Indian Journal of Ecology (2022) 49(3): 888-893
DOI: https://doi.org/10.55362/IJE/2022/3611

Manuscript Number: 3611
NAAS Rating: 5.79

Impact of Selected Environmental Parameters on Marine Fish Landings of Coastal West Bengal

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Abstract: With the advent of satellite oceanography, environmental and oceanographic variables like Chlorophyll a, rainfall can be estimated on a scale not possible before. The objective of this study, is to investigate the relationship between the total annual marine catch of West Bengal of the last 20 years and these three important variables, coastal rainfall, Chlorophyll a and sea surface temperature. The relevant independent variables are rainfall for the months of May to August, Chl a for the months of November to December, and sea surface temperature for the months July to December. The study has found significant statistical correlations between the annual marine landings of West Bengal and the above mentioned parameters. Both Chlorophyll a and rainfall have been found to have significant statistical correlations with annual catch.

Keywords: Chl a, MODIS, SEAWIFS, SST, Monsoon rainfall, West Bengal Marine Fisheries, Climate change, Cobb Douglas model

Ocean color remote sensing started with the CZCS (Coastal Zone Colour Scanner) instrument in the 1980s. More advanced instruments like SEAWIFS (Sea Viewing Wide Field of View Sensor) from 1997, and the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor from 2002, have made estimating ocean color (Chlorophyll a), over a wide area. Similarly sea surface temperature (SST) has been estimated from Sensors like AVHRR (Advanced Very High Resolution Radiometer). Agencies like NOAA (National Oceanographic and Atmospheric Agency), and NASA (National Aeronautics and Space Administration) maintain a large database of atmospheric and oceanic parameters like SST (Sea surface temperature), Chl a (Chlorophyll a) and rainfall online. The primary production in a given area(which is closely related with planktonic biomass), is governed by the flow of nutrients like N, P, K, Si as well as other factors like sea surface temperature. In shallow coastal estuarine areas the major source of nutrients is river discharge and runoff. The positive effect of rainfall on coastal marine fish landings is well established (Ayub 2010, Hoguane and Cuamba 2012). The second variable is Chl a, is a pigment present in marine algae like diatoms, cyanobacteria which make up the bulk of the phytoplankton. Therefore by quantifying this variable with satellite sensors can estimate the concentration of phytoplankton over a given area. Therefore a positive relationship with this variable and marine nekton in a given area is expected (Friedland et al 2012, Nammalwar et al 2013, Hu et al 2015, Dutta et al 2016). The third variable is sea surface temperature (SST), which can give an estimate of upwelling in an ocean area,a low SST contributes to ocean productivity. Studies have also been conducted on linkages between catch of specific pelagic species like mackarel, tuna and these parameters with positive results (Zainuddin and Saitoh 2004, Pitchaikani and Lipton 2012, Nurdin et al 2013). Therefore, it can be said that in tropical coastal zones, the most important variables governing marine productivity are discharge and runoff (quantified with coastal rainfall), Chl a and SST .In this study SST was found to be inversely correlated with catch, but since the correlation was not statistically significant, the empirical Cobb Douglas model was empirically estimated using only rainfall and chl a as independent variables.

The state of West Bengal is situated between latitudes, 21^{0}- $0'$- $5''$ N and 24^{0}-$0'$- $5''$ N and longitudes 86^{0} E and 89^{0} E. It is the northern-most Indian state bordering the Bay of Bengal and has to its south the state of Orissa, while Bangladesh is to its north and north-east. West Bengal has a short coastline - only about 158 km, spread along the edge of its two maritime districts, south 24 parganas and east Mednipur. The marine resource base includes around 780 sq km of inshore area (about 20 m depth ,1815 sq km(about 20 m and 80 m depth) and a continental shelf of 17,049 km^2 (upto 200 m depth). The short coastline, around 158 km is however very productive, as the river discharge from the Ganges river system acts as a rich source of nutrients, the coastal waters in the Bengal delta region has high primary productivity, as can be seen clearly from NASA MODIS satellite imagery. The continental shelf is also much wider than the average in the eastern Indian coast in this sector, more than 50 km long. The wide continental shelf, due to the high sedimentation of the region, as well as seasonal monsoon rainfall runoff and river discharges from the Gangetic river system as well as smaller rivers like the Subornorekha contribute to the productivity of this area. The fishing season is highly seasonal starting in late June and ending in April. May and half of June has been enforced as a fishing ban .The peak season is from September to January. Historicaly, the major species caught in these fishing area is Hilsa, Bombay duck, species from the Catfish family and croaker family. Central Marine Fisheries Research Institute (CMFRI) found the major species during monsoon to be hilsa, prawn, B duck and post monsoon (October - January) species from the croaker family, Arius sea catfish family, hilsa and prawn (Mini and Kuriakose 2013). From a commercial point of view, hilsa and prawns are most important, because of high prices, but from an ecological point of view, the benthic and benthopelagic species like the croaker and catfish family dominate. This is probably because of the high turbidity of the coastal waters. The total retail value of annual marine catch of West Bengal is more than 8000 crores (Selim et al 2017). Therefore the investigation of whether the annual catch can be predicted from relevant environmental variables quantified from SRS (Satellite Remote Sensing) is of substantial economic importance and is the focus of this study.

MATERIAL AND METHODS

Study area: The coastal ocean off the Digha coast, West Bengal was chosen, because Digha along with nearby Shankarpur are the major marine fish landings zones of West Bengal. For coastal rainfall coastal area corresponding to Digha coast was chosen. The area corresponding to this data (Chla) is represented by (Fig. 1).

Data sources: Data was obtained from various sources, secondary data as well as remotely sensed data from online data severs of NOAA and NASA. The variables are:

Chl a data (MODIS and SEAWIFS) was obtained from NASA Ocean color website. SEAWIFS and MODIS data was correlated and a very strong correlation was observed and regression equation was used to estimate of the MODIS equivalent of SEAWIFS data for the years 1998-2001 (since MODIS is not available prior to 2002). For the years 2002-2018, MODIS data was used (4 Km resolution, OCI algorithm). This algorithm measures Chl a with the reflectance in the blue green region of the spectrum. The three bands used are in the 440 -660 nm region. The unit for the Chl a data is mg/m^{-3}. The estimates are derived using empirically derived relationships between the in situ measurements and reflectance's in the blue green spectrum.

VGPM (Vertically Generalised Productivity Model) net primary productivity data (strongly correlated with MODIS Chl a data), was downloaded from the University of Oregon Website to estimate the Chl a for a few months for which MODIS data was not available due to cloud cover.

Rainfall: Rainfall data for the Bengal Coastal region was obtained from NOAA PSL website. Data was sourced from NOAA PSL, CMAP precipitation data provided by (NOAA/OAR/ESRL PSL, Boulder, from their website). The variable chosen was CPC merged analysis (enhanced) average daily rainfall for the months of May, June, July, August (CMAP). The advantage of this method to get rainfall over for a wide area, just by giving latitude and longitude. The system subsets the wide area data in a color coded format, rainfall data is provided in mm/day. The values are calculated using a combination of satellite measurements and in situ measurements calculated on a global 2.5 by 2.5 degree grid. This coastal rainfall data was used to estimate the river discharge and coastal runoff. The latitudes and longitudes taken into consideration were (21, 22.5 and 87, 88).

Dependant variable: The dependant variable is total annual marine catch (1998-2018) of West Bengal.

Fish landings data: The annual landings data was obtained from Handbook of state fisheries published by the state fisheries department, for the years 2002-2018. Data for the years 1998-2001 has been sourced from the handbook of fisheries statistics (ministry of fisheries and agriculture). The estimate was arrived by sampling done at multiple landing centers like Digha, Shankarpur, Bakhali, Fraserganj, Namkahana, Kakdwip, Bakhkhali etc, (Handbook of Fisheries Statistics, 2014). The catch has been largely stable for the last 20 years, following a period of rapid growth due to intensive mechanization of the catch in the 90s, hence total volume of catch has been taken for 1998-2018, where

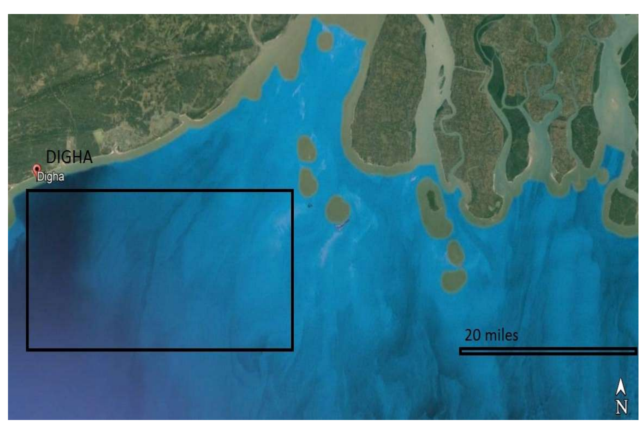

Fig. 1. Digha coastal area

the catch can be said to be dependent on environmental factors only. Most of the statistical computations were performed with SPSS software.

Digha coastal area: Digha along with Shankarpur are two of the major zones for marine fish in coastal west Bengal. Digha is close to the Hooghly estuary on the right as well the river Subarnorekha on the left. The Black boxed area represents the area chosen for calculation of average Chla concentration, this area represents the area in which most of the mechanized fishing takes place.

RESULTS AND DISCUSSION

Multivariate relationship using Cobb Douglas Model: The dependent variable is annual catch (1998-2018) and the independent variables are Chl a, and rainfall. The widely used Cobb Douglas model (Najimuddin and Sathiadas 2007, GG et al 2016) was used to model the relationship between catch and the independent variables rainfall, SST and Chl a. The Model can be defined as the form Y (output)= $kA^{a1}B^{a2}$ (k is a constant, A, B inputs, a1, a2 are the parameters).

In Linear multivariate form, can be represented as Log Y=Logk+a1logA+a2LogB. Using Method of least squares (OLS method). The Model equation was estimated to be Y (catch) $=98.6Rain^{0.187}Chla^{0.09}$, where Y (catch) is in 1000 tonnes. Rainfall is in mm/day, Ch la = mg/m^{-3}.

Model summary: R=0.667 R^{sq}=0.44, Adj R^{sq}=0.378 ,S. E =0.042,(p<0.01). N=20. Both rainfall and Chl a are positively related to total catch. From the multivariate relationship, it follows that a 100 % increase in Chl a and rainfall will result in a 9% and 19% increase in the catch respectively.

Relationship between rainfall and annual catch

Model of rainfall (R) with total catch.

Model equation: $Y=107.5R^{0.23}$, Y (catch) in 1000 tonnes. Rainfall=mm/day.

Model summary: R= 0.48, R^{sq}=0.23, S.E =0.04 , N=20. There is a significant positive bivariate relationship (p< 0.04) between 4 months average rainfall and total annual catch. From the regression equation, 100 percent increase in rainfall will lead to increase of catch by 23 %.

Relationship of Chla with annual catch:

Model equation: $Y=144.3Chla^{0.11}$. Y (catch) in 1000 tonnes.Chla: mg/m^{-3}.

Model summary: R=0.53,R^{sq}=0.28 ,S.E=0.044,N=20.

There is a statistically significant positive relationship (p< 0.02), between Chl a and total catch. The null hypothesis that there is no significant statistical correlation between total catch and Chl a, can be rejected (95% level). An 100 % increase in the quantity of Chl a will result in the 11 % increase in total catch. It can concluded that among the independent variables Chl a has the greatest variation, followed by rainfall.

The positive correlations between catch and Chl a, and catch and rainfall were e significant at 0.05 level. From the multivariate relationship (Fig. 1), there is a statistically significant correlation between annual marine fish landings as dependent variable, and monsoon rainfall and post monsoon Chl a as independent variables. The positive relationship between runoff / river discharge and primary productivity/marine fish landings in coastal ecosystems is well established. These contribute essential nutrients like nitrates, phosphates, and silicates into the coastal ocean. In coastal tropical regions because of high sea temperatures,

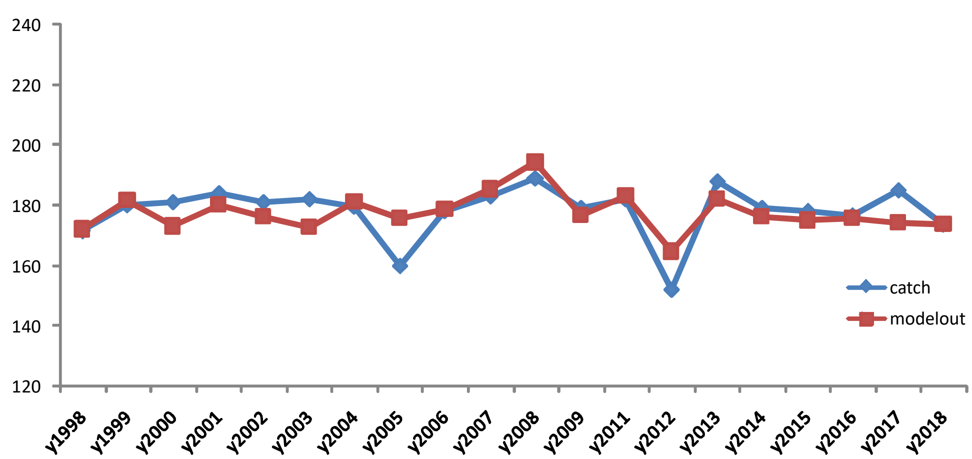

Fig. 2. Multivariate relationship of total catch (1998-2018) with rainfall and Chl a. Annual catch, Model output is in 1000 tonnes

ocean productivity is relatively less and more dependent on coastal runoff and discharge. Monsoon rainfall (4 months average), over a wide area(21 N,22.5N,87 E,88 E), has been used to estimate the variation in discharge and runoff. Monsoon rainfall generally contributes significantly to the runoff and discharge in the Ganges system, (Jian et al 2009). There is discharge into the coastal waters of Bengal not only from the Ganges system but also from the Subornorekha system, near Digha. The inflow of nutrients from the Ganges Brahmaputra System leads to an increase of primary productivity from the month of August-September (Das et al 2015). The post monsoon season contributes to majority of the fish landings (Mini and Kuriakose 2013). The monsoon rainfall also contributes to migration of fishes like Hilsa and Bombay duck. According to a study in the Rhone River delta, apart from dissolved nutrients, there is a linkage between benthic productivity and particulate organic matter (POM) in the freshwater discharge. The POM content in the river water in the deltaic regions contributes to a food source for benthic invertebrates like prawn and polychaete worms (Darnaude et

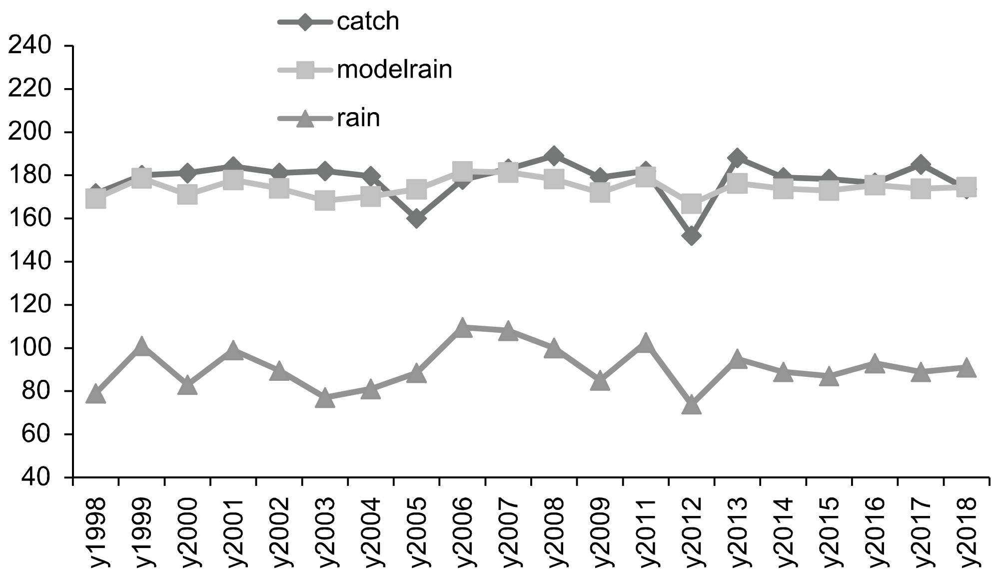

Fig. 3. Model output (with rainfall as independent variable), Catch (1998-2018) and rainfall. Catch and model output is in 1000 tonnes. Rainfall is in 0.1 mm/day

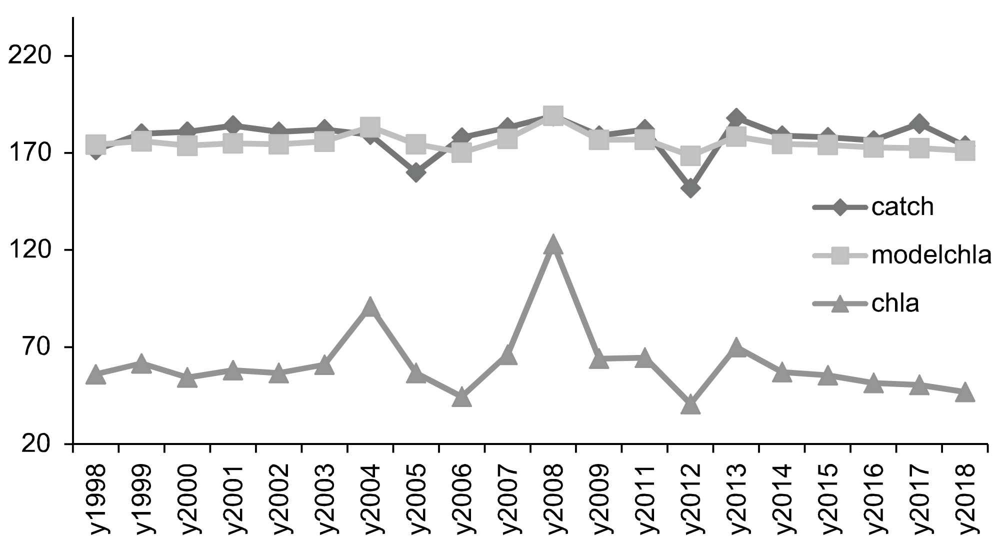

Fig. 4. Annual catch (1998-2018), model output (with Chl a as independent variable), and Chl a (2 months average , Nov-Dec). Catch and Model outputin 1,000 tonnes. Chla in 0.1 mg/m^{-3}

Table 1. Experimental details of various parameters

Variable	Units	Latitude and Longitude	Years	Months
Chl a, 4 km	mg/m^{-3}	(21.11 N,21.28 N ,87.11 E,87.46 E)	1998-2018	November-December
Rainfall (CMAP)	mm/day	(21 N,22.5 N and 87 E, 88 E)	1998-2018	May-August
Annual catch	Tonnes		1998-2018	Annual

Table 2. Cobb Douglas model parameters

Parameter	Value	P-value
Rainfall	0.187	0.044
Chl a	0.09	0.02

Table 3. Mean and standard deviation of rainfall, Chl a and total catch

Variable	Units	Mean	Standard deviation
Total catch	1000 tonnes	178	8.74
Rainfall	mm/day	9.1	0.99
Chl a	$mg\ m^{-3}$	6.12	1.78

Table 4. Correlation Matrix

	Rainfall	Chla	Catch
Rainfall	1	0.168	0.47
Chl a	0.013	1	0.478
Catch	0.47	0.478	1

al 2004). Since there are significant number of benthic species in the Bengal delta and coastal region, it is quite possible that this pathway contributes to the production of benthic species in the region.

The second significant variable is Chl a. High values of Chl a in surface waters is used as a proxy for plankton biomass, and primary productivity, which in turn enhance secondary productivity and landings of marine nekton. Average value of Chl a (MODIS 4km, OCI algorithm) was taken of November and December. These months were chosen because of a high percentage of noise free data during these months. November and December are also are ideal for plankton growth, because of low turbidity, adequate nutrients, and low SST. A higher value of SST leads to stratification, resulting in decreased productivity, also increased temperatures lead to fall in dissolved oxygen. The Chl a concentration in the coastal waters of this region starts increasing from August on an average (Jutla and Akanda 2011). The highest values are in the months of October, November and December in a typical year. The significant positive relationship with Chl a also validates the concept Of PFZ(Potential fishing zone), of INCOIS, in which remotely sensed Chl a and SST is used to prepare maps of productive ocean areas (Nammlawar et al 2013). Previous research has indicated that inverse relationship between Chla and SST (Chaturvedi and Pandya 2016, Kumar and Swapna 2016). Hence, climate change, leading to SST rise is likely to affect Chl a and hence catch. In conclusion there is a positive significant correlation of both rainfall and Chl a with annual catch, which is borne out by the multivariate relationship (Table 4).

CONCLUSIONS:

There is a positive significant correlation at both the multivariate as well as bivariate level between Annual catch as dependent variable and rainfall and Chl a as independent variables. As a consequence of climate change, there might be changes in rainfall and SST, which will affect the total catch .Since Chl a is negatively correlated with SST, SST rise due to climate change will have an negative impact on the catch .It is evident that despite limitations in accuracy of remotely sensed values atmospheric and oceanographic variables, they can be used for quantifying annual marine fish landings in West Bengal, which are of considerable economic importance to the state of West Bengal.

REFERENCES

Das S, Chanda A, Akhand A and Hazra S 2015. Characterizing the influence of tide on the physico-chemical parameters and nutrient variability nutrient variability in the coastal surface water of Northern Bengal during the winter season, of northern Bengal during the winter season. *Acta Oceanol Sin* **34**(12): 102-111.

Dutta S and Chanda A 2016. Correlation of Phytoplankton Biomass (Chlorophyll-*a*) and nutrients with the catch per unit effort in the PFZ forecast areas of Northern Bay of Bengal during simultaneous validation of winter fishing season. *Turkish journal of Fisheries* **16**(4): 767-777.

Darnaude M Audrey, Chantal Salen-Picard and Harmelin-VivienL Mireille 2004. Depth variation in terrestrial particulate organic, matter exploitation by marine coastal benthic communities off the Rhone River delta, (NW Mediterranean). *Marine ecology progress Series* **275**: 47-57.

Freidland Kevin, Stock Charles, Drinkwater Kenneth, Link S Jason, Leaf Robert, Shan Burton Rose Julie, Pilskaln H Cynthia and Fogarty Michael 2012. Pathways between Productivity of large marine ecosystems. *PlosOne* **7***(1)*: e28945 1-11

GG Mcnickle, Lynch DJ, Gonzalez-Meler, Baltzer JL and Brown 2016. The worlds biomes and Primary production as a triple tragedy of the commons played among plants. *Proceedings of the Royal Society* **275**: 47-57.

Govt of West Bengal, Department of Fisheries, Directorate of Fisheries 2014. *Handbook of Fisheries Statistics* 2014, 54-56.

Hoguane Antonio Mubango and Cuamba Ezidio da Lucia 2012. Effect of rainfall on artisanal fisheries of Mozambique. *Journal of Integrated Coastal Zone Management* **12**(4): 477-482.

Hu Solanki, Bhatpuria Dev and Chauhan P 2015. Applications of generalized additive model (GAM) to satellite derived variables and fishery data for prediction of fishery resources distributions in the Arabian Sea. *Geo Carto International* **32**(1): 1-16.

Jian Juan, Webster Peter and Hoyes Carlos 2009. Large scale Controls on Ganges and Brahmaputra river discharge on intraseasonal and seasonal time scales. *Quaterly Journal of Royal Meteorological Society* **135**: 353-370.

Jutla Antarpreet and Akanda S Ali 2011. Phytoplankton and River discharge: implications for Cholera. *American journal of Tropical medicine and Hygiene* **85**(2): 303-308.

Kumar Prassana and Panickal Swapna 2016. Declining Marine Phytoplankton in a rapidly warming Indian Ocean. *Geophysics Research Letter* **43**(2): 826-833.

Mini KG and Kuriakose Somy 2013. Evaluation of multispecies marine fishery in West Bengal India, using diversity indices. *Indian Journal of Fishries* **60**(2): 43-47.

Najmudeen TM and Sathiadhas R 2007. Economic efficiency of input utilisation mechanised trawlers along the Kerala coast. *Journal of Marine Bio Association of India* **49**(2): 113-117.

Nammalwar P, Satesh S and Ramesh R 2013. Applications of potential fishing zones in Tamil Nadu .*Indian Journal of Geo Marine Science* **42**(3): 283-292.

Nurdin S, Mustapha MA and Lihan T 2013. Relationship between SST and chlorophyll concentration in fisheries aggregation area in the archipelagic waters of Spermonde using satellite imagery. *American Institute of Physics* **466**(2013): 1-8.

Pitchaikani J Selvin and Lipton A P2012. Impact of environment variables on pelagic fish landings: Special emphasis on Indian oil sardine off Tiruchendur coast, Gulf of Mannar. *Journal of Oceanography and Marine Science* **3**(3): 56-67.

Shah Meghal, Chaturvedi Neera and Pandya H 2016. Climate change and biological productivity, Indian ocean. *Indian Journal of Geo Marine Sciences* **46**(3): 480-484.

Selim S, Raju S, Narayanakumar R, Sathianandan TV, Vipin Kumar, Swathilekhsmi P and Athira NR 2018. Valuation of marine fish landings in India. *Marine Fisheries Information Service Technical & Extension Series* **237** .

Zainuddin Mukti and Saitoh Sei Ichi 2004. Detection of potential Fishing ground For Tuna using synoptic measurement of ocean color.*Geophyical Research letters* **31**(20): 1-4.

Received 07 January, 2022; Accepted 03 June, 2022