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Study on Sea Surface Temperature and Chlorophyll-a concentration along the south-west coast of India

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Global climate change affects the oceanographic features and distribution of marine fishes as they are poikilothermic animals. Study of oceanographic variables in a localized region is more relevant in the context of ecological responses rather than global or continental variations. In this study, time series analysis of chlorophyll-a concentration (Chl-a) in sea water and sea surface temperature (SST) was performed separately for southern, middle and northern stratum along south-west coast of India using various statistical tools. The SST showed an increasing trend along the entire south-west coast of India after the year 1995. The northern and southern stratum of south-west coast were highly influenced by rising SST, whereas middle stratum in present scenario showed stable conditions in terms of Chl-a concentration. The study provides a baseline information about changing patterns of oceanographic features along the south-west coast of India giving a better understanding of changing global climatic conditions in coastal ecosystems.

[**Keywords**: Chlorophyll-a; Sea surface temperature; South-west coast of India; Stratum]

Introduction

South-west coast of India is one of the important productive regions in the world due to the occurrence of upwelling phenomena during the south-west monsoon period[1,2]and this region comprises of three maritime States of India namely Kerala, Karnataka and Goa with a total coastline of 994 km, contributing about 31 % to the marine fish catch of India[3]. Oceanographic factors control the upwelling system along the south-west coast of India, which influences mostly the planktivorous marine pelagic fishes such as *Sardinellalongiceps* and *Rastrelligerkanagurta* within the region[4-6]. The marine environment fluctuates rapidly with climate change[7] where noticeable changes in variables such as SST, ocean pH, sea level, ocean currents, productivity, wind fields and dissolved oxygen are observed[8-11]. Large scale spatial and temporal responses to marine fishery can be observed with variations in atmospheric and oceanic forcing such as winds, intermittent upwelling, seasonal change in stratification, warming and El Niño Southern Oscillation[12,13]. Climate change alters ocean conditions, particularly water temperature and biogeochemistry, whereby these changes affect the primary productivity and marine fish production[7,14-19]. In the context of climate change, regional ecological responses are often more relevant than throughout the global trends, especially along a latitudinal gradient[7,20], as the responses of climate change are expected to differ for different marine systems[7]. SST has risen 0.4 - 0.8 °C over the past century, resulting in warming of water column up to 2000 m depth and SST is expected to increase 1.2 - 3.2 °C by 2100 due to atmospheric CO_2 emissions trajectory[21,22]. SST has a high correlation with Chl-a[23]. SST is the important factor for influencing phytoplankton abundance and biomass[24] and also led to decrease in larval duration and increased larval mortality[25], other than forcing the extension of pelagic fishes into deeper water[26].

Despite SST and Chl-a are playing a vital role in the success of fisheries, over the past years changes in the pattern of SST and Chl-a along the south-west coast of India have received limited attention and therefore require an adequate database to understand the phenomenon associated with changing environmental variables. This study aimed to know the effect of climate change on oceanographic parameters such as SST and Chl-a along the south-west coast of India.

Materials and Methods

Study area

The study region was selected between 8° to 16° N latitude and 73° to 77° E longitude, up to 100 m depth in the south-eastern Arabian Sea. This coastal area is the most productive amongst all regions of Indian EEZ and it is also more productive compared to open sea water. Therefore, out of total estimated marine fisheries potential in Indian EEZ, 58 % resources are available at 50 m depth and 35 % resources are available between 50 and 200 m depth[27] and major fishing activities remain restricted to waters within 100 m depth[28]. The entire south-west coast has been classified into three strata for the study of trend in the regional oceanographic features including SST and Chl-a.

Cluster analysis of all major marine fish landing centres based on landings and effort during the year 2014-16 along the south-west coast of India was performed to know the homogeneity among them. Therefore, the grouping of landing centres resulted three latitudinal strata viz. stratum_1 (8-10.2° N, southern part), stratum_2 (10.2-13° N, middle part) and stratum_3 (13-16° N northern part), as in the figure 1.

Data collection

This study was conducted with data obtained from a suite of satellite sensors and databases for different

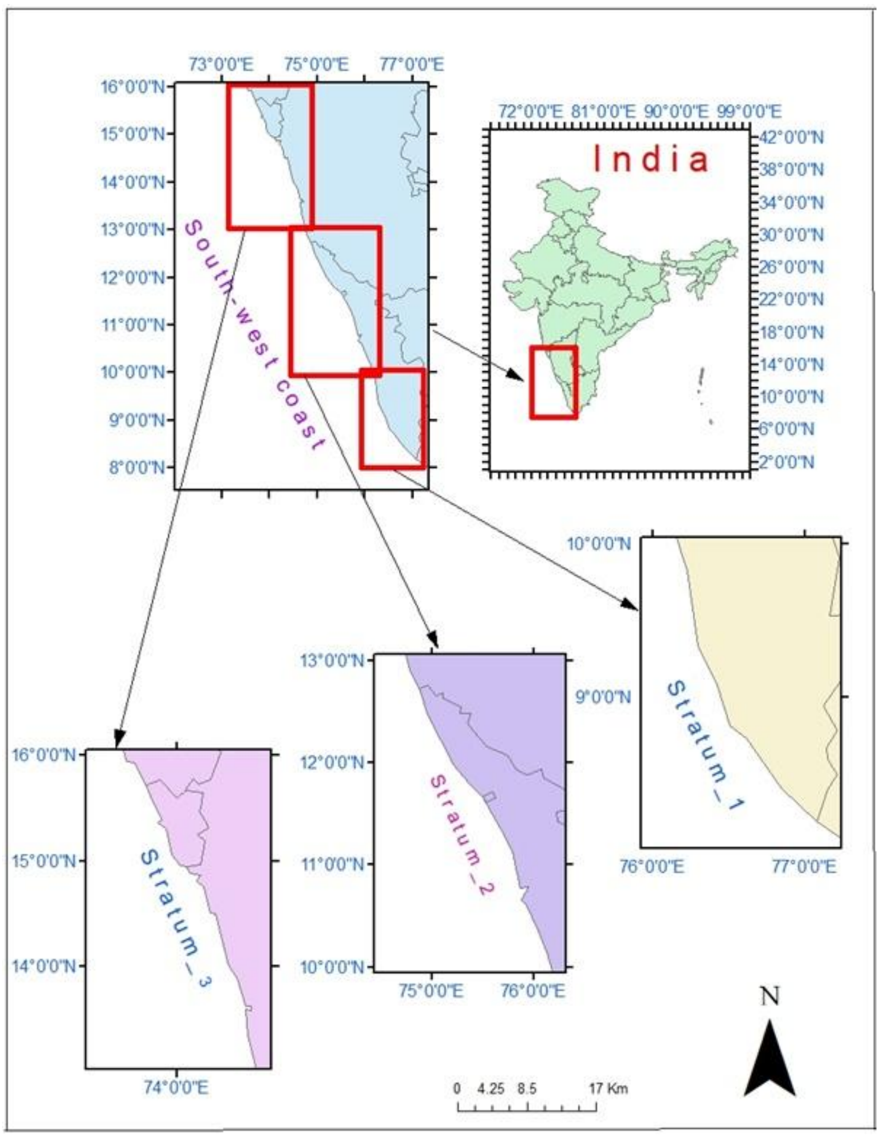

Fig. 1 — Map showing the strata in the south-west coast of India

time interval. The monthly data pertaining to Chl-a was obtained at a spatial resolution of 4 km × 4 km during 1998-2016 from the open source of Ocean Colour Climate Change Initiative (OC-CCI) website[29]. SST was retrieved at a spatial resolution of 1° × 1° during 1987-2016 on monthly basis from NOAA Optimum Interpolation (OI) SST, V2 from Asia-Pacific Data-Research Centre website[30]. Monthly data on four pelagic fishes (*Sardinella longiceps*, *Rastrelliger kanagurta*, *Stolephorus* sp. and *Thryssa* sp.) was collected for each landing centre of south-west of India for period 2014-16 from the database of National Marine Living Resources Data Centre (NMLRDC) of Central Marine Fisheries Research Institute (CMFRI), which is an internationally acclaimed statistically sound repository of data collected by following the stratified random sampling design[31].

Data processing

Monthly data on SST and Chl-a were extracted for 8° to 16° N latitude and 73° to 77° E longitude. NOAA - bathymetric maps in R (library Marmap) was used to partition data for depth up to 100 m[32,33]. The partitioned data was again segregated at stratum level to observe stratum-wise variation on oceanographic variables.

Statistical analysis

The stratification was accomplished based on cluster analyses of landings and effort of four selected resources at all major landing centres along south-west coast of India. In order to know the homogeneity in data of SST and Chl-a along each stratum, three homogeneity tests namely Pettitt's test[34], Buishand range test[35] and Standard normal homogeneity test (SNH)[36] were performed. These non-parametric tests were selected due to their usefulness in evaluating trend shifts independent of underlying distributional strappings and by way of evaluating a significant change in the mean of a time series of climatic features[12,37-38]. All statistical analyses were carried out with the help of software R 3.4.4 for Windows (62 megabytes, 32/64 bit)[38].

Results

Chlorophyll-a

In the case of Chl-a along stratum_1, only Buishand range test showed significant change at 5 % level at the point 4th (year 2001). The trend of Chl-a along stratum_1 has been given in figure 2a, where continuous downward trend was found after 2005. Both Pettitt's and Buishand range test showed the uniform change in Chl-a along stratum_2 during the study period, but Standard normal homogeneity (SNH) test detected the change in its trend at the point 18th (year 2015). Trend of Chl-a along stratum _2 also shows a uniform change up to 2015 (Fig. 2b). At stratum_3, both Pettitt's and Buishand range test showed significant change at 5 % level at the point 13 (year 2010) and SNH test detected the change at the point 14 during the year 2011 (Table 1). A decreasing trend of Chl-a along stratum_3 was also found after 2005 (Fig. 2c).

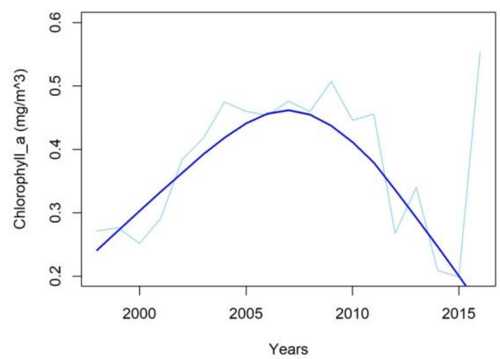

Fig. 2a — Chlorophyll-a concentration along stratum_1

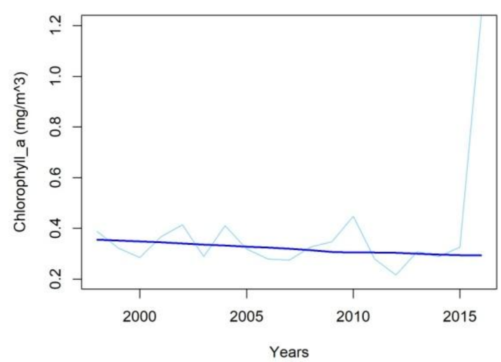

Fig. 2b — Chlorophyll-a concentration along stratum_2

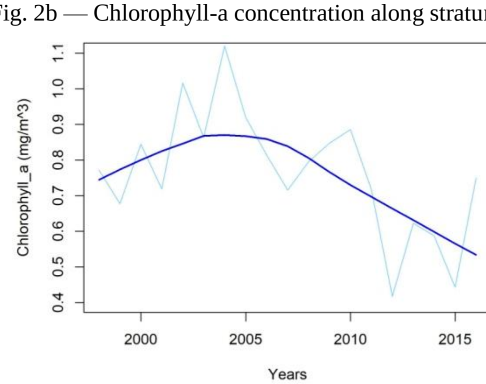

Fig. 2c — Chlorophyll-a concentration along stratum_3

Table 1 — Homogeneity tests for chlorophyll-a concentration in sea water

Parameters	Regions		
	Stratum_1	Stratum_2	Stratum_3
Pettitt's test	K=5 p=0.5291	K=7 p=1.14	K=13 p=0.04287
Buishan range test	K=4 p=0.0128	K=18 p=0.65	K=13 p=0.02695
Standard normal homogeneity (SNH) test	K=4 p=0.2555	K=18 p=2.2e-16	K=14 p=0.01385

Where, K= Pettitt's test statistic, Buishand range test statistic and SNH test statistic

Table 2 — Homogeneity tests for sea surface temperature

Parameters	Regions		
	Stratum_1	Stratum_2	Stratum_3
Pettitt's test	K=10 P=0.5775	K=21 P=0.7617	K=21 P=0.3641
Buishan range test	K=10 p=0.2608	K=10 p=0.4128	K=20 p=0.1658
Standard normal homogeneity (SNH) test	K=28 p=0.3912	]K=28 p=0.2889	K=21 p=0.4718

Where, K= Pettitt's test statistic, Buishand range test statistic and SNH test statistic

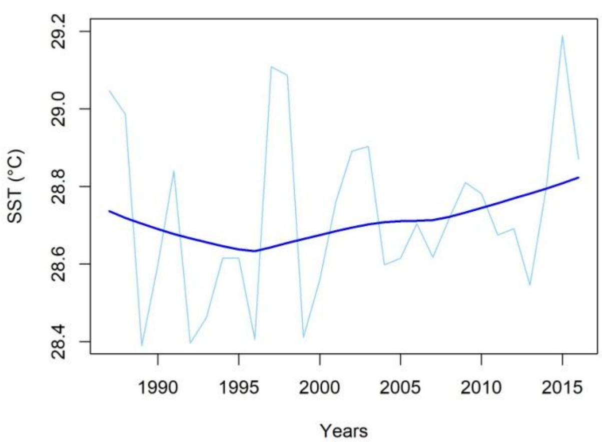

Fig. 3a — Sea surface temperature along stratum_1

Sea surface temperature

Pettitt's test, Buishand range test and SNH test did not showed abrupt change in SST at 5 % level of significance along the entire south-west coast and strata (Table 2), means the time series data of SST showed homogeneity in their distribution over the study period. An upward trend for SST was found after 1995 along all stratum_1, stratum_2 and stratum_3 as shown in Figure 3a, 3b and 3c, respectively. The upward trend of SST indicates the rise in SST along all strata simultaneously.

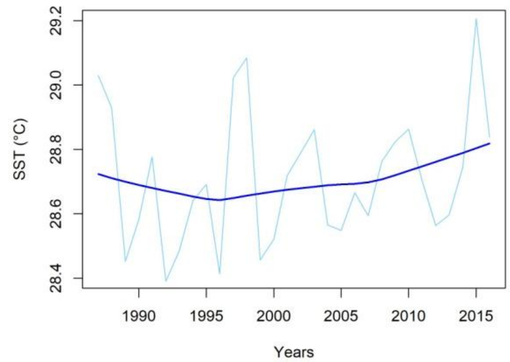

Fig. 3b — Sea surface temperature along stratum_2

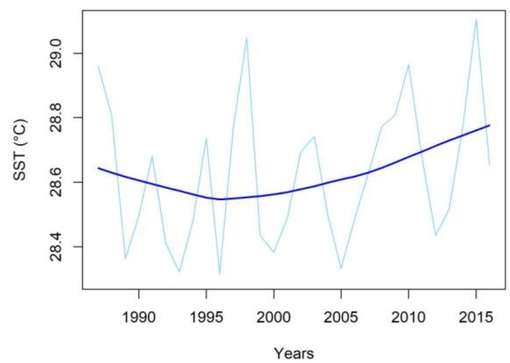

Fig.3c — Sea surface temperature along stratum_3

Discussion

We found a homogenous change in SST along all strata at south-west coast of India by all three tests namely Pettitt's test, Buishand Range test and SNH test. Also a continuous upward trend in time series for SST after 1995 along strata has been observed in the study area, which must have associated with the global warming with effect of rapid rise in global greenhouse gas sharing of India after 1990[39]. This study demonstrates that a uniform and steady increase in SST since 1995 due to the impact of climate change along the entire south-west coast of India rather the longitudinal differences in the position of strata. This indicated that all the three strata of south-west coast of India has similar SST pattern. Even though having the similar SST pattern along all strata, the difference in the pattern of Chl-a among strata has been observed in the current study.

The northern part (stratum_3) of south-west coast is most affected by the climate change, where Chl-a in sea water significantly alters during the period 2010-11. Both stratum_1 and stratum_3 shows a similar pattern in case of Chl-a throughout the study period, whereas a decreasing trend of Chl-a is found after 2005 onwards. However, along stratum_2, Chl-a did not change up to 2015, which indicates that stratum_2 is more stable in respect of Chl-a compare to other two strata. However, an inverse relationship between Chl-a and SST along stratum_1 and stratum_3 along south-west coast of India after 2005 has been observed in the study. At initial stage, rising in SST might have enhanced the proliferation of phytoplankton via increasing metabolic rates of phytoplankton[40]. Later, a simultaneous change in SST and several other oceano-physical variables such as wind speed, ocean current, sea surface height and upwelling anomaly might be the cause of decrease in Chl-a along two strata (1 & 3) with rise in SST, visible after 2005. SST has only 29.4 % of contribution for the variation in Chl-a, while the remaining of 71.6 % is influenced by other factors together like current, wind, salinity, run-off, rainfall, etc. The change in primary productivity of marine water is influenced by SST, sea-level pressure, surface winds, surface air temperature and cloudiness, where the primary productivity shows the inverse relationship of SST[24,41].

It seems that stratum_2 is comparatively less influenced by the rise in SST, which might be due to the presence of 30 km wide Palghat gap at 11° N in parallel run of Western Ghat range along the south-west coast of India between 8° and 21° N latitudes[42]. Palghat gap in Western Ghat range is responsible for heavy rainfall at immediate northern to 10° N latitude. Therefore, continuously putative action of nutrient driven by precipitation along stratum_2 might be reason of continuously stable Chl-a in this region via nullifying adverse effect of SST. The higher Chl-a is generally scattered along the coast, due to the nutrients run-off from land[24]. Further, the study of climate change impact on wind speed, sea surface anomaly, sea water current and precipitation along the south-west coast of India will give more comprehensive idea to understand changes in physicochemical variables of sea water and upwelling anomaly over the period and their effects on marine fishes.

Conclusion

The pattern of rising SST was similar for all the three strata, despite of longitudinal variation in the stratum position. But, in case of Chl-a change, all strata did not have the similar pattern. In respect to Chl-a, impact of climate change is much earlier along stratum_3 in comparison to stratum_1 and stratum_2. This study also reveals that stratum_2 is the most stable stratum in case of Chl-a. Therefore, only SST rising alone does not influence Chl-a change.

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