Life cycle of anchovy and climate driven changes in its distribution on the southwest coast of India

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Abstract

Large scale fluctuations of anchovy catch are observed across Indian coast and an understanding of the complex interactions of climato-oceanic and biological factors of fishes is essential to realize the cause of such catch variations. Therefore, the trend of sea surface temperature anomaly in the context of the spatial and temporal aspects of anchovy (*Stolephorus* spp.) fisheries along southwest coast of India were investigated. The coast was classified into three strata; first (ST_1, 8° to 10.2° N), second (ST_2, 10.2° to 13° N) and third (ST_3, 13° to 16° N) to study the spatial variation. Similarly, seasonality was studied by considering three seasons in a year as pre-monsoon (February-May, PRM), monsoon (June-September, MON) and post-monsoon (October-January, POM). The catch (kg) per unit effort (hour) for the all gears operated was also analyzed to observe the distribution of *Stolephorus* spp. The impact of climate change on *Stolephorus* fisheries was evident in both vertical and horizontal shifting of the catch.

Key words: *Stolephorus* spp., sea surface temperature, catch shifts

Introduction

Anchovy fisheries are constituted by five genera belonging to Engraulidae family, but maximum catch is accounted by the genus *Stolephorus* in Indian marine fishery. Commonly known as whitebait, about seven species occur in fishery along southwest coast of India and is hereafter referred to as *Stolephorus*. During 80's decades, about 70% of total landed *Stolephorus* along the southwest coast of India was accounted from the coast extending from Cape Comorin to Quilon at the depth between 10 and 50 m (Luther, 1979). These fishes are plankton feeders, mainly zooplankton with copepods, cladocerans, lucifer and fish larvae dominating. Changes in physico-chemical properties of the ecosystem regulate its migration, resulting on the annual and seasonal fluctuations in its fisheries. The northward distribution of the stock in shallow shelf water from October onwards and the southward distribution from March-April onwards are evidently governed by the current patterns during the southwest monsoon and post-monsoon period. This study reports the distributional shift of *Stolephorus* along southwest coast of India against the recent scenario of rising Sea Surface Temperature (SST) under the influence of climate change phenomenon.

Sea Surface Temperature

SST was retrieved at 1° spatial resolution for the period from 1988 to 2016 on monthly basis from NOAA Optimum Interpolation (OI) SST, V2 in Asia Pacific Data Research Centre website (http://apdrc.soest.hawaii.edu) for southwest coast of India between 8° to 16° N latitude and 73° to 77° E longitude. NOAA-bathymetric maps in R (library Marmap) were used to partition data for depth up to 100 m. The partitioned data was used in analysis of the SST anomaly. The statistical tool as change-point analysis which is able to detect discontinuities and regime shifts in climate was used

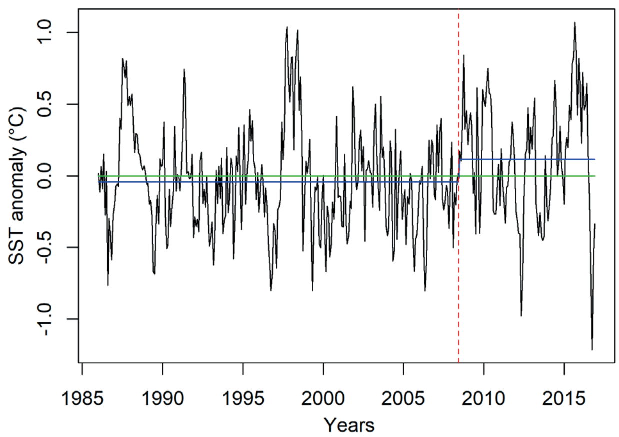

Fig.1. SST anomaly on southwest coast of India

in time series data of SST anomaly in R3.4.4 software for windows. The result showed a significantly high SST anomaly after 2008 (Fig.1).

Spatial and seasonal analysis of catch

The fishery trends of genus *Stolephorus* only from the southwest coast of India was used because it dominated the anchovy fisheries of the region. Monthly data on gear wise landings of *Stolephorus* from 1997 to 2017 and the fishing effort expended in terms of operational hour for all gears were obtained from the National Marine Fishery Resources Data Centre (NMFDC) of the ICAR-Central Marine Fisheries Research Institute (CMFRI). A standardized catch per hour (CPH) for all strata was estimated by applying the gear standardization method for multi-species and multi-gear fisheries (Bharti *et. al*., 2019). For the study of spatial variation in *Stolephorus* fisheries, the entire southwest coast of India was converted into three strata. The first stratum (ST_1) was considered between 8° to 10.2° N, second stratum (ST_2) was between 10.2° to 13° N and third stratum (ST_3) was between 13° to 16° N (Fig. 2). To observe seasonal variation, the monthly CPH again was grouped into three seasons viz. pre-monsoon (February-May; PRM), monsoon (June-September, MON) and post-monsoon (October-January, POM).

The spatial distribution of *Stolephorus* was conducted with comparison of the trend of CPH at three strata (Fig. 3). The highest CPH was observed along ST_1 before 2007, but later, CPH at ST_1 became lowest as a result of its decreasing trend. In contrast ST_3 showed

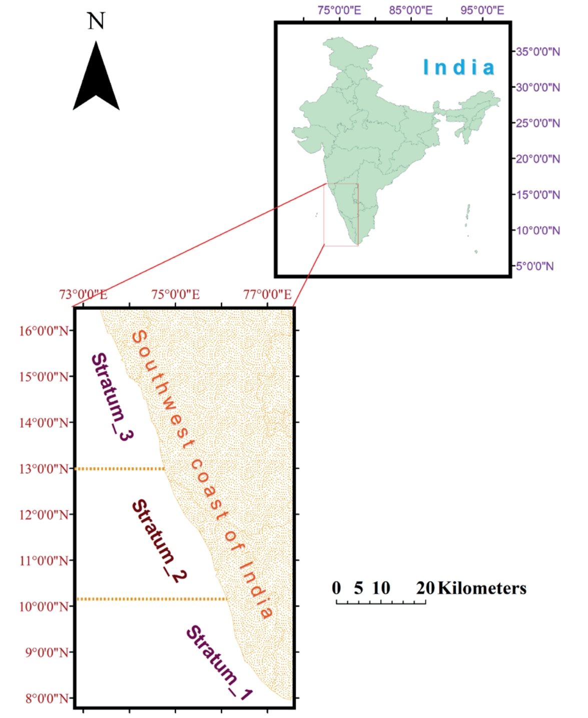

Fig. 2. Map of southwest coast of India indicating strata used

a continuously increasing trend with rising CPH trend after 2010. Due to increasing trend since starting of study period, CPH along ST_3 became highest among all strata after 2008. ST_2 also showed an increasing trend after 2005. Correlation analysis for CPH among all three strata showed a significantly positive correlation (0.77) between ST_2 and ST_3 (Table 1). The CPH of *Stolephorus* had increasing trend at both ST_2 and ST_3, but the same had decreasing trend at ST_1. The trend of CPH during three seasons was analyzed to observe the seasonal shift (Fig.4) which showed the maximum CPH

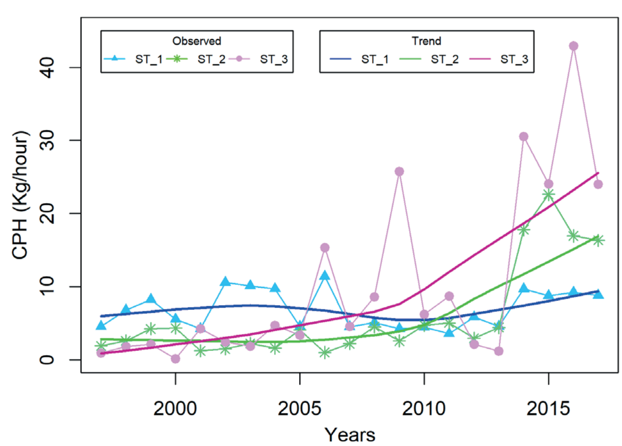

Fig. 3. Stratum wise trend of CPH for *Stolephorus* spp.

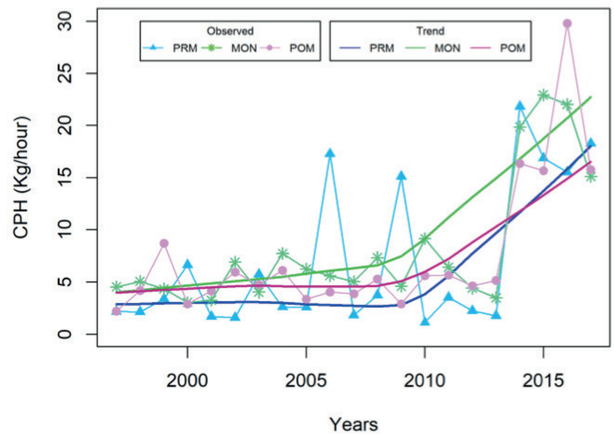

Fig. 4. Seasonal trend of CPH for *Stolephorus* spp.

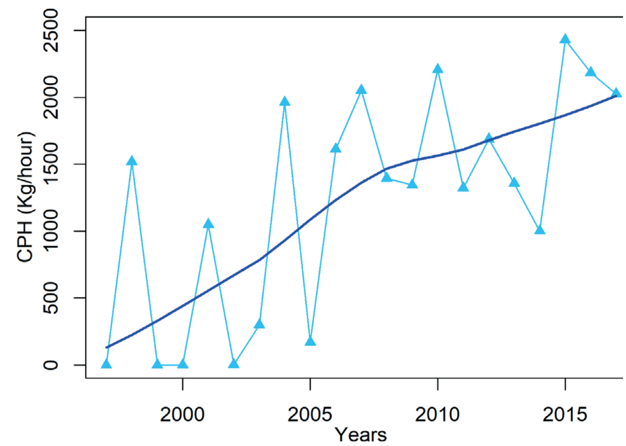

Fig. 5. CPH trend of MRS

during MON. The lowest CPH was always during PRM except 2015 onward, where its CPH was higher than POM. However, all three seasons showed increasing trend in CPH after 2010 onwards. The seasonal trend of CPH showed a significantly positive correlation among each other (Table 1).

Gear wise analysis of catch

All gears operated targeting *Stolephorus* were classified into five major generic gear categories viz. mechanized ring seine (MRS), mechanized trawl net (MTN), outboard ring seine (OBRS), outboard trawl net (OBTN) and non-mechanized gears (NM). Gear wise CPH along each stratum was also estimated by dividing standardized effort of a particular gear into the total landing of *Stolephorus* in the same gear. The time series CPH of MRS showed a continuously increasing trend while that for MTN had an upward trend since 2010 (Figs. 5 and 6). On the other hand, the CPH of OBRS (Fig. 6), OBTN and NM (Fig. 7), which are operated in comparatively lower depth had a decreasing trend. The correlation analysis for CPH among the different gears did not show any significant correlation during the study period.

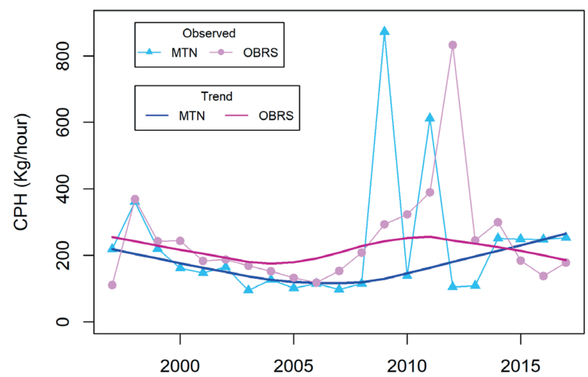

Fig. 6. CPH trend of MTN and OBRS

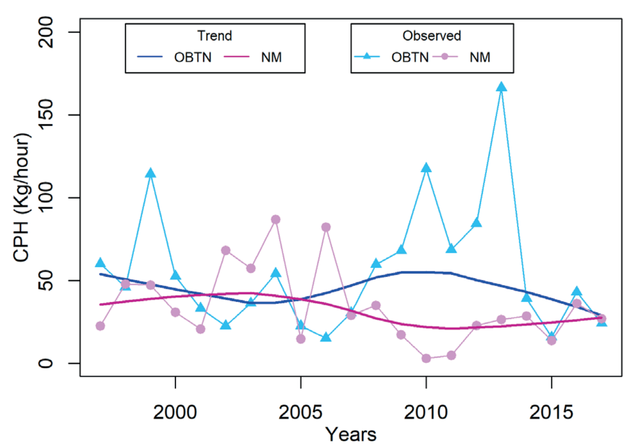

Fig.7. CPH trend of OBTN and NM

Table 1. Correlation of spatial and seasonal change in CPH of *Stolephorus* spp.

	Strata				Seasons		
	ST_1	ST_2	ST_3		PRM	MON	POM
ST_1	1.00	0.32	0.34	PRM	1.00	0.71***	0.63***
ST_2		1.00	0.77***	MON		1.00	0.89***
ST_3			1.00	POM			1.00

***0.001 level of significance

Life cycle

The life cycle model of *Stolephorus* was derived based on the conceptual knowledge on its biological attributes (Fig. 8). The assemblage of *Stolephorus* on the southwest coast of India starts by October, when the temperature becomes slightly higher after cessation of southwest monsoon. After entering in the southwest region, it spreads in entire ST_1 area by November. Its movement is continued towards the northern region with decreasing of temperature on the onset of the winter season at the northern region of the southwest coast of India, therefore this decreased temperature facilitate it to continue northward migration and finally reaches up to ST_3 by the end of February. As the temperature starts to increase at ST_3 after onset of summer season, it forces them to move again towards south. By the end of May, they again get aggregated at ST_2 and ST_1. After May, the upwelling phenomenon appears at the southwest coast, which reduces the both temperature and dissolved oxygen at surface water. During these adverse oceanic conditions, *Stolephorus* assembles in the southeast region. However, the rising SST under global warming phenomenon, apparently is forcing it to move to southwest coast comparatively earlier in the recent past period as indicated by a sharp increasing trend in CPH of *Stolephorus* during POM after 2008 in this study. To minimize the adverse effect of global warming, they might have utilized both possibilities by extending their existence vertically in deeper water and horizontally towards the northern region. This might be the reason for the upward trend of CPH in strata ST_2 and ST_3, while CPH of ST_1 was decreased after 2008.

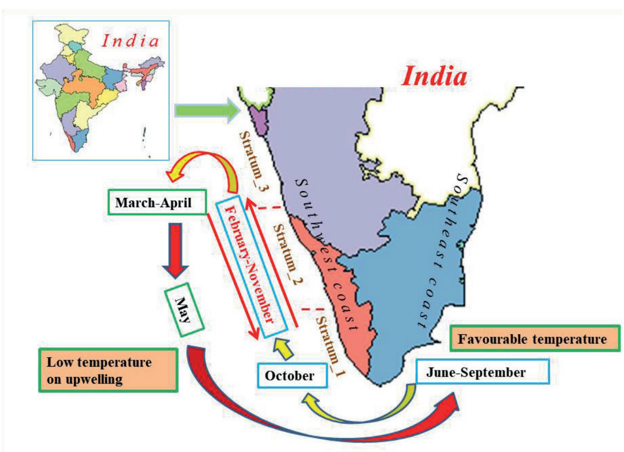

Fig. 8. Life cycle model for *Stolephorus* spp.

This increasing of *Stolephorus* population from southern to northern region emerges from a significant positive correlation between ST_2 and ST_3.Normally, the lowest CPH was observed during PRM which is the summer season on southwest coast, but with rising SST, the CPH also showed an increasing trend during this period. It could mean that *Stolephorus* tends to remain on southwest coast during the pre-monsoon season, but it might have shifted into deeper water to avoid high temperature on both southwest and southeast coastal region due to rising SST. Shifting to deeper water might be the reason for continuously increasing of CPH in mechanized gears that are operated in deeper water region while in the same period CPH of motorized and non-mechanized gears has decreased. Therefore, a shifting of *Stolephorus* distribution in three dimensions-vertical shift to deeper water, horizontal shifting toward northern region and also seasonal shifting under impact of climate change is recorded.

References

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