23.31%
SST_M	0.43	0.09	0.17
SST_M_STA	0.03	0.24	0.01
CHL_A	---	0.17	0.02
CUR_M_STA	0.00	0.00	0.02
RF_STA	0.01	0.03	0.02
DHM	0.02	0.02	0.05
DHM_Y	0.02	0.01	0.06
CUR_D	0.00	0.00	0.05
IOD	0.00	0.23	0.00
DCM	0.45	0.08	0.16
DCM_Y	0.04	0.14	0.44

Table 6.16 - Regression model results of Alappuzha district using the catch of Penaeid prawns and *Thryssa* as Response (Dependant) variables and SST, Standardized anomaly of SST, rainfall and current velocity, Chlorophyll anomaly, DHM, DCM, IOD, current direction as covariate (Independent variables).

Response variable	Penaeid prawns catch	*Thryssa* landing
variance explained by model	35.14%	19.46%
SST_M	0.29	0.11
SST_M_STA	0.04	0.16
CHL_A	0.02	0.06
CUR_M_STA	0.00	0.00
RF_STA	0.01	0.00
DHM	0.01	0.02
DHM_Y	0.08	0.18
CUR_D	0.17	0.12
IOD	0.01	0.17
DCM	0.30	0.11
DCM_Y	0.06	0.07

Table 6.17 - Multiple linear regression equations for the response variables in the coast of Alappuzha

Model No:	REGRESSION EQUATION
1	CHL = -68.2 + 2.27 * SST_M + 0.18 * SST_M_STA + 0.01 * CUR_M_STA -0.014 * RF_STA -1.8 * DHM + 0.13 * DHM_Y -0.0004 * CUR_D + 0.03 * IOD + 3.14 * DCM + 0.01 * DCM_Y
2	NM_CPUE = -1542 + 52.5 * SST_M + 1.8 * SST_M_STA -0.02 * CHL_A + 2.8 * CUR_M_STA -0.99 * RF_STA - 69.96 * DHM + 0.13 * DHM_Y -0.02 * CUR_D -13.9 * IOD + 53.6 * DCM -0.04 * DCM_Y
3	OBGN_CPUE = 6078.8 -201.6 * SST_M + 23.02 * SST_M_STA -0.52 * CHL_A -1.6 * CUR_M_STA -6.78 * RF_STA + 137.3 * DHM + 2.5 * DHM_Y -0.04 * CUR_D + 63.96 * IOD -184.4 * DCM + 2.4 * DCM_Y
4	OBHL_CPUE = -629.4 + 21.2 * SST_M + 4.8 * SST_M_STA -0.02 * CHL_A + 17.87 * CUR_M_STA -2.18 * RF_STA + 5.8 * DHM -7.4 * DHM_Y -0.05 * CUR_D + 27.3 * IOD + 26.26 * DCM + 0.49 * DCM_Y
5	OBRS_CPUE = -1418.7 + 71.2 * SST_M -11.4 * SST_M_STA + 0.8 * CHL_A + 29.9 * CUR_M_STA + 30.1 * RF_STA + 347.9 * DHM + 102.3 * DHM_Y -0.54 * CUR_D + 135.4 * IOD + 96.5 * DCM + 11.7 * DCM_Y
6	OBTN_CPUE = 4899 -161 * SST_M -0.91 * SST_M_STA + 0.001 * CHL_A + 3.24 * CUR_M_STA -4.02 * RF_STA + 119.5 * DHM +5.27 * DHM_Y -0.09 * CUR_D + 10.3 * IOD -172.7 * DCM -0.35 * DCM_Y
7	TOT = 243423 -8009.7 * SST_M + 321 * SST_M_STA -13.9 * CHL_A -346.5 * CUR_M_STA -227 * RF_STA + 4272 * DHM + 816 * DHM_Y -10.16 * CUR_D -729.2 * IOD -7038 * DCM + 273 * DCM_Y
8	OS = 139800 -4616 * SST_M -879 * SST_M_STA -7.2 * CHL_A -394 * CUR_M_STA + 520.6 * RF_STA + 5378 * DHM + 272.7 * DHM_Y + 0.13 * CUR_D + 189 * IOD -5065 * DCM + 226 * DCM_Y
9	STL = 67521 -2234 * SST_M + 601 * SST_M_STA + 0.94 * CHL_A -233 * CUR_M_STA -135 * RF_STA + 1197 * DHM + 195 * DHM_Y -4.97 * CUR_D + 131 * IOD -1452 * DCM + 22.2 * DCM_Y
10	IM = 12104 -401 * SST_M + 14.6 * SST_M_STA -1.7 * CHL_A + 35 * CUR_M_STA -15.94 * RF_STA -350 * DHM + 390.5 * DHM_Y -0.96 * CUR_D + 381 * IOD -347 * DCM + 32.96 * DCM_Y
11	PP= 9448 -307.7 * SST_M + 62 * SST_M_STA + 1.07 * CHL_A + 6.75 * CUR_M_STA -13.3 * RF_STA + 135.6 * DHM + 87.5 * DHM_Y -1.14 * CUR_D + 15.5 * IOD -143 * DCM -9.9 * DCM_Y
12	OTS = 12600 -416 * SST_M -12.9 * SST_M_STA -0.21 * CHL_A + 8.18 * CUR_M_STA -32 * RF_STA + 400 * DHM + 16.1 * DHM_Y -0.06 * CUR_D -117.4 * IOD -494 * DCM + 17.2 * DCM_Y
13	THR = 6795 -223.2 * SST_M + 42.5 * SST_M_STA -0.62 * CHL_A + 5.7 * CUR_M_STA + 3.8 * RF_STA + 88 * DHM + 44.6 * DHM_Y -0.36 * CUR_D -148.7 * IOD -187 * DCM + 3.57 * DCM_Y

Kerala Fishery

Coefficient of determination(R^2) value for the total catch, CPUE of OBGN and OBTN was 46.69, 55 and 36.39% respectively. 46.69% variance explained by the regression model for the total catch, SST and DCM contribute 19 and 17%. In the 55% variance explained by the regression model for OBGN –CPUE, 19% was contributed by LTA. For the variance explained by regression model for OBTN CPUE, Chlorophyll Standardized anomaly contribute 31% (Table 6.18). 44.37, 32.4 and 31.4% of penaeid prawn, Stolephorous and oil sardine catch could be explained.The 44.37% variance explained by the regression model for penaeid prawn catch, 18% contributed by chlorophyll concentration. Out of the 32.35% variance explained by the regression model for *Stolephorous* fishery, 35% contributed by chlorophyll concentration. 31.39% variance explained by regression model for oil sardine catch, 23% contributed by the standardized anomaly of sea surface current velocity. 20.9% variance explained by regression model, 27% contributed by the LTA index (Table 6.19).

Table 6.18 - Regression model results of Kerala district using chlorophyll concentration, total catch, CPUE of NM, OBGN and OBTN gears as Response(Dependant)variables and SST, chlorophyll concentration, LTA, Standardized anomaly of current velocity, rainfall and chlorophyll concentration, DHM, DCM, anomalies of SST, salinity and current direction as covariate (Independent variables)

Response variable	Chlorophyll concentration	Total catch	CPUE of NM	CPUE of OBGN	CPUE of OBTN
Variance explained by model	82.43%	46.69%	26.02%	55.4%	36.39%
SST_M	0.29	0.19	0.09	0.15	0.14
CHL	---	0.11	0.17	0.14	0.18
LTA_M	0.30	0.07	0.07	0.19	0.11
SST_M_A	0.02	0.01	0.05	0.04	0.02
CUR_M_STA	0.01	0.13	0.00	0.01	0.00
SALT_A	0.02	0.00	0.03	0.01	0.07
RF_STA	0.01	0.00	0.02	0.01	0.01
DHM	0.01	0.04	0.03	0.01	0.01
CUR_D_A	0.01	0.05	0.04	0.01	0.02
CHL_STA	---	0.01	0.12	0.16	0.31
DCM	0.30	0.17	0.08	0.15	0.14
DCM_Y	0.03	0.22	0.28	0.13	0.01

Table 6.19 - Regression model results of Kerala district using landings of Penaeid prawns, stolephorous, oil sardine, Indian mackerel and scads as Response(Dependant)variables and SST, chlorophyll concentration, LTA, Standardized anomaly of current velocity, rainfall and chlorophyll concentration, DHM, DCM, anomalies of SST, salinity and current direction as covariate (Independent variables)

Response variable	Penaeid prawns catch	*Stolephorous* catch	Oil sardines landing	Indian mackerel landing	Scads catch
variance explained by model	44.37%	32.35%	31.39%	21.84%	20.90%
SST_M	0.16	0.13	0.08	0.07	0.19
CHL	0.18	0.25	0.03	0.07	0.17
LTA_M	0.14	0.10	0.12	0.11	0.27
SST_M_A	0.01	0.08	0.05	0.02	0.05
CUR_M_STA	0.00	0.03	0.23	0.07	0.01
SALT_A	0.04	0.05	0.00	0.01	0.01
RF_STA	0.03	0.05	0.01	0.04	0.03
DHM	0.01	0.01	0.04	0.02	0.01
CUR_D_A	0.01	0.02	0.04	0.17	0.03
CHL_STA	0.17	0.14	0.08	0.02	0.02
DCM	0.16	0.13	0.07	0.07	0.20
DCM_Y	0.09	0.01	0.25	0.33	0.01

Table 6.20 - Multiple linear regression equations for the response variables in the coast of Kerala

Model No:	REGRESSION EQUATION
1	CHL= -39.2 + 1.3 * SST_M + 0.83 * LTA_M + 0.06 * SST_M_A -0.07 * CUR_M_STA + 0.07 * SALT_A + 0.097 * RF_STA - 1.12 * DHM -0.003 * CUR_D_A + 1.78 * DCM + 0.009 * DCM_Y
2	TOT = 605334 -20003.5 * SST_M + 532.45 * CHL -5178.07 * LTA_M + 161.3 * SST_M_A -2686.3 * CUR_M_STA -92.2 * SALT_A -680.3 * RF_STA + 12163 * DHM -78.6 * CUR_D_A + 140.52 * CHL_STA -14602.66 * DCM + 560.6 * DCM_Y
3	NM_CPUE = 237.1 -7.26 * SST_M + 2.2 * CHL -0.72 * LTA_M + 0.27 * SST_M_A + 0.12 * CUR_M_STA + 0.24 * SALT_A + 0.46 * RF_STA + 1.6 * DHM-0.05 * CUR_D_A -1.05 * CHL_STA -7.4 * DCM + 0.33 * DCM_Y
4	OBBS_CPUE = -57.77 + 8.98 * SST_M -47.25 * CHL + 4.86 * LTA_M + 3.5 * SST_M_A + 29.14 * CUR_M_STA + 19.2 * SALT_A -18.1 * RF_STA -123.02 * DHM -1.15 * CUR_D_A + 10.46 * CHL_STA + 55.8 * DCM + 0.46 * DCM_Y
5	OBGN_CPUE = 1929.6 -62.8 * SST_M -0.26 * CHL + 19.88 * LTA_M + 2.36 * SST_M_A + 1.64 * CUR_M_STA + 0.99 * SALT_A + 2.9 * RF_STA + 47.42 * DHM -0.12 * CUR_D_A -5.52 * CHL_STA -55.87 * DCM + 1.28 * DCM_Y
6	OBHL_CPUE = -191.5 + 8.96 * SST_M -6.1 * CHL + 14.9 * LTA_M + 3.5 * SST_M_A -0.5 * CUR_M_STA -1.45 * SALT_A + 2.06 * RF_STA -4.4 * DHM + 0.12 * CUR_D_A -1.56 * CHL_STA + 15.56 * DCM -0.22 * DCM_Y
7	OBOTHS_CPUE = -87743.8 + 2950.3 * SST_M -580.89 * CHL + 636.3 * LTA_M + 61.3 * SST_M_A + 48.05 * CUR_M_STA -16.13 * SALT_A + 95.03 * RF_STA -2660.37 * DHM -2.49 * CUR_D_A -33.43 * CHL_STA + 3217.15 * DCM + 2.56 * DCM_Y
8	OBRS_CPUE = 26005.48 -835.22 * SST_M -77.47 * CHL + 14.8 * LTA_M -19.6 * SST_M_A -87.98 * CUR_M_STA + 43.18 * SALT_A + 47.6 *RF_STA + 725.4 * DHM-2.99 * CUR_D_A + 33.69 * CHL_STA -781.49 * DCM + 2.98 * DCM_Y
9	OBSS_CPUE = 269.9 -9.17 * SST_M + 6.15 * CHL -3.42 * LTA_M + 2.23 * SST_M_A -0.34 * CUR_M_STA -0.25 * SALT_A + 0.65 * RF_STA + 15.37 * DHM + 0.04 * CUR_D_A + 0.85 * CHL_STA -8.87 * DCM + 0.02 * DCM_Y
10	OBTN_CPUE = 35.97 + 0.0003 * SST_M + 32.9 * CHL -29.2 * LTA_M -2.7 * SST_M_A -2.01 * CUR_M_STA + 8.4 * SALT_A -4.8 * RF_STA -19.25 * DHM + 0.35 * CUR_D_A -21.5 * CHL_STA + 14.05 * DCM -0.8 * DCM_Y
11	OS = 471560.5 - 15658.9 * SST_M -782.5 * CHL -6064.45 * LTA_M -460.4 * SST_M_A -2097.8 * CUR_M_STA -126.35 * SALT_A + 9.8 * RF_STA + 11959.5 * DHM -40.8 *CUR_D_A + 513.16 * CHL_STA -12691.99 * DCM + 375.8 * DCM_Y
12	STL = 64164.09 - 2153.59 * SST_M + 1497 * CHL -1577.4 * LTA_M + 250.6 * SST_M_A -242.66 * CUR_M_STA + 213.09 * SALT_A -463.5 * RF_STA + 354.4 * DHM -4.28 * CUR_D_A -410.6 * CHL_STA -1612.5 * DCM -6.7 * DCM_Y
13	IM = 7758.68 -218 * SST_M -724.26 * CHL + 1660.5 * LTA_M + 152.8 * SST_M_A -295.76 * CUR_M_STA -48.8 * SALT_A + 264.4 * RF_STA -966.7 * DHM -22.97 * CUR_D_A + 155 * CHL_STA + 146.14 * DCM + 96.8 * DCM_Y
14	PP = -4350.3 + 151.4 * SST_M + 373 * CHL -134 * LTA_M -39.9 * ST_M_A -5.17 * CUR_M_STA + 80.8 * SALT_A -100 * RF_STA -312.5 * DHM -1.3 * CUR_D_A -192.87 * CHL_STA + 380.8 * DCM -39.3 * DCM_Y
15	OTS = -20272.5 + 693 * SST_M -277 * CHL -212 * LTA_M + 18.3 * SST_M_A + 77.7 * CUR_M_STA + 10.67 * SALT_A - 89.3 * RF_STA -165.2 * DHM -1.5 * CUR_D_A + 1.01 * CHL_STA + 777.9 * DCM + 37.15 * DCM_Y
16	SC = -19759 + 661 * SST_M -119.67 * CHL + 958.6 * LTA_M + 140.7 * SST_M_A -88.3 * CUR_M_STA -36.9 * SALT_A - 85.6 * RF_STA -854.1 * DHM -4.4 * CUR_D_A + 66.6 * CHL_STA + 1057.8 * DCM -1.05 * DCM_Y

6.2 TAMILNADU

Correlation Analysis

Total catch and Environmental variables

In Chennai, a moderate positive correlation (0.41) was found between the total catch and SST ($p<0.001$). Total catch showed a weak positive correlation with MEI (0.2) ($p<0.05$), Standardized anomaly of SST (0.23) ($p<0.001$) and chlorophyll (0.24) ($p<0.001$).DCM showed a moderate negative correlation (-0.4) with total landings ($p<0.001$) (Table 6.21).

In Thanjavur coastal zone, total catch showed a weak positive correlation with chlorophyll (0.21) ($p<0.05$) and its Standardized anomaly (0.32) ($p<0.001$). A weak negative correlation (-0.25) was found between the total catch and Standardized anomaly of rainfall ($p<0.01$) (Table 6.24).

In Thirunelveli district, total catch showed a weak negative correlation (-0.2) with LTA and the correlation was significant ($p<0.05$) (Table 6.27).

In Tuticorin, a weak positive correlation (0.37) was found between the rainfall and total landings ($p<0.001$) (Table 6.28).

Overall in Tamil Nadu state, total catch showed a weak positive correlation (0.25) with salinity ($p<0.01$) (Table 6.29).

Catch per unit effort of Non-motorized craft and Environmental variables

In Tuticorin coast, CPUE of NM crafts showed a weak negative and positive correlation (0.2) with SST and DCM ($p<0.05$) respectively (Table 6.28).

Catch per unit effort of OBBN craft and Environmental variables

In Chennai, a weak positive correlation (0.2) was found between the SST and OBBN-CPUE ($p<0.05$) (Table 6.21).

A weak positive correlation (0.2) was noted between rainfall and CPUE of OBBN in the Cuddalore district ($p<0.05$) (Table 6.22).

In Thiruvallur coast, OBBN-CPUE showed a moderate positive correlation (0.54) with chlorophyll concentration ($p<0.001$) (Table 6.25).

A weak positive correlation (0.25) was observed between the OBBN-CPUE and LTA ($p<0.01$) in the Kanyakumari district (Table 6.26).

Catch per unit effort of OBGN and Environmental variables

In Thiruvallur district, a weak positive correlation (0.26) was found between the CPUE of OBGN and IOD ($p<0.01$) (Table 6.25).

OBGN-CPUE shows a weak positive correlation (0.24) with sea surface salinity ($p<0.01$) in Kanyakumari coast (Table 6.26).

In Tuticorin, OBGN-CPUE shows a weak positive correlation (0.23) with rainfall ($p<0.01$) (Table 6.28).

In general along Tamil Nadu coast, a weak positive correlation (0.31) is found between the rainfall and CPUE of OBGN ($p<0.001$) (Table 6.29).

Catch per unit effort of OBHL and Environmental variables

A weak positive correlation (0.2) was found between SST and OBHL-CPUE in Chennai coast ($p<0.05$) (Table 6.21).

In Cuddalore, CPUE of OBHL craft showed a weak positive correlation (0.22) with IOD ($p<0.01$) (Table 6.22).

In Thiruvallur district, CPUE of OBHL craft shows a weak positive correlation (0.29) with IOD and the correlation is significant ($p<0.001$) (Table 6.25).

A weak negative correlation (-0.24) is exist between the salinity and OBHL-CPUE ($p<0.01$) in the Kanyakumari district (Table 6.26).

In Thirunelveli, a weak negative correlation (-0.36) was observed between the LTA and OBHL-CPUE ($p<0.001$) (Table 6.27).

In Tuticorin district, CPUE of OBHL showed a weak positive correlation (0.23) with rainfall and its Standardized anomaly ($p<0.01$). A weak negative correlation (-0.21) was found between the chlorophyll concentration and OBHL-CPUE ($p<0.05$) (Table 6.28).

In general in Tamil Nadu state, a weak negative correlation (-0.2) was found between the chlorophyll concentration and OBHL-CPUE ($p<0.05$) (Table 6.29).

Catch per unit effort of OBTN and Environmental variables

In Cuddalore, a weak positive correlation (0.37) was found between chlorophyll anomaly and OBTN-CPUE ($p<0.001$) (Table 6.22).

Catch per unit effort of OBRS and Environmental variables

In Cuddalore district, OBRS-CPUE showed a weak positive correlation (0.21) with Standardized anomaly of SST ($p<0.05$) (Table 6.22).

A weak negative correlation (-0.22) was found between the CPUE of OBRS and LTA ($p<0.05$) in Thirunelveli coast (Table 6.27).

In Tamil Nadu in general, OBRS-CPUE showed a weak positive correlation with chlorophyll (0.26) and salinity (0.28) ($p<0.01$) (Table 6.29).

Catch per unit effort of OBPS and Environmental variables

In Thiruvallur, CPUE of OBPS showed a weak positive correlation (0.25) with LTA ($p<0.01$) (Table 6.25).

In Thirunelveli coast, CPUE of OBPS showed a weak positive correlation with rainfall Standardized anomaly (0.2) ($p<0.05$) and anomaly of current velocity (0.23) ($p<0.01$) (Table 6.27).

A weak positive correlation (0.23) was found between the CPUE of OBPS and rainfall in Tuticorin ($p<0.01$) (Table 6.28).

In Tamil Nadu coast, a weak positive correlation (0.22) was found between the CPUE of OBPS and chlorophyll anomaly ($p<0.05$) (Table 6.29).

Oil sardine fishery and Environmental variables

In Chennai, oil sardine fishery showed a weak positive correlation with SST (0.31) ($p<0.001$) and its Standardized anomaly (0.23) ($p<0.01$). A weak negative correlation was found between the DCM and oil sardine landing ($p<0.001$) (Table 6.21).

In Tuticorin, rainfall showed a weak positive correlation (0.2) with oil sardine catch ($p<0.05$) (Table 6.28).

The catch of oil sardine showed a weak positive correlation with chlorophyll concentration (0.22) and sea surface salinity (0.27) ($p<0.01$) in Tamil Nadu coast (Table 6.29).

Other sardine fishery and Environmental variables

In Tuticorin, other sardine fishery showed a weak positive correlation with rainfall (0.25) and DCM (0.27) ($p<0.01$). Other sardine catch showed a weak negative correlation with SST (-0.27) ($p<0.01$) and its anomaly (-0.2) ($p<0.05$) (Table 6.28).

Indian mackerel fishery and Environmental variables

In Chennai, a weak positive correlation (0.23) was found between the Indian mackerel fishery and Standardized anomaly of rainfall ($p<0.01$) (Table 6.21).

Mullet fishery and Environmental variables

In Chennai, a weak positive correlation (0.22) was found between the mullet fishery and chlorophyll Standardized anomaly ($p<0.05$) (Table 6.21).

Crab fishery and Environmental variables

In Kancheepuram, crab fishery showed a weak negative (-0.22) correlation with IOD ($p<0.05$) (Table 6.23).

In Thiruvallur, crab fishery showed a weak positive correlation with MEI (0.2), SST (0.2) ($p<0.05$) and its anomaly (0.23) ($p<0.01$) (Table 6.25).

A weak negative correlation was found between the chlorophyll Standardized anomaly (-0.23) ($p<0.01$) in Tuticorin coast (Table 6.28).

Silver belly fishery and Environmental variables

In Cuddalore, salinity (0.2) ($p<0.05$), IOD (0.26) ($p<0.01$) and current direction anomaly (0.29) ($p<0.001$) showed a weak positive correlation with silver bellies landing (Table 6.22).

In Tuticorin, a weak positive correlation (0.2) was found between the rainfall and silver bellies catch ($p<0.05$) (Table 6.28).

Thryssa fishery and Environmental variables

In Cuddalore, *Thryssa* landing showed a weak positive correlation with IOD (0.21) and Standardized anomaly of SST (0.22) ($p<0.05$) (Table 6.22).

In Tuticorin, a weak positive correlation (0.29) found between the chlorophyll Standardized anomaly and *Thryssa* catch ($p<0.001$) (Table 6.28).

Croaker fishery and Environmental variables

In Kancheepuram, a weak negative correlation (-0.21) was found between the rainfall and croaker landing ($p<0.05$) (Table 6.23).

Croaker fishery shows a weak positive correlation (0.3) with chlorophyll Standardized anomaly and the correlation is significant ($p<0.001$) in Thanjavur district (Table 6.24).

In Thirunelveli, croaker fishery showed a weak positive correlation (0.22) with chlorophyll Standardized anomaly and DCM ($p<0.05$). Croaker landing showed a weak negative correlation with SST (-0.21) ($p<0.05$) and its Standardized anomaly (-0.24) ($p<0.01$) (Table 6.27).

Catfish fishery and Environmental variables

In Thiruvallur, a weak positive correlation (0.27) was found between the catfish landing and IOD ($p<0.01$) (Table 6.25).

Ray fishery and Environmental variables

In Thanjavur, a weak positive correlation (0.29) was found between the chlorophyll Standardized anomaly and catch of rays ($p<0.001$) and a weak negative correlation (-0.23) was found between the ray landing and rainfall Standardized anomaly ($p<0.01$) (Table 6.24).

Stolephorous fishery and Environmental variables

In Kanyakumari, a weak positive correlation (0.24) was found between the *Stolephorous* fishery and salinity ($p<0.01$). *Stolephorous* catch showed a weak negative correlation (-0.23) with SLA ($P<0.01$) (Table 6.26).

In Tamil Nadu, *Stolephorous* catch showed a weak positive correlation with chlorophyll (0.22) and salinity (0.27) ($p<0.01$) (Table 6.29).

Pigface breams fishery and Environmental variables

In Tuticorin, a weak negative correlation (-0.23) was found between chlorophyll concentration and pigface bream catch ($p<0.01$) (Table 6.28).

Table 6.21 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Chennai district and CPUE of NM, OBBN, OBGN, OBHL, Total catch and the landings of oil sardine, Indian mackerel, mullet.

	TOT	NM_CPUE	OBBN_CPUE	OBGN_CPUE	OBHL_CPUE	OS	IM	MLT
SST_M	0.41***	-0.02	0.20*	0.12	0.20*	0.31***	0.13	0.13
SST_M_STA	0.23**	-0.07	0.09	0.06	0.19*	0.23**	0.06	0.07
CHL_STA	0.24**	-0.08	0.18*	0.06	0.15	0.13	0.12	0.22*
RF_STA	0.08	0.01	0.09	0.09	-0.01	-0.02	0.23**	0.07
LTA_M	-0.18*	-0.04	-0.03	-0.11	-0.19*	-0.15	0.16	0.01
MEI	0.20*	0.07	0.15	0.13	0.09	0.1	0.09	0.09
DCM	-0.40***	0.02	-0.19*	-0.12	-0.19*	-0.29***	-0.13	-0.12

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_STA – Sea surface temperature standardized anomaly, CHL_STA – Chlorophyll concentration standardized anomaly, RF_STA – Rainfall standardized anomaly, LTA_M –Monthly mean Local Temperature Anomaly, MEI – Multivariate ENSO index, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBBN_CPUE – Catch per unit effort of Out Board Bag Net, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OS – Oil sardine landing, IM – Indian mackerel landing, MLT – Mullet catch

Table 6.22 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Cuddalore district and CPUE of OBBN, OBGN, OBHL, OBRS and OBTN, Total catch and the landings of *Thryssa* and silver bellies.

	TOT	OBBN_CPUE	OBGN_CPUE	OBHL_CPUE	OBRS_CPUE	OBTN_CPUE	THR	SVB
SST_M_STA	0.01	0.13	-0.01	0.1	0.21*	-0.07	0.22*	-0.06
CHL_A	-0.17	0.07	-0.17	-0.14	-0.11	0.37***	-0.17*	0.01
RF	-0.14	0.20*	-0.04	-0.02	-0.12	0.14	-0.11	0
SALT	0.13	0.03	0.1	0.1	-0.02	-0.18*	0.06	0.20*
CUR_D_A	0.14	-0.1	0.19*	0.02	-0.08	-0.02	-0.03	0.29***
IOD	0.12	0.11	0.14	0.22**	-0.02	-0.1	0.21*	0.26**
DCM	0.13	-0.17*	0.05	0.1	0.07	0	-0.06	0.13

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_STA – Sea surface temperature standardized anomaly, CHL_A – Chlorophyll concentration anomaly, RF – Rainfall, SALT – Sea surface salinity, CUR_D_A – Current direction anomaly, IOD – Indian Ocean Dipole Index, DCM - Degree Cooling Month, IOD – Indian Ocean Dipole index, TOT – Total catch, OBBN_CPUE – Catch per unit effort of Out Board Bag Net, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, OBTN_CPUE – Catch per unit effort of Out Board Trawl net, SVB – Silverbellies catch, THR – *Thryssa* landing

Table 6.23 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Kancheepuram district and CPUE of NM, OBGN, OBHL, OBRS, Total catch and the landings of crabs, silver bellies and croakers.

	TOT	NM_CPUE	OBGN_CPUE	OBHL_CPUE	OBRS_CPUE	CRB	SVB	CKS
SST_M	0.1	-0.01	0.06	0.1	0.09	0.08	-0.06	0.01
CHL	0	-0.15	-0.06	-0.03	0	-0.07	0.03	0.06
RF	-0.01	-0.19*	-0.09	-0.09	-0.06	-0.03	-0.18*	-0.21*
RF_A	-0.06	-0.08	-0.06	-0.07	-0.04	-0.07	-0.05	-0.12
SLA	-0.15	0.11	-0.13	-0.01	-0.05	0.08	-0.13	-0.01
SALT	0.12	-0.02	0.04	0	0.12	0.03	-0.08	0.16
SALT_A	0	0	-0.04	-0.14	0.04	-0.11	-0.16	0.03
LTA_M	-0.15	-0.02	-0.16	-0.14	0.03	-0.07	-0.03	-0.07
CUR_M_STA	-0.11	0.02	-0.07	0.06	-0.11	0.05	-0.01	0.02
CUR_D	0.04	0.13	0.11	0.13	0.09	-0.12	-0.07	-0.08
IOD	-0.03	-0.01	-0.02	-0.06	-0.18*	-0.22*	0.11	-0.1
DCM	-0.1	0.01	-0.06	-0.1	-0.09	-0.07	0.06	-0.01

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL – Chlorophyll concentration, RF_A – Rainfall anomaly, RF – Rainfall, SLA – Sea level anomaly, SALT – Sea surface salinity, SALT_A – Sea surface salinity anomaly, LTA_M – Local temperature anomaly, CUR_M_STA – Current magnitude standardized anomaly, CUR_D – Current direction, IOD – Indian Ocean Dipole Index, , DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, CRB – Crab landing, SVB – Silverbellies catch, CKS – Croakers catch

Table 6.24 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Thanjavur district and CPUE of OBGN, OBHL, and OBTN, Total catch and the landings of crabs, croakers, rays.

	TOT	OBGN_CPUE	OBHL_CPUE	OBTN_CPUE	CRB	CKS	RS
SST_M	-0.02	-0.05	0.14	-0.03	0.12	-0.01	-0.01
CHL	0.21*	0.03	0.17	-0.11	0.18*	0.1	0.1
CHL_STA	0.32***	0.15	0.09	-0.19*	0	0.30***	0.29***
RF_STA	-0.25**	-0.07	-0.01	0.01	-0.03	-0.18*	-0.23**
LTA_M	0.02	0.02	-0.06	-0.04	-0.06	0.02	0.06

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL – Chlorophyll concentration, CHL_STA – Chlorophyll concentration standardized anomaly, RF_STA – Rainfall standardized anomaly, LTA_M – Local temperature anomaly, IOD – Indian Ocean Dipole

Index, MEI – Multivariate ENSO index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBTN_CPUE – Catch per unit effort of Out Board Trawl net, CRB – Crab landing, CKS – Croakers catch, RS – Rays catch

Table 6.25 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Thiruvallur district and CPUE of NM, OBBN, OBGN, OBHL, OBPS, Total catch and the landings of crabs, catfish and *Thryssa*.

	TOT	NM_CPUE	OBBN_CPUE	OBGN_CPUE	OBHL_CPUE	OBPS_CPUE	CRB	CF	THR
SST_M	0.06	0.17*	0.01	0.07	0.02	0.09	0.20*	0.05	-0.03
SST_M_A	-0.14	0.18*	-0.17	-0.09	-0.1	0.06	0.23**	-0.01	0.13
CHL	0.06	-0.15	0.54***	0.14	0.09	0.02	-0.15	0.03	-0.18*
RF_A	-0.04	0	0.02	0.13	-0.07	0.03	-0.04	0	-0.06
LTA_M	0.01	-0.09	0.05	-0.02	0.11	0.25**	-0.14	-0.09	-0.05
MEI	0.16	0.17	-0.04	0.13	0.13	-0.01	0.20*	0.08	0.16
IOD	0.08	-0.15	0.04	0.26**	0.29***	-0.07	-0.03	0.27**	-0.08
DHM	-0.04	0.16	-0.03	-0.01	-0.08	-0.02	0.08	-0.03	0.01
DCM	-0.07	-0.15	-0.02	-0.08	-0.02	-0.11	-0.19*	-0.07	0.03

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_A – Sea surface temperature anomaly, CHL – Chlorophyll concentration, RF_A – Rainfall anomaly, LTA_M – Local temperature anomaly, IOD – Indian Ocean Dipole Index, MEI – Multivariate ENSO index, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBBN_CPUE – Catch per unit effort of Out Board Bag Net, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBPS_CPUE – Catch per unit effort of Out Board Purse Seine, CRB – Crab landing, CF – Cat fish catch, THR – *Thryssa* landing

Table 6.26 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Kanyakumari district and CPUE of NM, OBBN, OBGN, OBHL, Total catch and the landings of *Stolephorous* and squids

	TOT	NM_CPUE	OBBN_CPUE	OBGN_CPUE	OBHL_CPUE	STL	SQD
SST_M	-0.15	0.14	-0.19*	-0.08	0.18*	-0.13	-0.17
CHL_A	0.08	0.1	0.15	0.03	0.03	0.02	0.13
RF_STA	-0.01	0.05	-0.01	0.01	0.12	-0.06	-0.04
SLA	-0.19*	0.06	-0.11	-0.18*	0.16	-0.23**	-0.18*
SALT	0.19*	0.04	0.06	0.24**	-0.24**	0.24**	0.18*
LTA_M	0.14	-0.07	0.25**	0.13	-0.12	0.16	0.16
CUR_M_A	0.05	0.04	0.08	-0.05	0.13	0.06	-0.01
CUR_D	-0.08	-0.18*	-0.07	-0.05	-0.16	0.05	0.12
DHM	-0.18*	-0.09	-0.02	-0.04	-0.03	-0.05	-0.03
DCM	0.14	-0.15	0.19*	0.1	-0.18*	0.13	0.17*

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL_A – Chlorophyll concentration anomaly, RF_STA – Rainfall standardized anomaly, SLA – Sea level anomaly, SALT – Sea surface salinity, LTA_M – Local temperature anomaly, CUR_M_A – Current magnitude anomaly, CUR_D – Current direction, DHM – Degree Heating Month, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBSS_CPUE – Catch per unit effort of Out Board Shore Seine, STL – *Stolephorous* catch, SQD – Squid landing

Table 6.27 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Thirunelveli district and CPUE of OBGN, OBHL, OBPS, OBRS, Total catch and the landings of pigface breams and croakers

	TOT	OBGN_CPUE	OBHL_CPUE	OBPS_CPUE	OBRS_CPUE	PFB	CKS
SST_M	0.04	-0.04	0.19*	0.01	0.13	-0.07	-0.21*
SST_M_STA	-0.01	0.04	0.18*	-0.13	-0.01	-0.08	-0.24**
CHL_STA	0.12	0	-0.14	-0.08	0.11	0.18*	0.22*
RF_STA	-0.01	0.01	-0.14	0.20*	0.05	-0.08	0
LTA_M	-0.20*	-0.04	-0.36***	-0.12	-0.22*	-0.04	0.13
CUR_M_A	-0.07	-0.07	0.03	0.23**	-0.13	-0.01	-0.03
DCM	-0.05	0.03	-0.19*	-0.02	-0.15	0.08	0.22*

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_STA – Sea surface temperature standardized anomaly, CHL_STA – Chlorophyll concentration standardized anomaly, RF_STA – Rainfall standardized anomaly, LTA_M – Local temperature anomaly, CUR_M_A – Current magnitude anomaly, DCM - Degree Cooling Month, TOT – Total catch, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBPS_CPUE – Catch per unit effort of Out Board Purse Seine, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, PFB – Pigface breams catch, CKS – Croakers landing

Table 6.28 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Tuticorin district and CPUE of NM, OBGN, OBHL, OBPS, Total catch and the landings of other sardines, pigface breams, crabs, *Thryssa*, silver bellies and oil sardine

	TOT	NM_CPUE	OBGN_CPUE	OBHL_CPUE	OBPS_CPUE	OTS	PFB	CRB	THR	SVB	OS
SST_M	-0.17	-0.20*	-0.1	-0.01	-0.02	-0.27**	0.13	0.08	-0.17	-0.07	-0.07
SST_M_A	-0.05	0	0.1	0.11	-0.06	-0.20*	0.1	0.14	-0.19*	-0.02	-0.03
CHL	-0.02	-0.14	0.08	-0.21*	0.17	0.06	-0.23**	-0.16	0.05	-0.09	-0.17*
CHL_STA	0.03	-0.08	-0.17*	-0.12	0.19*	0.08	-0.08	-0.23**	0.29***	-0.03	0.01
RF	0.37***	-0.03	0.23**	0.23**	0.23**	0.25**	-0.03	0.04	0.19*	0.20*	0.20*
RF_STA	0.1	-0.15	0	0.23**	0.12	0.06	-0.02	-0.1	0.11	0.04	-0.06
DCM	0.15	0.20*	0.09	0	0.02	0.27**	-0.14	-0.08	0.16	0.06	0.07

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, SST_M_A – Sea surface temperature anomaly, CHL – Chlorophyll concentration, CHL_STA – Chlorophyll concentration standardized anomaly, RF – Rainfall, RF_STA – Rainfall standardized anomaly, DCM - Degree Cooling Month, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBPS_CPUE – Catch per unit effort of Out Board Purse Seine, OTS – Other sardine landing, PFB – Pigface breams catch, CRB – Crab catch, THR – *Thryssa* landing, SVB – Silver bellies catch, OS – Oil sardine catch

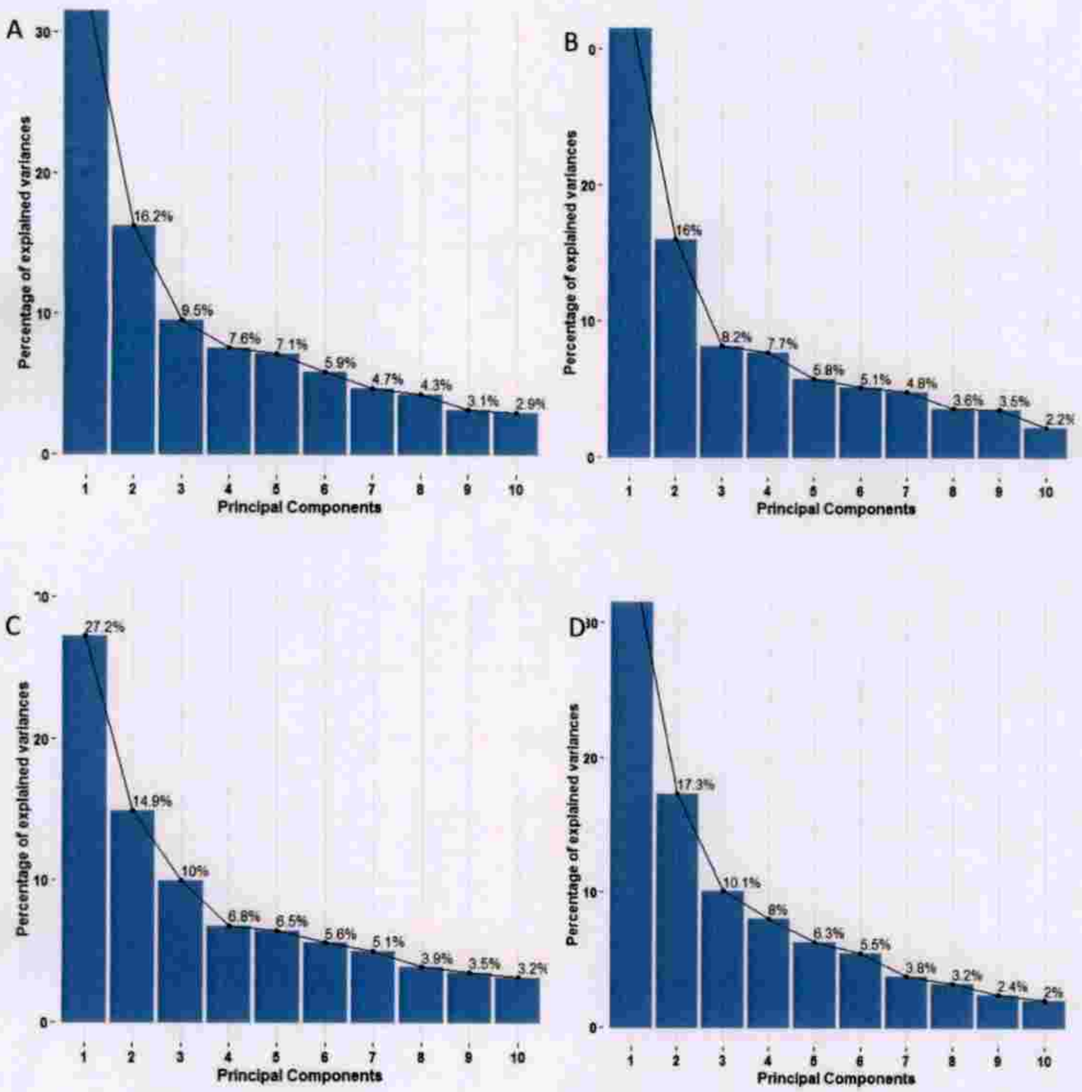
Table 6.29 - Correlation coefficient of Pearson's correlation test between the oceanographic parameters in the MDS (Minimum data set) selected by PCA analysis of Tamil Nadu district and CPUE of NM, OBGN, OBHL, OBPS, OBRS, Total catch and the landings of oil sardine and *Stolephorous*

	TOT	NM_CPUE	OBGN_CPUE	OBHL_CPUE	OBPS_CPUE	OBRS_CPUE	OS	STL
SST_M	0.05	0.17*	0.11	0.12	0.04	0.13	0.12	0.1
CHL	0.15	-0.18*	0.16	-0.20*	0.18*	0.26**	0.26**	0.22**
CHL_A	0.04	-0.15	-0.05	0	0.22*	0.07	0.11	0.07
RF	0.09	0.14	0.31***	-0.05	0	0	0.05	0.07
SALT	0.25**	-0.07	0.19*	-0.17*	0.16	0.28**	0.35***	0.27**
LTA_M	-0.06	-0.16	0.02	-0.14	-0.08	-0.05	-0.01	0.05

* ⟶ $p<0.05$; ** ⟶ $p<0.01$; *** ⟶ $p<0.001$

SST_M – Monthly mean sea surface temperature, CHL – Chlorophyll concentration, CHL_A – Chlorophyll concentration anomaly, RF – Rainfall, SALT – Sea surface salinity, LTA_M – Local temperature anomaly, TOT – Total catch, NM_CPUE – Catch per unit effort of Non motorized craft, OBGN_CPUE – Catch per unit effort of Out Board Gill Net, OBHL_CPUE – Catch per unit effort of Out Board Hook and Line, OBPS_CPUE – Catch per unit effort of Out Board Purse Seine, OBRS_CPUE – Catch per unit effort of Out Board Ring Seine, OS – Oil sardine catch, STL – *Stolephorous* catch

PCA ANALYSIS



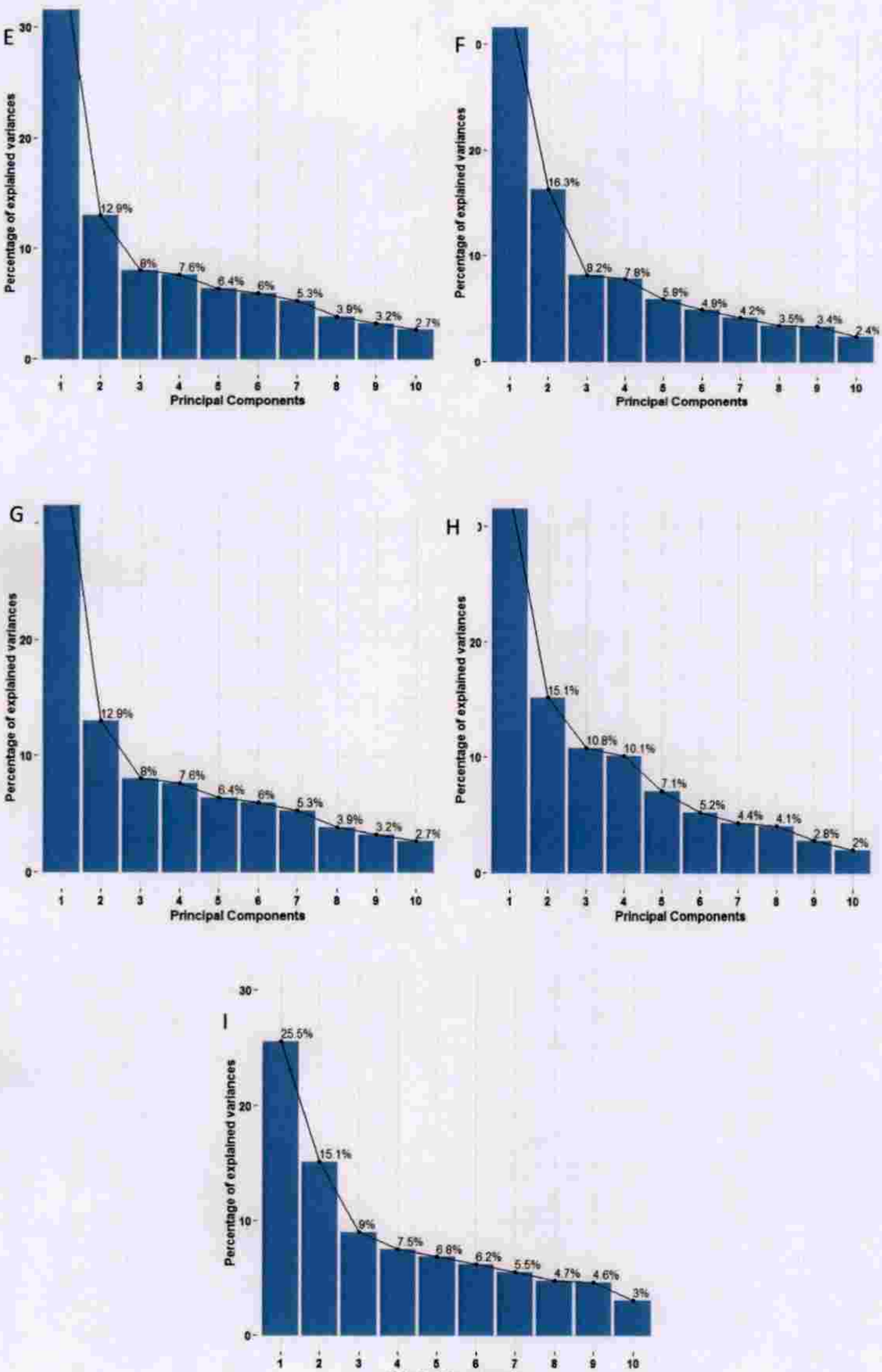


Fig. 6.2 : Scree plot of principle components for A)Chennai B)Cuddalore C)Kancheepuram D)Thanjavur E)Thiruvallur F)Kanyakumari G)Thirunelveli H)Tuticorin I)Tamil Nadu

Results of the Multiple Linear Regression Modelling using different environmental parameters as regressors and catch parameters as Response Variables

CHENNAI

25.78% of total catch variation could be explained by this model. In this 33 and 30% contributed by SST and DCM respectively (Table 6.30). Regression model was found to be able to explain 18.48 and 18.19% variation of oil sardine and Indian mackerel fishery. SST and DCM contribute 38 and 34% of 18.48% of total variance explained by regression modelfor the oil sardine fishery. 18.19% variance explained by regression model for the Indian mackerel fishery, rainfall standardized anomaly contribute 27% (Table 6.31).

Table 6.30 - Regression model results of Chennai district using chlorophyll concentration and total catch as Response (Dependant) variables and SST, LTA, chlorophyll concentration, Standardized anomaly of SST and Chlorophyll concentration, MEI, DCM, IOD, rainfall anomaly as covariate (Independent variables)

Response variable	Chlorophyll concentration	Total catch
variance explained by model	20.33%	25.78%
SST_M	0.05	0.33
LTA_M	0.07	0.06
SST_M_STA	0.55	0.07
CHL_STA	---	0.12
CHL	---	0.01
RF_A	0.00	0.01
IOD	0.03	0.01
MEI	0.01	0.06
DCM	0.05	0.30
DCM_Y	0.25	0.04

Table 6.31 - Regression model results of Chennai district using oil sardine and Indian mackerel as Response (Dependant) variables and SST, LTA, chlorophyll concentration, Standardized anomaly of SST and Chlorophyll concentration, MEI, DCM, IOD, rainfall anomaly as covariate (Independent variables).

Response variable	Oil sardine catch	Indian mackerel catch
variance explained by model	18.48%	18.19%
SST_M	0.38	0.05
LTA_M	0.05	0.17
SST_M_STA	0.12	0.01
CHL_STA	0.03	0.07
CHL	0.01	0.02
RF_STA	0.03	0.27
IOD	0.01	0.02
MEI	0.02	0.02
DCM	0.34	0.06
DCM_Y	0.01	0.31

Table 6.32 - Multiple linear regression equations for the response variables in the Chennai coastal zone

Model No:	REGRESSION EQUATION
1	CHL = -35.3 + 1.19 * SST_M + 0.13 * LTA_M -0.27 * SST_M_STA + 0.00001 * RF_A + 0.09 * IOD + 0.02 * MEI + 1.23 * DCM + 0.04 * DCM_Y
2	TOT = -33200 + 1138 * SST_M -61.5 * LTA_M + 7.4 * SST_M_STA + 3.9 * CHL_STA + 6.5 * CHL + 3.33 * RF_STA + 69.6 * IOD + 14.1 * MEI + 1077 * DCM -9.2 * DCM_Y
3	OS = -35560 + 1198 * SST_M -19 * LTA_M + 17.6 * SST_M_STA + 0.76 * CHL_STA + 15.5 * CHL -13.8 * RF_STA + 50.7 * IOD -2.1 * MEI + 1161 * DCM + 0.6 * DCM_Y
4	SVB = 1042 -34.8 * SST_M -3.6 * LTA_M -0.96 * SST_M_STA -0.15 * CHL_STA + 6.8 * CHL -0.64 * RF_STA -10.5 * IOD + 4.4 * MEI -37.6 * DCM -0.19 * DCM_Y
5	IM = 1739 -55 * SST_M + 19.4 * LTA_M + 1.38 * SST_M_STA + 0.49 * CHL_STA -3.53 * CHL + 6.64 * RF_STA -2.03 * IOD + 0.88 * MEI -61.2 * DCM -3.11 * DCM_Y
6	MLT = -2866 + 98.4 * SST_M + 0.002 * LTA_M -1.27 * SST_M_STA + 0.78 * CHL_STA -4.8 * CHL + 1.27 * RF_STA -18.8 * IOD + 1.99 * MEI + 98.5 * DCM -0.66 * DCM_Y
7	OTS = -1223 + 44.8 * SST_M -26.3 * LTA_M -4.6 * SST_M_STA + 0.84 * CHL_STA -6.68 * CHL + 4.8 * RF_STA + 6.74 * IOD -7.96 * MEI + 53.8 * DCM -2.68 * DCM_Y
8	CRB = 1216 -39.6 * SST_M -6.2 * LTA_M + 2.46 * SST_M_STA + 0.32 * CHL_STA + -0.44 * CHL + 0.94 * RF_STA -2.78 * IOD + 2.4 * MEI -40.01 * DCM + 0.01 * DCM_Y
9	NM_CPUE = 157.4 -5.5 * SST_M -7.4 * LTA_M -5.6 * SST_M_STA -0.37 * CHL_STA + 2.19 * CHL + 1.67 * RF_STA + 0.18 * IOD + 5.23 * MEI -6.9 * DCM -0.68 * DCM_Y
10	OBBN_CPUE = -39510 + 1343 * SST_M -28.4 * LTA_M + 6.12 * SST_M_STA + 0.38 * CHL_STA + 130.3 * CHL + 17.7 * RF_STA -242 * IOD + 93.8 * MEI + 1266 * DCM + 14.2 * DCM_Y
11	OBGN_CPUE = -261 + 10.8 * SST_M -6.3 * LTA_M -1.8 * SST_M_STA + 0.19 * CHL_STA -4.9 * CHL + 1.58 * RF_STA -1.15 * IOD + 2.58 * MEI + 10.4 * DCM -0.22 * DCM_Y
12	OBHL_CPUE = -2315 + 82 * SST_M -17.4 * LTA_M + 2.5 * SST_M_STA + 0.98 * CHL_STA -13.2 * CHL -0.67 * RF_STA + 13.07 * IOD -0.73 * MEI + 83.1 * DCM -0.73 * DCM_Y
13	OBOTHS_CPUE = 510.7 -17.1 * SST_M + 0.33 * LTA_M + 1.34 * SST_M_STA -0.06 * CHL_STA -0.31 * CHL -0.25 * RF_STA + 2.7 * IOD -1.48 * MEI -18.4 * DCM + 0.14 * DCM_Y
14	OBTN_CPUE = 3721 -120.6 * SST_M -6.4 * LTA_M + 7.4 * SST_M_STA + 1.39 * CHL_STA -8.7 * CHL -1.5 * RF_STA + 44.9 * IOD -0.28 * MEI -123 * DCM -2.61 * DCM_Y

CUDDALORE

Coefficient of determination (R^2) value for the chlorophyll concentration was 80%. In this, SST (34%), sea surface salinity (27%) and DCM (35%) were the major influencing parameters. Coefficient of determination (R^2) value for the CPUE of NM and OBGN were 20.13 and 24.19% respectively. In the percentage variance explained by the regresion model for OBGN-CPUE, 29% was contributed by the rainfall anomaly. Similarly 19.9% of OBTN CPUE could be explained by this regresson model. In this, 70% was contributed by rainfall anomaly (Table 6.33).

Table 6.33 - Regression model results of Cuddalore district using chlorophyll concentration, CPUE of NM, OBHL and OBTN gears as Response (Dependant) variables and SST, rainfall, salinity , anomaly of rainfall and chlorophyll concentration, DHM, DCM, IOD and current direction anomaly as covariate (Independent variables)

Response variable	Chlorophyll concentration	CPUE of NM	CPUE of OBHL	CPUE of OBTN
variance explained by model	80.02%	20.13%	24.49%	19.90%
SST_M	0.34	0.03	0.02	0.01
RF_A	0.00	0.02	0.29	0.02
RF	0.00	0.07	0.01	0.00
CHL_A	---	0.02	0.07	0.70
SALT	0.27	0.01	0.02	0.14
IOD	0.01	0.01	0.00	0.01
CUR_D_A	0.00	0.04	0.00	0.09
DHM	0.01	0.06	0.02	0.00
DCM	0.35	0.03	0.03	0.01
DHM_Y	0.02	0.72	0.53	0.01

Table 6.34 - Table 6.42 - Multiple linear regression equations for the response variables in the Cuddalore coastal zone

Model No:	REGRESSION EQUATION
1	CHL = -53.4 + 1.29 * SST_M + 0.0002*RF_A -0.0001*RF + 0.45 * SALT -0.2 * IOD -0.001 * CUR_D_A -1.17 * DHM + 1.9 * DCM + 0.21 * DHM_Y
2	TOT = -59355 + 1937 * SST_M + 1039 * IOD + 7.37 * CUR_D_A -13.24 * CHL_A + 85.4 * SALT -78.02 * RF_STA -2.29 * RF -3140 * DHM + 2233 * DCM + 836 * DHM_Y
3	OS =32660 -1232 * SST_M -161.24 * IOD -0.43 * CUR_D_A -8.58 * CHL_A + 124.8 * SALT + 0.68 * RF_STA -1.13 * RF + 1028 * DHM -1012 * DCM -66.4 * DHM_Y
4	SVB = 963 -36.3 * SST_M + 34.8 * IOD + 0.28 * CUR_D_A + 0.09 * CHL_A + 3.94 * SALT -1.59 * RF_STA -0.01 * RF + 18.6 * DHM -32.7 * DCM -12.37 * DHM_Y
5	IM = -20220 + 660 * SST_M + 161 * IOD + 2.12 * CUR_D_A -1.78 * CHL_A + 20.7 * SALT + 2.31 * RF_STA -0.19 * RF - 647 * DHM + 712 * DCM + 209 * DHM_Y
6	CKS = 634 -20.8 * SST_M + 7.76 * IOD -0.02 * CUR_D_A -0.035 * CHL_A -0.24 * SALT -3.79 * RF_STA + 0.011 * RF + 14.9 * DHM -17.85 * DCM -4.45 * DHM_Y
7	OTS = 344 -31.5 * SST_M +292 * IOD + 0.36 * CUR_D_A + 0.82 * CHL_A + 20.14 * SALT -2.48 * RF_STA -0.17 * RF -400 * DHM -39.3 * DCM + 240 * DHM_Y
8	THR = -40160 + 1355 * SST_M + 169 * IOD -0.06 * CUR_D_A -0.57 * CHL_A + 1.9 * SALT -10.96 * RF_STA -0.11 * RF - 1438 * DHM + 1353 * DCM + 69.6 * DHM_Y
9	NM_CPUE = 531 -18.8 * SST_M + 5.13 * IOD + 0.052 * CUR_D_A -0.023 * CHL_A + 0.92 * SALT -0.06 * RF_STA -0.015 * RF -10.8 * DHM -19.7 * DCM + 16.13 * DHM_Y
10	OBBN_CPUE = 14750 -525 * SST_M + 85.12 * IOD -0.72 * CUR_D_A + 1.17 * CHL_A + 26.6 * SALT + 2.45 * RF_STA + 0.27 * RF + 404 * DHM -583 * DCM -17.7 * DHM_Y
11	OBGN_CPUE = 2064 -70.3 * SST_M + 28.8 * IOD + 0.45 * CUR_D_A -0.63 * CHL_A + 3.49 * SALT + 7.9 * RF_STA -0.08 * RF + 4.4 * DHM -61.5 * DCM -12.2 * DHM_Y
12	OBHL_CPUE = -2090 + 71.6 * SST_M + 59 * IOD + 0.055 * CUR_D_A -0.14 * CHL_A -0.98 * SALT + 1.39 * RF_STA -0.02 * RF -88.9 * DHM + 75.6 * DCM + 41.3 * DHM_Y
13	OBRS_CPUE = -91620 + 3178 * SST_M + 113 * IOD -1.14 * CUR_D_A -5.32 * CHL_A -67.6 * SALT -105 * RF_STA -0.37 * RF -2483 * DHM + 3321 * DCM + 384 * DHM_Y
14	OBTN_CPUE = -54 + 9.7 * SST_M + 8.8 * IOD + 0.04 * CUR_D_A + 0.46 * CHL_A -6.85 * SALT + 0.33 * RF_STA + 0.04 * RF -7.5 * DHM + 8.09 * DCM + 3.45 * DHM_Y

KANCHEEPURAM

Coefficient of determination (R^2) value for the chlorophyll concentration was 46.31%. In this, salinity influence was found to be 29% (Table 6.35). Using regression model, 16.53 and 16.33% of croaker and crab catch could be explained. In the percentage variance explained by regression model for the croaker fishery, salinity and rainfall contribution were 26 and 22% respectively.

Table 6.35 - Regression model results of Kancheepuram district using chlorophyll concentration as Response (Dependant) variables and SST, LTA, rainfall, salinity , anomaly of rainfall and salinity, DCM, IOD, Standardized anomaly of current speed and current direction as covariate (Independent variables)

Response variable	Chlorophyll concentration
variance explained by model	46.31%
SST_M	0.19
RF_A	0.00
RF	0.02
SALT	0.29
SALT_A	0.11
IOD	0.02
CUR_D	0.04
CUR_M_STA	0.03
DCM_Y	0.18
LTA_M	0.12

Table 6.36 - Multiple linear regression equations for the response variables in the coastal zone of Kancheepuram

Model No:	REGRESSION EQUATION
1	CHL = -5.05 -0.39 * SST_M -0.00003 * RF_A + 0.0005 * RF + 0.49 * SALT -0.15 * SALT_A -0.01 * IOD + 0.0009 * CUR_D + 0.09 * CUR_M_STA + 0.05 * DCM_Y + 0.301 * LTA_M
2	TOT = -4741 -99.6 * SST_M -223.7 * IOD -0.47 * CUR_D -164.9 * CUR_M_STA + 251.9 * SALT -105.24 * SALT_A -0.198 * RF_A + 0.28 * RF + 4.9 * DCM_Y -423.95 * LTA_M
3	THR = -31 -0.78 * SST_M + 10.3 * RF_A -0.002 * CUR_D -1.07 * CUR_M_STA + 2.39 * SALT -1.26 * SALT_A -0.004 * RF_A -0.02 * RF -1.09 * DCM_Y + 6.99 * LTA_M
4	SVB = 6.7 -2.05 * SST_M + 10.8 * IOD -0.04 * CUR_D -2.39 * CUR_M_STA + 2.4 * SALT -2.49 * SALT_A -0.001 * RF_A -0.03 * RF -0.199 * DCM_Y -2.71 * LTA_M
5	IM = -156 + 61.8 * SST_M -111 * IOD + 0.01 * CUR_D + 14.8 * CUR_M_STA -41.5 * SALT + 18.3 * SALT_A -0.03 * RF_A -0.12 * RF -10.8 * DCM_Y -13.15 * LTA_M
6	CKS = -104.8 -3.8 * SST_M -5.3 * IOD -0.04 * CUR_D -0.72 * CUR_M_STA + 7.13 * SALT -2.44 * SALT_A -0.002 * RF_A -0.02 * RF -0.06 * DCM_Y -2.63 * LTA_M
7	OTS = 1177 + 38.38 * SST_M + 70.8 * IOD -0.11 * CUR_D -104.8 * CUR_M_STA -64.95 * SALT + 6.2 * SALT_A -0.06 * RF_A + 0.05 * RF + 6.8 * DCM_Y -252.6 * LTA_M
8	CRB = -116 -1.49 * SST_M -11.8 * IOD -0.05 * CUR_D -1.29 * CUR_M_STA + 5.8 * SALT -2.5 * SALT_A -0.003 * RF_A + 0.007 * RF -0.99 * DCM_Y -1.5 * LTA_M
9	NM_CPUE = 51.1 + 2.0 * SST_M + 1.67 * IOD + 0.02 * CUR_D + 0.73 * CUR_M_STA -3.04 * SALT + 0.82 * SALT_A -0.002 * RF_A -0.02 * RF -0.06 * DCM_Y -0.56 * LTA_M
10	OBBN_CPUE = 372.3 -68.1 * SST_M + 14.4 * IOD + 0.48 * CUR_D -43.7 * CUR_M_STA + 48.3 * SALT -23.3 * SALT_A -0.07 * RF_A + 0.24 * RF + 3.49 * DCM_Y -195 * LTA_M
11	OBGN_CPUE = 22.4 + 0.03 * SST_M -3.39 * IOD + 0.03 * CUR_D -1.91 * CUR_M_STA -0.09 * SALT -1.15 * SALT_A -0.005 * RF_A -0.02 * RF + 0.71 * DCM_Y -12.95 * LTA_M
12	OBHL_CPUE = -38.2 + 0.51 * SST_M -4.6 * IOD + 0.03 * CUR_D + 1.21 * CUR_M_STA + 1.38 * SALT -2.12 * SALT_A -0.01 * RF_A -0.004 * RF -0.27 * DCM_Y -7.19 * LTA_M
13	OBRS_CPUE = -1896 -0.61 * SST_M -232 * IOD + 0.01 * CUR_D -31.8 * CUR_M_STA + 62.3 * SALT -17.3 * SALT_A -0.03 * RF_A + 0.09 * RF -3.65 * DCM_Y + 56.7 * LTA_M
14	OBSS_CPUE = 49.1 + 5.89 * SST_M + 0.58 * IOD + 0.05 * CUR_D + 0.14 * CUR_M_STA -5.8 * SALT + 1.67 * SALT_A -0.005 * RF_A -0.06 * RF -0.68 * DCM_Y -16.95 * LTA_M

THANJAVUR

20.96% of total catch variation could be explained with this regression model. In this, chlorophyll anomaly and rainfall standardized anomaly were found to contribute 29 and 25% respectively (Table 6.37).

Table 6.37 - Regression model results of Thanjavur district using total catch as Response (Dependant) variables and SST, LTA, SLA, anomaly of chlorophyll concentration, Standardized anomalies of SST and rainfall, DHM, DCM and IOD as covariate (Independent variables)

Response variable	Total catch
variance explained by model	20.96%
SST_M	0.01
SST_M_STA	0.03
CHL_A	0.29
RF_STA	0.25
LTA_M	0.02
SLA	0.06
IOD	0.01
MEI	0.12
DHM	0.04
DCM	0.01
DCM_Y	0.17

Table 6.38 - Multiple linear regression equations for the response variables in the coastal zone of Thanjavur

Model No:	REGRESSION EQUATION
1	CHL = -9.75 + 0.41 * SST_M -0.06 * SST_M_STA -0.03 * RF_STA + 0.33 * LTA_M -1.68 * SLA -0.04 * IOD -0.03 * MEI - 0.68 * DHM + 0.298 * DCM + 0.004 * DCM_Y
2	TOT = -13505 + 469.5 * SST_M -14.7 * SST_M_STA + 8.06 * CHL_A -103.7 * RF_STA + 184.5 * LTA_M -452.4 * SLA + 102.5 * IOD -102.6 * MEI -850 * DHM + 398.8 * DCM -23.3 * DCM_Y
3	RS = -32.8 + 4.03 * SST_M -2.74 * SST_M_STA + 0.76 * CHL_A -15.8 * RF_STA + 44 * LTA_M -10.16 * SLA + 11.36 * IOD -14.13 * MEI -20.9 * DHM -14.55 * DCM -2.35 * DCM_Y
4	SP = -2437 + 79.3 * SST_M -0.89 * SST_M_STA + 0.15 * CHL_A + 1.19 * RF_STA + 2.77 * LTA_M -79.6 * SLA -3.03 * IOD + 1.39 * MEI -92.6 * DHM + 79.6 * DCM + 1.41 * DCM_Y
5	CF = -5231 + 171 * SST_M -2.98 * SST_M_STA + 0.35 * CHL_A -3.49 * RF_STA + 6.95 * LTA_M -86 * SLA -21.6 * IOD + 4.9 * MEI -176.6 * DHM + 176.6 * DCM -1.36 * DCM_Y
6	CKS = 3531 -112.4 * SST_M -3.56 * SST_M_STA + 1.02 * CHL_A -11.4 * RF_STA + 18.6 * LTA_M -135.8 * SLA -18.1 * IOD -3.68 * MEI + 88.2 * DHM -117.6 * DCM -1.08 * DCM_Y
7	CRB = -19830 + 655 * SST_M -5.75 * SST_M_STA + 0.12 * CHL_A -7.06 * RF_STA + 100.2 * LTA_M -75.7 * SLA + 12.65 * IOD -40.3 * MEI -744 * DHM + 601.7 * DCM -7.7 * DCM_Y
8	PP = 6184 -199.8 * SST_M + 1.87 * SST_M_STA + 0.29 * CHL_A -12.05 * RF_STA -33.3 * LTA_M -145.9 * SLA -38.2 * IOD -5.4 * MEI + 143.2 * DHM -186.5 * DCM + 1.099 * DCM_Y
9	NM_CPUE = 115.4 -3.8 * SST_M -0.51 * SST_M_STA + 0.06 * CHL_A + 0.22 * RF_STA -4.1 * LTA_M -4.97 * SLA -0.71 * IOD + 0.52 * MEI + 3.8 * DHM -2.12 * DCM + 0.01 * DCM_Y
10	OBGN_CPUE = 2317 -73.2 * SST_M + 5.4 * SST_M_STA + 0.29 * CHL_A -1.02 * RF_STA + 2.31 * LTA_M + 52.4 * SLA + 6.6 * IOD -2.26 * MEI + 7.9 * DHM -75.3 * DCM -1.78 * DCM_Y
11	OBHL_CPUE = 264.3 -8.28 * SST_M + 0.32 * SST_M_STA + 0.001 * CHL_A -0.09 * RF_STA + 3.18 * LTA_M -6.65 * SLA -2.24 * IOD -0.59 * MEI + 11.2 * DHM -9.7 * DCM -0.13 * DCM_Y
12	OBTN_CPUE = 1708 -55.1 * SST_M + 5.38 * SST_M_STA -0.36 * CHL_A -0.2 * RF_STA -16.04 * LTA_M + 7.66 * SLA - 13.12 * IOD -1.71 * MEI + 12.8 * DHM -49.7 * DCM -0.08 * DCM_Y

THIRUVALLUR

Regression model could explain the 31.88% of monthly OBBN-CPUE variation. In this chlorophyll-a concentration was found to influence 89% of CPUE variation (Table 6.39).

Table 6.39 - Regression model results of Thiruvallur district using chlorophyll concentration, CPUE of OBBN and OBRS gears as Response (Dependant) variables and SST, LTA, chlorophyll concentration, anomalies of SST and rainfall, DHM, DCM, MEI and IOD as covariate (Independent variables)

Response variable	Chlorophyll concentration	CPUE of OBBN	CPUE of OBRS
variance explained by model	23.55%	31.88%	19%
SST_M	0.04	0.01	0.13
SST_M_A	0.62	0.05	0.21
CHL	---	0.89	0.06
LTA_M	0.04	0.00	0.05
RF_A	0.01	0.00	0.05
MEI	0.01	0.00	0.18
IOD	0.01	0.00	0.11
DHM	0.03	0.00	0.01
DCM_Y	0.15	0.03	0.01
DHM_Y	0.10	0.01	0.20

Table 6.40 - Multiple linear regression equations for the response variables in the coastal zone of Thiruvallur

Model No:	REGRESSION EQUATION
1	CHL = -2.72 + 0.12 * SST_M -0.31 * SST_M_A + 0.004 * LTA_M + 0.0003 * RF_A + 0.04 * MEI -0.14 * IOD + 0.94 * DHM + 0.06 * DCM_Y -0.66 * DHM_Y
2	TOT = -2267 + 98.8 * SST_M -103.2 * SST_M_A -23.1 * CHL -77.5 * LTA_M -0.02 * RF_A + 104.8 * MEI -36.9 * IOD + 263 * DHM + 1.25 * DCM_Y -336 * DHM_Y
3	CF = 2.44 -0.49 * SST_M -0.07 * SST_M_A -0.44 * CHL -8.49 * LTA_M -0.001 * RF_A + 1.7 * MEI + 24.6 * IOD - 1.48 * DHM + 1.59 * DCM_Y -12.4 * DHM_Y
4	CRB = -37.1 + 1.68 * SST_M + 0.92 * SST_M_A -1.17 * CHL -3.34 * LTA_M -0.002 * RF_A + 3.01 * MEI -5.6 * IOD -9.95 * DHM + 0.23 * DCM_Y + 5.32 * DHM_Y
5	IM = -560.7 + 23.1 * SST_M + 1.6 * SST_M_A + 7.85 * CHL + 37.2 * LTA_M + 0.003 * RF_A + 17.9 * MEI + 37.2 * IOD -47.5 * DHM -3.39 * DCM_Y -93.9 * DHM_Y
6	CKS = 152.1 -4.8 * SST_M -0.28 * SST_M_A + 3.4 * CHL -16.5 * LTA_M + 0.002 * RF_A + 7.54 * MEI -0.75 * IOD + 0.54 * DHM + 0.55 * DCM_Y + 5.49 * DHM_Y
7	OTS = 278.4 -5.33 * SST_M -20.99 * SST_M_A -39.4 * CHL -45.1 * LTA_M -0.01 * RF_A + 14.5 * MEI + 18.7 * IOD + 39.7 * DHM -0.61 * DCM_Y -103.9 * DHM_Y
8	THR = 28.1 -0.7 * SST_M + 0.42 * SST_M_A -1.096 * CHL -0.72 * LTA_M -0.001 * RF_A + 1.23 * MEI -2.27 * IOD + 0.64 * DHM -0.09 * DCM_Y -3.2 * DHM_Y
9	NM_CPUE = -17.8 + 0.81 * SST_M -0.14 * SST_M_A -0.59 * CHL -0.31 * LTA_M + 0.001 * RF_A + 0.96 * MEI -3.68 * IOD + 5.28 * DHM -0.11 * DCM_Y -1.38 * DHM_Y
10	OBBN_CPUE = -368.2 + 12.9 * SST_M + 2.68 * SST_M_A + 86.9 * CHL + 3.66 * LTA_M -0.005 * RF_A -7.88 * MEI + 26.4 * IOD -11.9 * DHM -7.86 * DCM_Y + 23.7 * DHM_Y
11	OBGN_CPUE = -10.2 + 1.61 * SST_M -1.45 * SST_M_A + 1.19 * CHL -1.23 * LTA_M + 0.01 * RF_A + 1.76 * MEI + 13.12 * IOD + 10.7 * DHM -0.33 * DCM_Y -7.03 * DHM_Y
12	OBHL_CPUE = -59.6 + 3.36 * SST_M -0.81 * SST_M_A + 2.11 * CHL + 10.2 * LTA_M -0.01 * RF_A + 0.91 * MEI + 37.1 * IOD -9.59 * DHM -1.78 * DCM_Y + 0.51 * DHM_Y
13	OBRS_CPUE = -4823.5 + 196 * SST_M -175.3 * SST_M_A + 30.5 * CHL -304.3 * LTA_M -0.297 * RF_A + 169.67 * MEI + 341.5 * IOD + 387 * DHM + 0.52 * DCM_Y -703.5 * DHM_Y
14	OBTN_CPUE = -38.7 + 1.5 * SST_M -0.49 * SST_M_A + 0.495 * CHL + 0.71 * LTA_M -0.0001 * RF_A + 0.08 * MEI -2.3 * IOD -0.85 * DHM -0.02 * DCM_Y -3.69 * DHM_Y
15	OBPS_CPUE = -1434 + 53.9 * SST_M + 25.9 * SST_M_A + 12.01 * CHL + 268.4 * LTA_M + 0.01 * RF_A -21.1 * MEI -20.2 * IOD -65.9 * DHM -9.48 * DCM_Y -44.7 * DHM_Y
16	OBSS_CPUE = -139.8 + 4.7 * SST_M -2.96 * SST_M_A -0.77 * CHL -11.7 * LTA_M -0.01 * RF_A -9.27 * MEI + 30.1 * IOD + 3.35 * DHM + 0.99 * DCM_Y -16.4 * DHM_Y

KANYAKUMARI

Coefficient of determination (R^2) value for the chlorophyll concentration, CPUE of OBGN, OBHL were 80.75, 53.67 and 26.47% respectively. In 80.75% variance explained by regression model for the CPUE of OBGN 29, 29 and 27% were contributed by SST, DCM and DHM. In the percentage variance explained by the regression model, 24, 23 and 23% contributed by SST, DCM and DHM respectively (Table 6.41).

Table 6.41 - Regression model results of Kanyakumari district using chlorophyll concentration, CPUE of OBGN and OBHL gears as Response (Dependant) variables and SST, salinity, current direction, anomalies of current magnitude and chlorophyll concentration, DHM, DCM and Standardized anomaly of rainfall as covariate (Independent variables).

Response variable	Chlorophyll concentration	CPUE of OBGN	CPUE of OBHL
variance explained by model	80.75%	53.67%	26.47%
SST_M	0.32	0.29	0.24
CHL_A	---	0.00	0.01
SALT	0.23	0.10	0.11
RF_STA	0.01	0.00	0.05
CUR_D	0.03	0.02	0.05
CUR_M_A	0.01	0.00	0.04
DHM	0.01	0.27	0.20
DCM	0.33	0.29	0.23
DCM_Y	0.04	0.01	0.05
DHM_Y	0.02	0.01	0.02

Table 6.42 - Multiple linear regression equations for the response variables in the coastal zone of Kanyakumari

Model No:	REGRESSION EQUATION
1	CHL = -76.9 + 2.1 * SST_M + 0.43 * SALT + 0.01 * RF_STA + 0.001 * CUR_D + 0.003 * CUR_M_A -1.86 * DHM + 2.7 * DCM + 0.01 * DCM_Y + 0.24 * DHM_Y
2	TOT = 49020.5 -2344.4 * SST_M + 3.09 * CHL_A + 704.6 * SALT -54.4 * RF_STA -6.77 * CUR_D + 9.68 * CUR_M_A + 1334.8 * DHM -2329 * DCM + 19.3 * DCM_Y -1344 * DHM_Y
3	BRC = 8949 -320.8 * SST_M -0.03 * CHL_A + 19.3 * SALT -14.6 * RF_STA -0.19 * CUR_D + 0.43 * CUR_M_A + 272.9 * DHM -326.1 * DCM -1.29 * DCM_Y -32.7 * DHM_Y
4	SQD = -10040 + 296.5 * SST_M + 1.15 * CHL_A + 33.9 * SALT -10.2 * RF_STA + 0.44 * CUR_D + 0.32 * CUR_M_A -144.4 * DHM + 320.7 * DCM + 8.7 * DCM_Y -60.9 * DHM_Y
5	IM = 9065.5 -303.5 * SST_M + 0.05 * CHL_A + 7.6 * SALT + 54.9 * RF_STA -0.79 * CUR_D + 0.81 * CUR_M_A + 141.3 * DHM -304.7 * DCM -4.8 * DCM_Y -77.03 * DHM_Y
6	PFB = 21952 -654.9 * SST_M + 0.96 * CHL_A -63.9 * SALT + 15.3 * RF_STA -1.29 * CUR_D -2.24 * CUR_M_A + 679 * DHM -621.3 * DCM + 3.85 * DCM_Y -180.9 * DHM_Y
7	OTS = -17880 + 604.6 * SST_M -1.53 * CHL_A + 4.4 * SALT -46.9 * RF_STA + 0.19 * CUR_D + 0.88 * CUR_M_A -660.9 * DHM + 552.2 * DCM + 14.2 * DCM_Y -129.2 * DHM_Y
8	STL = 12533.5 -873.4 * SST_M -0.45 * CHL_A + 410.8 * SALT -57.5 * RF_STA -1.19 * CUR_D + 6.69 * CUR_M_A + 783.4 * DHM -864.7 * DCM -4.46 * DCM_Y -228.8 * DHM_Y
9	NM_CPUE = -7530 + 236.3 * SST_M + 0.32 * CHL_A + 18.4 * SALT + 0.21 * RF_STA -0.22 * CUR_D + 0.27 * CUR_M_A - 276.2 * DHM + 219.2 * DCM + 0.85 * DCM_Y -22.4 * DHM_Y
10	OBBN_CPUE = -701 + 20.6 * SST_M + 0.11 * CHL_A + 2.77 * SALT + 0.83 * RF_STA -0.05 * CUR_D + 0.07 * CUR_M_A - 14.6 * DHM + 25.5 * DCM -0.18 * DCM_Y + 1.24 * DHM_Y
11	OBBS_CPUE = -1728 + 61.3 * SST_M -0.01 * CHL_A -3.6 * SALT + 0.05 * RF_STA + 0.18 * CUR_D -0.01 * CUR_M_A - 44.4 * DHM + 63.9 * DCM + 1.36 * DCM_Y -4.6 * DHM_Y
12	OBGN_CPUE = -36570 + 1220 * SST_M -0.01 * CHL_A + 14.9 * SALT + 4.5 * RF_STA -0.08 * CUR_D + 0.103 * CUR_M_A -1197 * DHM + 1228 * DCM + 0.64 * DCM_Y -9.42 * DHM_Y
13	OBHL_CPUE = -41200 + 1414 * SST_M + 0.15 * CHL_A -16.7 * SALT + 16.6 * RF_STA -0.06 * CUR_D + 0.34 * CUR_M_A -1421 * DHM + 1412 * DCM -1.04 * DCM_Y -15.9 * DHM_Y
14	OBOTHS_CPUE = 5343.5 -132.2 * SST_M + 0.19 * CHL_A -43.3 * SALT -0.27 * RF_STA + 0.64 * CUR_D -0.64 * CUR_M_A + 84.6 * DHM -142.3 * DCM -0.08 * DCM_Y -0.204 * DHM_Y
15	OBSS_CPUE = 4518 -163.7 * SST_M -0.32 * CHL_A + 11.2 * SALT -18.8 * RF_STA -0.01 * CUR_D + 0.68 * CUR_M_A + 164.1 * DHM -166.4 * DCM + 1.28 * DCM_Y -42.9 * DHM_Y

THIRUNELVELI

Regression model could explain 55.8, 26.93 and 21.18% of chlorophyll concentration, OBSS-CPUE and total catch variation respectively. In this, percentage variance explained by regression model for OBSS-CPUE, 33% was contributed by OBSS-CPUE variation (Table 6.43).

Table 6.43 - Regression model results of Thirunelveli district using chlorophyll concentration, total catch and CPUE of OBSS gear as Response (Dependant) variables and SST, current direction, anomalies of current magnitude and SST, DHM, DCM,IOD, Standardized anomaly of rainfall and chlorophyll concentration as covariate (Independent variables)

Response variable	Chlorophyll concentration	CPUE of OBSS	Total catch
variance explained by model	55.80%	26.93%	21.18%
SST_M	0.39	0.33	0.03
SST_M_A	0.07	0.01	0.01
CHL_STA	---	0.01	0.06
IOD	0.01	0.00	0.02
RF_STA	0.01	0.04	0.01
CUR_M_A	0.00	0.00	0.03
CUR_D	0.00	0.02	0.08
DHM	0.02	0.27	0.01
DCM	0.42	0.31	0.03
DCM_Y	0.07	0.02	0.57
DHM_Y	0.02	0.00	0.16

Table 6.44 - Multiple linear regression equations for the response variables in the coastal zone of Thirunelveli

Model No:	REGRESSION EQUATION
1	CHL = -77.95 + 2.61 * SST_M + 0.04 * SST_M_A + 0.297 * IOD + 0.07 * RF_STA + 0.001 * CUR_M_A + 0.001 * CUR_D - 2.01 * DHM + 3.49 * DCM + 0.03 * DCM_Y + 0.22 * DHM_Y
2	TOT = -71714 + 2467.97 * SST_M + 48.62 * SST_M_A + 318.3 * CHL_STA -86.06 * IOD -199.8 * RF_STA -4.47 * CUR_M_A -5.77 * CUR_D -1798.4 * DHM + 2084.4 * DCM + 134.04 * DCM_Y -1073.3 * DHM_Y
3	IM = 8476 -282.9 * SST_M + 18.88 * SST_M_A + 41.89 * CHL_STA -88.7 * IOD + 0.15 * RF_STA -0.58 * CUR_M_A -0.41 * CUR_D + 204 * DHM -324.3 * DCM + 13.18 * DCM_Y -91.06 * DHM_Y
4	THR = 10582 -354.5 * SST_M + 4.59 * SST_M_A + 3.22 * CHL_STA -43.12 * IOD -18.12 * RF_STA + 0.14 * CUR_M_A - 0.104 * CUR_D + 328.7 * DHM -366 * DCM + 2.42 * DCM_Y -69.9 * DHM_Y
5	CKS = 626 -20.1 * SST_M -4.81 * SST_M_A + 6.17 * CHL_STA -15.23 * IOD + 1.68 * RF_STA -0.17 * CUR_M_A -0.13 * CUR_D + 59.3 * DHM -17.29 * DCM + 1.04 * DCM_Y -12.28 * DHM_Y
6	PFB = -2885 + 100.2 * SST_M -0.94 * SST_M_A + 16.88 * CHL_STA + 37.14 * IOD -3.05 * RF_STA -0.103 * CUR_M_A - 0.201 * CUR_D -72.5 * DHM + 104.02 * DCM -2.05 * DCM_Y -15.24 * DHM_Y
7	OTS = -44620 + 1516 * SST_M -4.51 * SST_M_A + 133.6 * CHL_STA -263 * IOD -121.1 * RF_STA + 0.06 * CUR_M_A -1.43 * CUR_D -715.8 * DHM + 1289 * DCM + 80.6 * DCM_Y -424.3 * DHM_Y
8	SVB = 6636 -222.7 * SST_M + 10.79 * SST_M_A + 16.22 * CHL_STA -5.35 * IOD -7.53 * RF_STA + 0.198 * CUR_M_A - 0.14 * CUR_D + 207.4 * DHM -227.8 * DCM + 3.75 * DCM_Y -52.04 * DHM_Y
9	NM_CPUE = 130.5 -4.36 * SST_M -0.01 * SST_M_A + 0.404 * CHL_STA + 1.15 * IOD + 0.31 * RF_STA -0.001 * CUR_M_A -0.004 * CUR_D + 3.51 * DHM -4.57 * DCM -0.02 * DCM_Y -0.55 * DHM_Y
10	OBGN_CPUE = 1688 -55.99 * SST_M + 1.82 * SST_M_A -0.92 * CHL_STA -1.44 * IOD -1.79 * RF_STA -0.06 * CUR_M_A - 0.08 * CUR_D + 60.6 * DHM -56.4 * DCM + 1.55 * DCM_Y -12.2 * DHM_Y
11	OBHL_CPUE = 255.5 -7.5 * SST_M + 1.01 * SST_M_A + -2.4 * CHL_STA -2.28 * IOD -5.96 * RF_STA + 0.005 * CUR_M_A -0.04 * CUR_D + 2.08 * DHM -12.11 * DCM -0.196 * DCM_Y + 2.18 * DHM_Y
12	OBSS_CPUE = -7982 + 270 * SST_M -0.36 * SST_M_A -1.13 * CHL_STA + 4.52 * IOD + 3.71 * RF_STA + 0.14 * CUR_M_A -0.04 * CUR_D -272.6 * DHM + 270.5 * DCM -0.11 * DCM_Y + 0.92 * DHM_Y
13	OBPS_CPUE = 3761 -126.1 * SST_M -11.6 * SST_M_A -29.47 * CHL_STA + 12.26 * IOD + 30.3 * RF_STA + 1.06 * CUR_M_A + 0.11 * CUR_D + 170.5 * DHM -132.5 * DCM + 1.202 * DCM_Y -43.85 * DHM_Y
14	OBRS_CPUE = -19115 + 664.7 * SST_M -18.29 * SST_M_A + 114.7 * CHL_STA + 20.08 * IOD + 15.9 * RF_STA -2.9 * CUR_M_A -1.68 * CUR_D -945 * DHM + 492.6 * DCM + 14.76 * DCM_Y -130.9 * DHM_Y

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21.01% of total catch could be explined with this regression model. 22.33% of CPUE of OBGN could be explained by this model. In this, rainfall was found to contribute 55 and 32% of percentage variance explained by regression model for the total catch and OBGN-CPUE. With this model, 72.72% of chlorophyll concentration could be explained. Among this, 79% was contributed by the LTA (Table 6.45).

Table 6.45 - Regression model results of Tuticorin district using chlorophyll concentration, total catch, CPUE of OBGN gear as Response (Dependant) variables and SST, chlorophyll concentration, LTA, rainfall, Standardized anomaly of chlorophyll concentration and rainfall, DHM, DCM , SST anomaly as covariate (Independent variables)

Response variable	Chlorophyll concentration	CPUE of OBGN	Total catch
variance explained by model	72.72%	22.33%	21.01%
SST_M	0.01	0.05	0.08
SST_M_A	0.02	0.07	0.01
CHL	---	0.05	0.02
CHL_STA	---	0.19	0.00
LTA_M	0.79	0.05	0.01
RF_STA	0.04	0.05	0.04
RF	0.02	0.32	0.55
DHM	0.00	0.08	0.05
DCM	0.01	0.04	0.07
DCM_Y	0.09	0.04	0.15
DHM_Y	0.01	0.06	0.01

Table 6.46 - Multiple linear regression equations for the response variables in the coastal zone of Tuticorin

Model No:	REGRESSION EQUATION
1	CHL = -29.3 + 0.97 * SST_M + 0.04 * SST_M_A + 0.96 * LTA_M + 0.08 * RF_STA -0.001 * RF -0.44 * DHM + 1.07 * DCM + 0.03 * DCM_Y -0.09 * DHM_Y
2	TOT = 21089 -631.3 * SST_M + 16.1 * SST_M_A -269.5 * CHL + 9.9 * CHL_STA + 332.9 * LTA_M -124.8 * RF_STA + 7.1 * RF -597 * DHM -388.8 * DCM + 15.0 * DCM_Y -61.9 * DHM_Y
3	OS = 10538 -339.8 * SST_M + 4.98 * SST_M_A -167.3 * CHL + 40.1 * CHL_STA + 128 * LTA_M -63.6 * RF_STA + 1.45 * RF + 370.6 * DHM -307.9 * DCM -1.69 * DCM_Y -93.3 * DHM_Y
4	THR = 5826 -189.1 * SST_M -5.81 * SST_M_A -34.6 * CHL + 43.3 * CHL_STA + 12.8 * LTA_M -0.67 * RF_STA + 0.2 * RF + 272.9 * DHM -176.8 * DCM + 3.57 * DCM_Y -50.3 * DHM_Y
5	CRB = -2405 + 82.1 * SST_M + 0.72 * SST_M_A + 2.64 * CHL -15.9 * CHL_STA -12.09 * LTA_M -5.99 * RF_STA + 0.15 * RF -268.4 * DHM + 80.8 * DCM -1.38 * DCM_Y + 69.1 * DHM_Y
6	PFB = 9451 -298.6 * SST_M + 8.61 * SST_M_A -67.3 * CHL + 12.6 * CHL_STA + 28.1 * LTA_M + 1.68 * RF_STA -0.18 * RF + 96.1 * DHM -323 * DCM -0.09 * DCM_Y -32.6 * DHM_Y
7	OTS = -22752 + 752.5 * SST_M -59.4 * SST_M_A + 35.3 * CHL -26.4 * CHL_STA -16.0 * LTA_M -45.5 * RF_STA + 2.9 * RF -1042 * DHM + 931.6 * DCM + 3.17 * DCM_Y + 142.8 * DHM_Y
8	SVB = -280.4 + 10.9 * SST_M -2.09 * SST_M_A -14.4 * CHL -3.28 * CHL_STA + 7.9 * LTA_M -4.69 * RF_STA + 0.31 * RF -41.9 * DHM + 19.9 * DCM -0.21 * DCM_Y + 11.4 * DHM_Y
9	NM_CPUE = -137.2 + 4.59 * SST_M -0.27 * SST_M_A + 23.3 * CHL -9.7 * CHL_STA -31.5 * LTA_M -10.3 * RF_STA + 0.19 * RF -27.8 * DHM + 21.02 * DCM -3.66 * DCM_Y -4.13 * DHM_Y
10	OBBN_CPUE = 1738 -56.8 * SST_M -0.24 * SST_M_A + 9.47 * CHL -3.3 * CHL_STA + 6.8 * LTA_M + 3.98 * RF_STA - 0.03 * RF + 66.3 * DHM -58.9 * DCM + 0.82 * DCM_Y -21.5 * DHM_Y
11	OBBS_CPUE = 1659 -52.8 * SST_M -7.51 * SST_M_A -11.8 * CHL -3.09 * CHL_STA + 12.4 * LTA_M -4.97 * RF_STA + 0.003 * RF + 44.2 * DHM -61.3 * DCM -0.89 * DCM_Y -9.88 * DHM_Y
12	OBGN_CPUE = -191 + 8.14 * SST_M + 1.77 * SST_M_A + 7.95 * CHL -6.9 * CHL_STA + 2.69 * LTA_M -3.83 * RF_STA + 0.14 * RF -59.7 * DHM + 12.9 * DCM -0.63 * DCM_Y + 9.67 * DHM_Y
13	OBHL_CPUE = -303 + 11.9 * SST_M + 1.85 * SST_M_A -13.8 * CHL -1.43 * CHL_STA + 5.4 * LTA_M + 6.2 * RF_STA + 0.03 * RF -23.7 * DHM + 15.8 * DCM + 0.37 * DCM_Y + 1.1 * DHM_Y
14	OBOTHS_CPUE = 26443 -844 * SST_M -14.9 * SST_M_A + 52.6 * CHL -52.6 * CHL_STA -100.02 * LTA_M + 92.3 * RF_STA -2.1 * RF + 479.6 * DHM -834 * DCM -13.6 * DCM_Y -267.5 * DHM_Y
15	OBSS_CPUE = 25446 -824.3 * SST_M -32.9 * SST_M_A -32.2 * CHL + 54.9 * CHL_STA -86.03 * LTA_M -17.9 * RF_STA + 0.03 * RF + 618.6 * DHM -925 * DCM + 4.3 * DCM_Y -16.9 * DHM_Y
16	OBPS_CPUE = 3184 -105.8 * SST_M -3.7 * SST_M_A + 53.9 * CHL + 25.9 * CHL_STA + 18.9 * LTA_M -18.5 * RF_STA + 1.04 * RF + 197 * DHM -104.2 * DCM -4.03 * DCM_Y -32.5 * DHM_Y
17	OBRS_CPUE = 37189 -1201.3 * SST_M -60.8 * SST_M_A -240 * CHL + 68.6 * CHL_STA + 110.2 * LTA_M -91.4 * RF_STA + 1.4 * RF + 966.6 * DHM -1313.4 * DCM + 8.5 * DCM_Y -66.3 * DHM_Y
18	OBTN_CPUE = 1697.6 -54.8 * SST_M -3.96 * SST_M_A + 5.6 * CHL -1.46 * CHL_STA -11.14 * LTA_M -0.31 * RF_STA - 0.01 * RF -1.78 * DHM -61.2 * DCM -0.66 * DCM_Y + 23.7 * DHM_Y

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Coefficient of determination (R^2) value for the total catch was 31.27%. In this, SST and DHM were found to contribute 52% (Table 6.47). Coefficient of determination (R^2) value for the crab fishery was 20.29%. In this, 23% was contributed by LTA (Table 6.48).

Table 6.47 - Regression model results of Tamil Nadu district using chlorophyll concentration and CPUE of NM gear as Response (Dependant) variables and SST, chlorophyll concentration, LTA, rainfall, salinity, anomaly current direction and SST, DHM, DCM , rainfall Standardized anomaly as covariate (Independent variables)

Response variable	Chlorophyll concentration	CPUE of NM
variance explained by model	69.95%	31.27%
SST_M	0.02	0.26
CHL	---	0.05
LTA_D	0.07	0.01
LTA_N	0.42	0.06
SST_M_A	0.02	0.01
CUR_D_A	0.01	0.02
SALT	0.41	0.01
RF	0.02	0.06
RF_STA	0.00	0.01
DHM	0.00	0.26
DCM	0.02	0.25

Table 6.48 - Regression model results of Tamil Nadu district using crabs, other sardines, Indian mackerel and oil sardine fishery as Response (Dependant) variables and SST, chlorophyll concentration, LTA, rainfall, salinity, anomaly current direction and SST, DHM, DCM and rainfall Standardized anomaly as covariate (Independent variables)

Response variable	Crab catch
variance explained by model	20.29%
SST_M	0.14
CHL	0.09
LTA_D	0.03
LTA_N	0.23
SST_M_A	0.06
CUR_D_A	0.01
SALT	0.06
RF	0.16
RF_STA	0.01
DHM	0.07
DCM	0.16

Table 6.49 - Multiple linear regression equations for the response variables in the coastal zone of Tamil Nadu

Model No:	REGRESSION EQUATION
1	CHL = 16.8 -0.85 * SST_M - 0.65 * LTA_D + 1.29 * LTA_N -0.01 * SST_M_A * - 0.001 * CUR_D_A + 0.28 * SALT + 0.0009 * RF -0.006 * RF_STA + 0.69 * DHM -0.75 * DCM
2	TOT = 290205.6 - 10988.9 * SST_M -370.2 * CHL -1567 * LTA_D -277.6 * LTA_N + 0.12 * SST_M_A -2.5 * CUR_D_A + 1624.5 * SALT + 6.17 * RF -251.9 * RF_STA -2159 * DHM -11154.8 * DCM
3	OBBN = 22555.9 -987 * SST_M -93.7 * CHL -659.7 * LTA_D + 491.5 * LTA_N + 35.4 * SST_M_A -1.3 * CUR_D_A + 215.05 * SALT + 1.96 * RF -4.1 * RF_STA + 631 * DHM -882.6 * DCM
4	OBPS = -23290 + 830.5 * SST_M + 176 * CHL + 119.5 * LTA_D -772 * LTA_N -82.6 * SST_M_A + 0.8 * CUR_D_A -44.97 * SALT + 1.3 * RF +34.9 * RF_STA -710.6 * DHM + 876 * DCM
5	NM_CPUE = -24570 + 820.6 * SST_M -7.7 * CHL -1.5 * LTA_D -46.6 * LTA_N -3.1 * SST_M_A -0.21 * CUR_D_A + 0.97 * SALT + 0.17 * RF -6.65 * RF_STA -854.6 * DHM + 823 * DCM
6	OBBS_CPUE = 10787.05 -354 * SST_M + 3.23 * CHL -190.44 * LTA_D + 193.6 * LTA_N + 14.3 * SST_M_A -0.21 * CUR_D_A -2.9 * SALT -0.3 * RF -10.3 * RF_STA + 111.46 * DHM -378 * DCM
7	OBGN_CPUE = 736 -25.2 * SST_M -0.44 * CHL -4.3 * LTA_D + 9.07 * LTA_N + 1.13 * SST_M_A + 0.02 * CUR_D_A + 2.05 * SALT + 0.06 * RF + 0.49 * RF_STA + 4.28 * DHM -26.7 * DCM
8	OBHL_CPUE = 2106 -60.95 * SST_M + 5.1 * CHL + 12.4 * LTA_D - 24.2 * LTA_N + 1.09 * SST_M_A - 0.0007 * CUR_D_A - 6.37 * SALT - 0.05 * RF + 1.6 * RF_STA + 14.63 * DHM -69.2 * DCM
9	OBOTHS_CPUE = 1887.57 -139.07 * SST_M -57.6 * CHL -6.86 * LTA_D -162.4 * LTA_N -74.87 * SST_M_A -0.5 * CUR_D_A + 83.2 * SALT -1.44 * RF + 18.46 * RF_STA - 92.1 * DHM -75.5 * DCM
10	OBRS_CPUE = 47309.8 -1669.6 * SST_M + 421.5 * CHL -234.9 * LTA_D - 212.54 * LTA_N -1.01 * SST_M_A + 0.19 * CUR_D_A + 110.5 * SALT -0.75 * RF + 5.3 * RF_STA + 2800.8 * DHM -1766.3 * DCM
11	OBSS_CPUE = 31586.4 -995.5 * SST_M -90.25 * CHL -206.8 * LTA_D + 165.14 * LTA_N -53.6 * SST_M_A + 0.29 * CUR_D_A -40.7 * SALT + 0.24 * RF + 73.3 * RF_STA + 828.2 * DHM -1103.8 * DCM
12	OBTN_CPUE = 6487 -207.5 * SST_M -32.3 * CHL -73.7 * LTA_D + 89.75 * LTA_N -1.1 * SST_M_A + 0.04 * CUR_D_A - 5.2 * SALT -0.07 * RF +9.75 * RF_STA + 118.3 * DHM -231 * DCM
13	OBBN_CPUE = 41240 – 1409 * SST_M -158 * CHL -364 * LTA_D + 449.3 * LTA_N + 38.15 * SST_M_A + 0.08 * CUR_D_A + 50.9 * SALT + 0.59 * RF -27.2 * RF_STA + 1564 * DHM -1463 * DCM
14	OBPS_CPUE = -67230 + 2267 * SST_M + 822.2 * CHL + 518.46 * LTA_D -1636.4 * LTA_N -71.76 * SST_M_A + 3.8 * CUR_D_A -20.8 * SALT -1.89 * RF + 152.5 * RF_STA -2582 * DHM + 2200.8 * DCM
15	OS = 99066 -4200 * SST_M + 447.8 * CHL -294.8 * LTA_D -4.85 * LTA_N + 182 * SST_M_A -3.13 * CUR_D_A + 866.96 * SALT-0.76 * RF + 91.49 * RF_STA + 1682.54 * DHM -4350.7 * DCM
16	STL = 59481.8 -2259.6 * SST_M + 140.5 * CHL -38.9 * LTA_D + 345.47 * LTA_N + 19.9 * SST_M_A -1.17 * CUR_D_A + 259.4 * SALT -0.19 * RF + 109 * RF_STA + 1203.46 * DHM -2418.27 * DCM
17	IM = 35157.96 -1624.36 * SST_M -837 * CHL -1000 * LTA_D + 1423 * LTA_N + 159.25 * SST_M_A - 6.46 * CUR_D_A + 449.25 * SALT + 1.46 * RF + 41.6 * RF_STA + 589 * DHM -1467.8 * DCM
18	CRB = 986 + 88.4 * SST_M + 83.8 * CHL -68.5 * LTA_D + 398 * LTA_N + -31.6 * SST_M_A + 0.8 * CUR_D_A -83.3 * SALT -1.1 * RF + 26.13 * RF_STA -630.96 * DHM -96.2 * DCM
19	OTS = -31279.3 + 1693 * SST_M + 52.1 * CHL -938.36 * LTA_D -1341 * LTA_N -336.6 * SST_M_A + 3.18 * CUR_D_A - 491.65 * SALT + 6.88 * RF -429.9 * RF_STA -4508.6 * DHM + 1522.9 * DCM
20	PFB = -10010 + 294 * SST_M -97.56 * CHL + 312 * LTA_D -121 * LTA_N + 28.3 * SST_M_A + 1.4 * CUR_D_A + 54.8 * SALT -0.61 * RF -35.5 * RF_STA -574.9 * DHM + 394 * DCM

CHAPTER 7

DISCUSSION

7.1 Impact on catch, effort and CPUE: South India Flood-2015 and Cyclone Ockhi

The impact of two extreme events, the South India Flood-2015 along northern Tamil Nadu and cyclone Ockhi-2017 along Kerala and Tamil Nadu coastal districts were studied. The analysis indicated that, the impact on total catch and effort varied between the flood affected districts, higher in Chennai and Cuddalore, lower impact at Kancheepuram and positive impact on marine fisheries in Thanjavur and Thiruvallur. During the SIF-2015, there were actually no direct loss in fishing days, but the catch and effort declined mainly due to other land based destruction and damages which affected the fisher families residing in the coastal villages of Chennai.

All public service activities in Chennai were affected and more than 400 people lost their lives, about 18 lakh people were displaced and the damage was assessed as more than US$ 18 billion (Anand *et al.*, 2016). Considering these impacts the fisher community would have found it difficult to go for fishing even though the natural disaster was land based. Moreover, all trade and transactions were also affected thereby making marketing of fishery resources impossible (NRSC, 2016; Narasimhan *et al.*, 2016; Rajya Sabha Report, 2016). Such instances where fish marketing becomes difficult after a natural disaster has occurred in several countries, especially small island nations (Benson *et al.*, 2001). Hence it could be presumed that the negative impact on marine fisheries at Chennai was mainly due to land based issues.

Unlike SIF-2015, cyclone Ockhi had a more severe direct impact on coastal communities of Thiruvananthapuram, Kollam, Alappuzha and Ernakulam of Kerala and Kanyakumari, Tuticorin and Thirunelveli districts of Tamil Nadu. This extreme event brought in loss of lives and fishery related infrastructure in the coastal communities (FAO and ICSF, 2019). In the present study it was observed that the most impacted districts were Thiruvananthapuram and Kanyakumari and the catch and effort remained very low during the cyclone and post cyclone period also while further north, the impact was comparatively less. This was mainly because the fisher communities were directly impacted since the cyclone had destroyed several fishing crafts and many fishermen had lost their fishing gear. The basic infrastructures in the landing centres in several areas were damaged. Apart from this, several fisher families were finding it difficult to recover from the shock of missing family members who had gone out to the sea and could not come back to the shore since they were totally unaware and unprepared for this natural disaster. The poor catch for several months was primarily due to low fishing activity. Such instances where marine fisheries have been directly affected due to non-resource factors, rather due to direct loss of fishing craft and gear and other losses has been recorded in other regions also (Westlund *et al.*, 2007). One such natural disaster which led to huge loss in fishing craft and gear, other post-harvest infra-structure and fisher fatalities was the Indian Ocean Tsunami - 2004 which affected several parts of Asia (Westlund *et al.*, 2007).

7.2 Resource abundance and assemblage –South India Flood

In the SIF-2015 analysis, the CPUE of MDTN and MTN operating from the flood impacted districts were found to be not negatively affected indicating that resource assemblages which were distant from the coastal area were same and did not change much. However, the CPUE of OBBN and OBGN were low indicating that the ecological changes have affected the fishery resources in the surface and column area of coastal waters. Moreover, in the species assemblage of these gears much variation was observed.

Environmental variations observed were mainly decrease in SST and increase in chlorophyll-*a*. Compared to previous months, SST lowered in November and December months (flood period) in all the districts. Chlorophyll-*a* concentration increased in December (0.39 to 1.19 mg/m^3) in Chennai and in all other districts except Cuddalore. Increase in rainfall and decrease in salinity was also noted in all districts but the range differed. High rainfall was noticed in the Chennai and Kancheepuram districts (>1000mm). Increase in current velocity was also observed during the flood period. LTA was positive and sharply declined in December. Compared to other districts, upwelling intensity was high in Thanjavur and Thiruvallur districts.

In the near shore areas where OBBN was operated, during the flood period at Chennai there was considerable decline in landings of sardine and *Stolephorus* and there was absence of Indian mackerel and *Thryssa* during this period. It has been observed that flood waters can displace large quantities of coastal waters which can reduce the salinity and increase the nitrogen /nutrient load in coastal ecosystem (Paerl *et al.*, 2001). Though this study has been basically for a very large estuary, the situation due to influx of flood waters in coastal fishing area in the present study is comparable.

Lobsters formed a large part of the coastal resource assemblage during the flood period. Mass movement of lobsters leading to increased catch has been observed when the salinity and temperature varied from Normal and ecological changes were pronounced following heavy rainfall after a hurricane (Jury *et al.*, 2005).

Several demersal shellfish and fish resources were found to be affected; they were either caught in large numbers during flood or post flood months. Moreover, the fluctuations were not uniformly similar or synchronised. For instance, penaeid prawn resources increased in the OBGN fishing area during flood as well as post flood but at Cuddalore there was a decrease. In the MDTN catches, there was an increase in landing of penaeid prawn, indicating that both nearshore and offshore areas were affected; Crabs were found to increase at Thanjavur and Thiruvallur and reduce at Chennai. In Tamil Nadu, Coefficient of regression (R^2) value was 20.29% for crab catch and LTA contribute 23% of the percentage variance explained by regression model. Catfishes were found to increase at Thanjavur during flood and at Cuddalore during post flood. Rays increased at Thiruvallur during flood and at Cuddalore during post flood. Cuttlefishes were found to increase in OBGN during flood period at Kancheepuram and Thiruvallur and at Cuddalore during post flood. These resources (Penaeid prawns, crabs, catfishes, rays and cuttlefishes) are basically bottom dwellers.

After the super cyclone and rainfall in Odhisha in 1999, Kundu *et al*. (2001) have reported high concentrations of total suspended solids (TSS) brought in from the rivers and also high chlorophyll. This organic load can lead to temporary hypoxic areas. During the flood of 1993 there was a 62-year maximum discharge which led to a hypoxic zone in the Gulf of Mexico which was twice the size relative to the average of 1985–1990 (Lehrter *et al.*, 2017). Similarly in marine teleosts like the bonehead and *Sphyrna tiburo*, salinity was found to make a profound impact on its movement (Ubeda *et al.*, 2009). Describing the effect of Tropical storm Agens in 1973 in the Chesapeake Bay Roman *et al.* (2005) have indicated that there was a very heavy rainfall which was followed by huge quantity of organic inputs into the bay which led to hypoxic condition.

Linking these it could be presumed that the ecological changes including low salinity due to huge influx of freshwater and the load of TSS and organic matter would have disturbed the benthic niches during the south India floods in the coastal waters near the impacted districts. Since the quantity of influx varied, the intensity of local impact also would have differed.

Small pelagic fishes were also found to be affected. Oil sardine was absent at Kancheepuram and declined at Chennai during flood but increased during post flood. Indian mackerel catch reduced in the OBGN at Chennai, but increased at Kancheepuram, Thiruvallur and also during post flood at Chennai, Kancheepuram and Cuddalore. Small pelagic fishes like sardines and mackerel which usually occupy the upper column water would have been disturbed by the high turbidity and low salinity which usually follows a flood and the fluctuation could be attributed to these variations. The increased chlorophyll after the cyclone can induce positive changes in productivity. These changes can support growth of phyto and zooplankton which in turn form food for small pelagic fishes like sardine, mackerel and anchovies. The oil sardine and *Stolephorous* fishery were positively correlated with Chlorophyll and Sea surface salinity.

Roman *et al*., (2005) have observed bloom of phytoplankton followed by high abundance of the calanoid copepod *Eurytemora affinis* in the Chesapeake after Hurricane Isabel made landfall in September 2003. They observed both physical and biological changes especially phytoplankton bloom trigged by nutrients increase from storm runoff. The probable reason for increase in other sardines during the flood and post flood period at Chennai and Kancheepuram could be related to situation like this which would have taken place in certain areas of the coast. The high levels of Chlorophyll-*a* observed in the present study after SIF 2015 could be compared to the increased Chlorophyll-*a* reported after Hurricane Isabel (Roman *et al.,* 2005).

In the case of large pelagics in Chennai in the MGN fishing area, there was a reduction in the abundance of *Auxis* spp, other tunnies, bill fishes and *K. pelamis.* However, during the post flood period the abundance of resources increased, especially other carangids, rays and *S. commersoni*. In the OBHL fishing area complete absence of bill fishes, and other tunnies (Chennai), *K. pelamis* (Chennai, Kancheepuram) and reduced catch of *Auxis* spp and other carangids was observed. Since these are fast moving fishes, the unfavourable conditions in the coastal waters would have made them avoid these regions, leading to a low catch.

In the Chennai MDTN catches, there was an increase in mullets catch (absent during the pre-flood period) which could be due to increased food available since they are herbivores/ planktivorous fishes. The comparatively low salinity which could be tolerated by mullets which are euryhaline also would have increased their abundance in the area. Contrary to this, it was observed that heavy rainfall and high water discharges into the Hudson River Estuary increased the water level and reduced the water temperature, salinity and dissolved oxygen levels and the striped bass moved out of the estuary exhibiting strong evacuations (Bailey and Secor, 2016)

7.3. Resource abundance and assemblage - Cyclone Ockhi

During the cyclone period, resources which formed a major component of the zone were either absent or in low abundance. Absence of *Stolephorus*, ribbon fishes and *K. pelamis* in the fishing area of Thiruvananthapuram and Kollam and low abundance of Indian mackerel and *Auxis* spp were found to be the main changes in resource assemblage. Similar variations especially low abundance was observed throughout the impacted districts during cyclone. This could be due to avoidance of the area by these teleosts which started appearing in the fishery after cyclone when the conditions started becoming normal. Subramanyan *et al.* (2002) have observed cyclone-induced divergent geostrophic currents in the Arabian Sea. In the present study also the current velocity was found to increase.

The low abundance/absence of oil sardine during the cyclone started recovering after the cyclone. The increase in chlorophyll-*a* concentration after the cyclone in almost all coastal districts would have supported early revival of the fishery. In one of the first observations in the country on increase in chlorophyll-*a* after a cyclone (Odisha cyclone - 1999) it was stated that there is a probability that the pelagic fishery could be positively be impacted and the Department of Fisheries of the state had informed that there was an increase in fishery in Chilka Lake (Kundu *et al.*, 2001). Subrahmanyam *et al.* (2002) have also indicated that short lived cyclone in the Arabian Sea can increase the chlorophyll-*a* to very high values (5–8 mg m^{-3}). The intense phytoplankton production is primarily through enhanced vertical turbulent mixing by the winds. In the present study an upwelling and downwelling was also observed after the cyclone Ockhi and this is could be compared with such episodes globally where typhoons are found to induce strong ocean mixing and upwelling (Price, 1981; Dickey *et al.*, 1998; Lin *et al.*, 2003; Sanford *et al.*, 2011; Lin *et al.*, 2012). All cyclones, however, need not increase chlorophyll and cause upwelling (Lin *et al.*, 2011).

The low abundance penaeid prawns in the coastal waters off Alappuzha and Ernakulum during the cyclone period changed immediately after the cyclone. In Alappuzha, the penaeid prawn catch almost doubled in OBTN during the post-cyclonic months. The CPUE of NM and OBGN improved significantly indicating that the resources in the area had increased. Upwelling is known to lead to low oxygen condition leading to higher catch of shrimps (Prasannakumar *et al*., 2018).

One major change observed was the increased catch of bivalves at Thiruvananthapuram in the non-motorised sector. The Vizhinjam Bay and the rocky zone in Thiruvananthapuram has supported a good mussel fishery for long (Ramachandran *et al*., 1998) and the fishers who were affected by Ockhi would have considered it safer to fish in the near-shore areas which would led to higher catch.

In Kanyakumari, small pelagic fishes like sardine and mackerel, large pelagics like tuna and seer fishes and demersals like threadfin breams which were the major components of the catch in different gears were found to be either absent or in very low abundance during the cyclone. These started appearing again during post cyclone period but the fishing effort continued to be low. In Tuticorin and Thirunelveli, the recovery was faster mainly because the fisher families were not affected. These indicate that the changes in the ecosystem are not long lasting, rather, the beneficial ecological changes in the habitats help the fishery to revive early. SST slightly decreased in all three affected districts during December. Compared to normal, chlorophyll concentration increased by 21.6% in Kanyakumari which was favourable for fishery.

High speed winds can increase the current magnitude. Cyclones may induce upwelling, but it mainly depends on the wind direction. During and after the cyclone months, velocity of the surface current was considerably high (0.08 to 0.25 ms^{-1}). The current direction had changed slightly along affected part of southwest coast but did not change in Tuticorin and Thirunelveli. Unlike Kerala coast, current velocity decreased by 82% from Normal in south east coast. There was also a variation in current direction. This variation in current velocity and direction would have affected the resources. Studies on this have not been undertaken in Indian waters. However, Roman *et al.* (2005) have observed large number of juvenile young Atlantic croaker occurred in Chesapeake Bay after Hurricane Isabel in the year 2003. Since November and December is the period when most demersal fishes spawn along the southwest coast, the impact of this change in current velocity and direction is actually a matter of concern. It could have transported the larvae and juvenile and affected the recruitment. A pronounced shift in water column characteristics and variation in the composition of plankton communities was observed along the margin of the southern Northwest Shelf, Australia following the passage of Tropical Cyclone Tiffany in January 1998 and it has been observed that long-shore water transport forced by cyclonic winds may be a mechanism for larval transport (McKinnon *et al.*, 2003). Jones and Syms (1998) and Lassig (1983) revealed that cyclones cause increased juvenile mortality and re-distribution of bottom or reef-associated fish communities.

7.4 Socio-economic aspects

As indicated earlier, there was no direct loss in fishing days during the South India Floods - 2015. However, the decline in catch due to decline in fishing effort was mainly a social or community problem which is basically land-based. The damage to interior fish market and telecommunication, transport and other support systems in Chennai indirectly affected the marine fisheries.

However, cyclone Ockhi which was a least expected extreme event along the south west coast directly affecting four coastal districts of Kerala and three districts of south Tamil Nadu was a unforgettable tragedy to the marine fishing communities spread across 100 fishing villages. It led to death or disappearance of more than 350 coastal villagers. Several fishers who had gone out to the sea for fishing could not be contacted and they could not be traced also. In Tamil Nadu, an estimated 60 mechanized boats and 3407 Fibre-reinforced plastic (FRP) vallams were fully damaged. Also, 640 mechanized boats and 3407 FRP vallams were partially damaged. In Kerala, fully damaged/losted boats were 384 (Rajya Sabha Report, 2018). Similar instances have affected fishers of Andhra Pradesh during cyclone of 1996 (Yadava *et al.*, 1998). However, in the recent years, fatalities are considerably less due to the better Disaster Management Plans and early warning and communication systems. For example in the cyclone Phailin, which struck Odisha coast in October 2013 affecting 44,806 fishers had only 50 fatalities (FAO and ICSF, 2019). This clearly indicates that the early warning system for extreme events should be improved for Kerala state and also for south Tamil Nadu which are not annually affected by cyclones and floods as in other parts of east coast.

Thiruvananthapuram district which has the highest population density was the worst affected and in Tamil Nadu, Kanyakumari was the badly affected district. In these two districts, the recovery of fisheries would be slow since several fishers had lost / damaged their craft and gear. Additionally loss of their other physical assets and human lives has also reduced the pace of recovery similar to the cyclone impact on fishers of Fiji (Radway *et al.*, 2016) Bangladesh (Paul, 2014) and most small island nations (Westlund *et al.*, 2007).

In this study, only the direct impact due to loss in fishing days was evaluated. In general an estimated 3,21,495 man days of fishers directly engaged in marine fishing activity was lost in Kerala due to cyclone Ockhi which led to an estimated loss of Rs.116.29 crores. In Tamil Nadu, the stimated total economic loss was 36.17 crores. Mechanized sector had the highest revenue loss while number of man day lost was highest in the motorized sector. The non motorized sector was also badly affected. In several villages they did not go for fishing for several days. The loss to mechanized sector was found to be higher than motorized crafts during cyclone Vardha in Chennai (Geetha *et al.*, 2016). Huge loss was incurred along Kerala coast when the non-mechanized and motorized sectors were badly affected by Tsunami of 2004 (Sathiadhas and Prathap, 2005). Maximum reduction in landings was experienced by plank-built boats with gillnet (motorised) and country crafts with gillnets (non-mechanized). In Fiji where fishermen were impacted through loss in fishing gear and damage to houses, post-cyclone, 52% of the fishers had stopped harvesting crabs because many were focussed on repairing their homes and had difficulties in accessing collection sites and markets. Similar situation was observed in flood affected regions.These observations clearly indicate that fishers and coastal communities are severely impacted by extreme events like floods and cyclones and that there should be clear cut plans to reduce the impacts and also for early and fast recovery from such events.

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CHAPTER 8

SUMMARY

Along the Tamil Nadu (TN) coast the number of cyclones has increased drastically since 1961. There was just one cyclone during the decade 1961-1970, no cyclones in 1971-1990 while it was nine in the present decade (2011-18) which gives a frequency of 1.12 per year from 0.1 per year in five decades back. This study was conducted to evaluate the impact of two extreme events South India Flood 2015 and Ockhi along Kerala-South TN coast 2017 on the marine fisheries of affected twelve districts. The study indicated strong impact on fish catch, resources, environment and livelihood of fishers indicating the need for increasing the preparedness in coastal communities. Details summarised below

South India Flood

Analysis of impact of 13 craft-gear combinations in the five flood affected districts of TN (Chennai, Cuddalore, Kancheepuram, Thiruvallur and Thanjavur) indicated that the impact on catch, effort and catch per unit effort (CPUE) varied between districts and gears.

Overall, the impact on catch and effort was highly negative in out-board motorised sectors especially in boat seines, hook and line and gill netters with 64 to 97% reduction compared to the pre-flood period. The impact continued for the immediate three month post flood period also. However, the impact was medium with 30% reduction in effort at Kancheepuram and while there was strong positive impact at Thanjavur.

High variation (79.54%) in species assemblage in the motorised boat seines operated in the near shore waters off Chennai was observed. Reduction / absence in pelagic fishes like sardine Indian mackerel, *Stolephorus*, and *Thryssa* was evident indicating the impact of flood waters in near-shore fishing grounds.

The large pelagic fishes like tunas and billfishes were also found to be reduced or absent in the upper column waters off Chennai, Cuddalore and Kancheepuram thereby impacting the hook and line and gill net fishers.

Increase in catch of penaeid prawns, lobsters and crabs were observed in some areas indicating disturbance in benthic regions which was beneficial for Mechanized trawlers.

Cyclone Ockhi 2017

The impact of Ockhi was very high with more than 90% reduction on the marine fisheries of Trivandrum, Kollam, Alappuzha and Ernakulam districts of Kerala during the cyclone period. The impact was highest in Thiruvananthapuram district with 57 to 85% reduction in catch and about 77.7% decrease in effort. The impact was less during the post cyclone.

Along TN coast, three districts were affected Kanyakumari, Tuticorin and Thirunelveli. Among this, the most impacted was Kanyakumari with more than 85% decline in catch for almost all major gears and the impact continued during the post cyclone period also. In Tuticorin and Thirunelveli, the impact was less and positive impact was also observed in OBGN effort and catch at Thirunelveli.

The SIMPER test revealed that the species constituting a community were almost the same, but with either low abundance or complete absence. In the MRS fishing area Indian mackerel abundance was very low which contributed to 32% of the variation in resource assemblage dissimilarity. Absence/low abundance of small pelagics in the near-shore affected the coastal fisheries.

Sudden increase in bivalve in the non-motorised fishing area and in lobsters in the OBBS fishing area of Thiruvananthapuram during the post cyclone period contributed to 59% and 39.8% of the dissimilarity respectively. This indicates that extra effort occurs during the post-cyclone period in this area.

Environmental changes induced by Cyclone Ockhi

During Cyclone Ockhi, SST decreased slightly while chlorophyll-*a* concentration, rainfall and salinity increased from normal. Chlorophyll concentration increased by 27% (0.42 to 0.54 mg m^{-3}). During and after the cyclone months, magnitude/ velocity of the surface current speed increased from 0.08 to 0.25 ms^{-1}. The current direction had changed slightly. During December and January, downwelling and upwelling occurred along the Kerala coast. Total catch was extremely low (-11322 tonnes). But the catch showed a sudden recovery in the post cyclone months.

Environmental changes and its impact on fisheries

The regression model indicated that environmental variations contribute to 47% of the total catch variation and in this SST and Degree Cooling Months values contribute 25 and 26% of its total variation in Kerala.

The percentage variance explained by the model for the OBGN-CPUE and OBHL-CPUE were 59% and 49% respectively. In OBGN-CPUE , changes in SST contributed 24% of its variation and in OBHL-CPUE , upwelling index (LTA) contributed 26% of its variation.

Using the regression model, 26.5, 16.02, 23.3, 20.98, 18.86, 28.23% of Indian mackerel, oil sardine, other sardine, scads, squid and *Stolephorous* landings could be explained respectively. Indian mackeral landing mainly depended on the Chlorophyll standardized anomaly (34%). The percentage variance explained by the regression model for oil sardine fishery, 39% contributed by sea surface salinity.

The Regression model could explain the 31.88% of monthly OBBN-CPUE variation of Tamil Nadu. The percentage variance explained by the regression model for the CPUE variation, 89% is contributed by chlorophyll-*a* concentration.

Socio-economic impact

In Kerala, economic loss due to loss in fishing days (abstaining from fishing) was estimated to be 107.29 crores. Based on the economic loss, Kollam (₹22.98 crores), Thiruvananthapuram (₹16.84 crores) and Kozhikode (₹15.6 crores) districts were found to be more impacted. The total economic loss from loss in fishing days and from craft and gear damages was 116.29 crores. In Kerala total loss in mandays was estimated as 3,21,494. Compared to other districts, loss in mandays was higher in Trivandrum (97,971).

In Tamil Nadu, the loss in fishing days due to cyclone Ockhi at Kanyakumari and Thirunelveli districts were 20 and 14 days respectively and Kanyakumari was the most impacted with a loss of ₹12.27 crores. There was no loss in fishing days at Tuticorin district. The total economic loss (loss in fishing days and craft and gear damage) in Tamil Nadu due to cyclone Ockhi was 36.17 crores.

General Conclusion

The study indicated that extreme events like floods can impact the fishermen due to land based destruction of essential infrastructure and facilities especially those related to post harvest like marketing. Events like Cyclone Ockhi which affects the fishers directly destroying the fishing craft/gear and the fisher's houses and loss in lives have a more lasting impact.

The increased vulnerability of fishermen community as indicated by the reduction in catch, loss in fishing infra-structure and lives clearly indicated the need to increase the adaptive capacity of fishers and also the preparedness for such extreme events which can reduce the impact and increase the resilience capacity of the fishers.

The study brought out the intricate relationship between environmental changes and fishery fluctuations. The ecological changes like increase in chlorophyll, low SST and upwelling induced by cyclone was understood from the analysis which is beneficial for most pelagic resources. However, the increase in current velocity and change in current direction found during the cyclone period can lead to drifting away of eggs, larvae and juvenile fishes which may impact recruitment to the fishery after cyclone.

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CHAPTER 9

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Assessment of the Impacts of Selected Extreme Climatic Events on the Marine Fisheries along Kerala and Tamil Nadu Coast

by

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THESIS ABSTRACT

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CHAPTER 10

ABSTRACT

Globally, one of the most severe impacts of climate change has been identified as the increase in the number of extreme events. The impact of two extreme events, the South India Flood 2015 in Tamil Nadu (TN) and tropical cyclone Ockhi which hit the Kerala and south TN coast in 2017 on the marine fisheries was studied. Analysis of impact on 13 craft-gear combinations in the five flood affected districts of TN indicated that the impact on catch, effort and catch per unit effort (CPUE) varied between districts and gears. Overall, the impact on catch and effort was highly negative in out-board motorised sectors with 64 to 97% reduction. Reduction / absence in pelagic fishes like sardine, Indian mackerel, *Stolephorus*, and *Thryssa* was evident and indicating the impact of flood waters in near-shore fishing grounds. Increase in catch of penaeid prawns, lobsters and crabs were observed in some areas indicating disturbance in benthic regions which was beneficial for Mechanized trawlers. The impact of tropical cyclone Ockhi was very high with more than 90% reduction on the marine fisheries of Thiruvananthapuram (TVM), Kollam, Alappuzha and Ernakulam districts. Along TN coast, Kanyakumari, Tuticorin and Thirunelveli were affected and the most impacted was Kanyakumari with more than 85% decline in catch for almost all major gears. The SIMPER test revealed that the species constituting a community were almost the same, but with either low abundance or complete absence. During Ockhi chlorophyll concentration increased by 27% (0.42 to 0.54 mg m^{-3}), the velocity of the surface current increased (0.08 to 0.25 ms^{-1}), SST reduced, there was change in current direction along the Kerala coast. In Kerala, total economic loss from loss in fishing days due to cyclone Ockhi was estimated as ₹107.29 crores with maximum loss at Kollam (₹22.98 crores) followed by TVM (₹16.84 crores). In TN coast, estimated economic loss was 12.5 crores. The study clearly indicated the increased vulnerability of marine fishers and the communities to climate change especially extreme events. The loss in human lives, fishing craft and gear due to Ockhi which was an unexpected event had a deep impact on the coastal communities making the recovery time from impact longer and stressful. The study points out that though the ecological system based changes were low due to tropical cyclone, the socio-economic impact was high and there is a need to develop early warning and vessel tracking systems to increase the preparedness of fishers to unexpected extreme events. Targeted research programs to assess the impact of environmental variations of extreme events on eggs, larvae and juveniles would help to identify the reasons for fishery fluctuations if any and help in fishery predictions.