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Distribution of Indian oil sardine *Sardinella longiceps* along south-west coast of India

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ABSTRACT

Rise in temperature directly affects the poikilothermic aquatic animals such as fishes influencing their population biomass and recruitment. With this perspective, a study on spatial-temporal distribution of Indian oil sardine along south-west coast of India (SW) was conducted by classifying the study area into three strata namely: southern, central and northern region. The data was collected and segregated into three seasons, i.e. pre-monsoon, monsoon and post-monsoon. The trend for sea surface temperature was analyzed and compared among three strata and seasons. The trend of standardized catch per hour for all strata and season was also analyzed, along with observation on gear-wise catch of Indian oil sardine. This study indicates towards latitudinal extension and seasonal changes of Indian oil sardine population, besides changing its distribution into deeper water for avoiding the adverse impact of rising temperature.

Key words: Region, Sardine, Seasons, Temperature

The landings of marine fish depend on fishing effort and the influence of climatological factors at the marine ecosystem (Vivekanandan and Krishnakumar 2010, Supraba *et al.* 2016). The long-term variability in oceanic-climate factors on the marine ecosystems leads to alteration in the growth and recruitment of fish, resulting in fluctuations in the distribution and abundance of exploited fish populations (Francis and Hare 1994, Vivekanandan and Krishnakumar 2010, Vivekanandan 2013). The climate change is likely to modify the ocean productivity, which adversely influences fishes and their larval distribution pattern and population abundance (Wood and McDonald 1997, IPCC 2007, Sumaila *et al.* 2011). Fish catch have increased at higher latitudes by 30–70%, and decreased in the tropics by 40% (Cheung *et al.* 2009). A rise in temperature even by 1°C could have notable and rapid effects on the geographical distributions (Perry *et al.* 2005). In Indian scenario, SST has increased by 0.2°C along the northwest, southwest and northeast coasts, and by 0.3°C along the southeast coast during the period from 1961 to 2005 (Vivekanandan 2013). Rising temperature is the single most important environmental factor directly affecting molecular, biochemical and physiological processes in fishes (Strussmann *et al.* 2010). Temperature has direct influence on two vital life traits of fish, namely, food utilization and spawning, thus changes in these two traits can cause fluctuations in population biomass and recruitment (Vivekanandan 2013).

Monsoon upwelling is prevalent along the SW, which supports the small pelagic fisheries by blooming the primary productivity (Jayaram and Dinesh Kumar 2018). Indian oil sardine (thereafter known as sardine) contributed 22% in SW marine fish catch during 2017 (FRAD 2018), which inhabits the coastal pelagic zone within depth range of 20–200 m (Nair *et al.* 2016). At Karanataka coast, the major catch of sardine is contributed by mechanized purse seine (90%), while only 6% and 4% catch are accounted by trawl net and boat seine, respectively (Rohit and Bhat 2003). Ring seine contributes 94% of the total sardine caught at Kerala coast, but this fishing method is confined to Central and Northern Kerala only (Abdussamad *et al.* 2015). Therefore, the study of catch in relation with gear may reflect the distribution of sardine along SW, where fishing gear operations are confined at regional level. However, several studies on various biological aspects such as growth, recruitment, stock assessment and fishing method for

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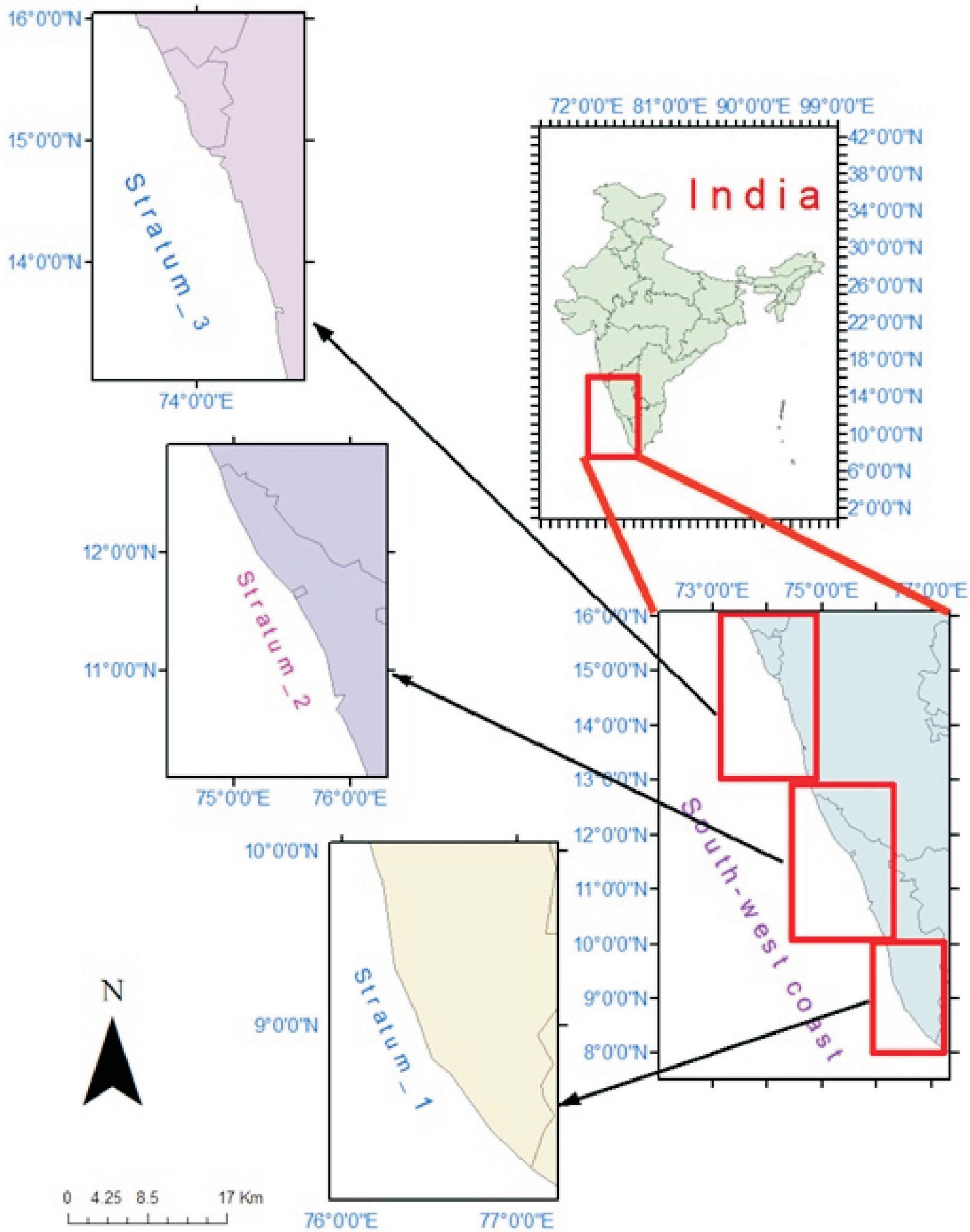

Fig. 1. Spatial distribution of sardine along the south-west coast of India.

sardine has been made since historical period, but information on its spatial-temporal dynamics with the progressing time so far are lacking along Indian coast. In view of climate change impact on marine ecosystem, this study was conducted with the aim to understand the trend in the seasonal and spatial dynamics in sardine along SW.

MATERIALS AND METHODS

One of the most productive marine ecosystems in the world, i.e. SW comprising of Kerala, Karnataka and Goa coast was selected for the study. The study region is situated between 8° to 16° N latitude and 73° to 77° E longitude, up to 100 m depth in the Southeastern Arabian Sea. To observe the spatial distribution of sardine, the entire SW has been classified into three latitudinal strata, viz. stratum_1 (8°–10.2° N, southern region, ST_1), stratum_2 (10.2°–13° N, middle region, ST_2) and stratum_3 (13°–16° N, northern region, ST_3), as in the Fig. 1.

Monthly SST data for 8°–16° N latitude and 73°–77° E longitude was retrieved at a spatial resolution of 1 km × 1 km for the period 1988–2015 from NOAA Optimum Interpolation (OI) SST, V2 in Asia Pacific Data Research Centre website (http://apdrc.soest.hawaii.edu). Further, the collected SST data was classified for depth up to 100 m by using Marmap package in R software (R Core Team 2013) due to confines of major fishing activities within this depth. For analyzing the trend, monthly time series data on estimated gear-wise landings of sardine along SW 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 Central Marine Fisheries Research Institute, Cochin, which is an internationally accepted and statistically sound repository of data on marine fish landings collected by multistage stratified random sampling design (Srinath *et al.* 2005). All locally known gears operated for sardine were classified into seven major generic gears categories, viz. mechanized purse seine (MPS), mechanized ring seine (MRS), mechanized trawl net (MTN), outboard ring seine (OBRS), outboard gill net (OBGN), outboard trawl net (OBTN) and non-mechanized gears (NM). A standardized catch per hour (CPH) for entire SW and also strata was estimated by applying the gear standardization method for tropical fisheries (Sparre and Venema 1992, Anon 2017).

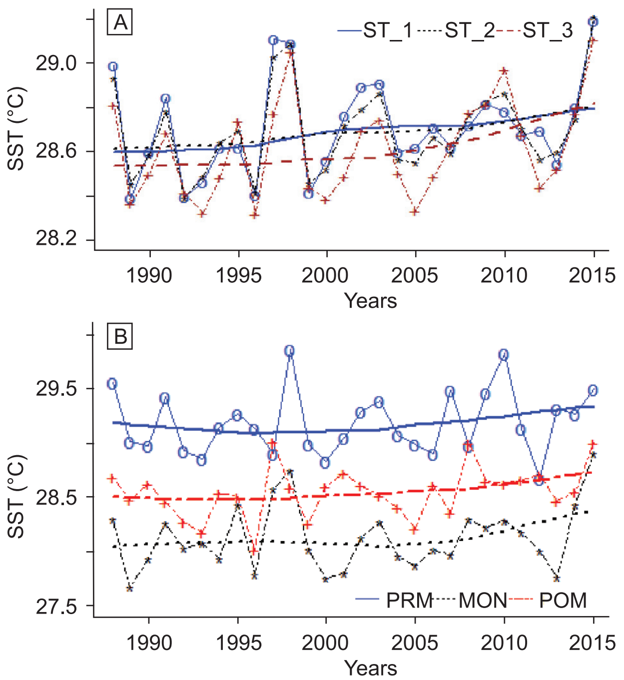

Fig. 2 (A–B). SST variation along the strata (A) and seasons (B), where ST_1, stratum_1; ST_2, stratum_2 and ST_3, stratum_3; PRM, pre-monsoon; MON, monsoon and POM, post-monsoon

Gear-wise CPH along each stratum was also estimated by dividing standardized effort of a particular gear into the total landing of sardine in the same gear. To observe seasonal variation, the monthly CPH was again grouped into three seasons, viz. pre-monsoon (February–May), monsoon (June–September) and post-monsoon (October–January).

The current study applies the structural breaks approach, which consists of detecting structural changes as structural breaks in the monthly time series by using R package strucchange (Goela *et al.* 2016). A time series plot for yearly standardized CPH was made for each stratum and season. To observe spatial and temporal catch of different types of gears operated in SW over the study period, again time series plot for gear-wise CPH was plotted for all three strata and seasons. All statistical analyses were carried out with the help of software R 3.4.4 for Windows (R Core Team 2013).

RESULTS AND DISCUSSION

The result shows a latitudinal gradient in SST along the entire SW, since SST reduced from its southern to northern region. The trends of SST along ST_1 and ST_2 are much closer to each other. However, the mean SST along all strata increased throughout study period, but the upward trend of SST along ST_3 was accelerated after 2005, resulting in SST of ST_3 approaching to same as ST_1. The rising of SST along ST_3 with faster rate compared to other two strata reduced the gap in the trend of SST between ST_3 and ST_1 after 2005 (Fig. 2a). A significant correlation among three strata and also three seasons for SST trend was observed (Table 1), which is indication of rising SST along all strata. Singificantly high correlation was noticed between ST_1 and ST_2 (0.97); and ST_2 and ST_3 (0.92). Similarly, a significant correlation with PRM and MON (0.52); and MON and POM (0.53) also observed in this study. The clear seasonal difference in SST can also be observed along SW, where the highest SST was found during pre-monsoon period, followed by intermediate and lowest SST during post-monsoon and monsoon, respectively (Fig. 2b). The differential rising in SST among strata might be due to a gradient of global warming impact along SW, where the vast geographical differences have existed from southern to northern region.

The standardized CPH of SW showed a break point in time series trend and significantly higher CPH was observed after 2013 (Fig. 3), which might be due to extension of sardine population towards northern region. With regards

Table 1. Correlation among stratum and season for SST

	Spatial			Season	Temporal		
Strata	ST_1	ST_2	ST_3		PRM	MON	POM
ST_1	1.00	0.97***	0.84***	PRM	1.00	0.52**	0.10
ST_2		1.00	0.92***	MON		1.00	0.53**
ST_3			1.00	POM			1.00

where ST_1, stratum_1; ST_2, stratum_2 and ST_3, stratum_3; PRM, pre-monsoon; MON, monsoon and POM, post-monsoon. ***Significant at P<0.001 and **Significant at P<0.01.

to spatial variation in the CPH, the study found that the highest and lowest CPH were along ST_1 and ST_3 at the starting period of the study, but the same were interchanged each other and became as lowest and highest during 2010 onwards, respectively (Fig. 4a). The upward trend of CPH along ST_3 was slow at initial period but, it was accelerated during the period of 2005 and also at the same time CPH started to decrease along ST_1. The highest SST during 2000 to 2005 along southern region might be unfavorable temperature for sardine, which could force sardine population to move towards northward according to its tolerance limit of environmental condition, resulting in sharp diminishing and increasing CPH along southern and northern region, respectively. A significant impact of temperature at fish distribution pattern may be observed, where even slight rise in temperature plays noticeable effects on the geographical distributions of fish as being a poikilothermic organism (Perry *et al.* 2005). Rohit and Bhat (2003) also reported that the landings of sardine have increased in recent five years. In the case of temporal study of CPH distribution, the study found the highest CPH was during PRM up to 2002, while later on, MON showed the maximum CPH. However, the CPH during POM continuously increased, but its upward trend slightly accelerated during 2010 (Fig. 4b). A positive correlation was found between PRM and POM (0.47) and MON and POM (0.22) in the study (Table 2). The seasonal differences in sardine distribution may be found as CPH decreases and increases during PRM and MON, respectively, where PRM may not be proven as a favorable season in the effect of rising of SST on the impact of global warming, therefore sardine might have temporal extension during MON.

In gear-wise analysis of catch, the CPH in MTN was accelerated compared after 2010. The extension of sardine

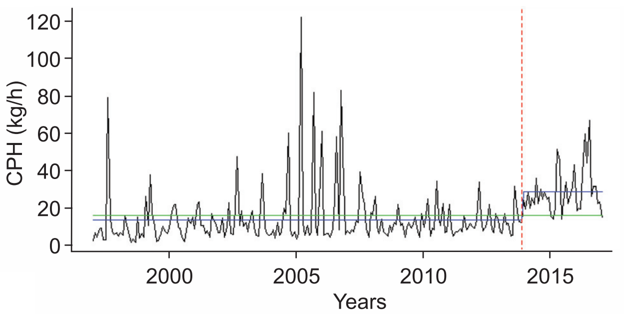

Fig. 3. Structure break point in CPH trend for sardine along SW

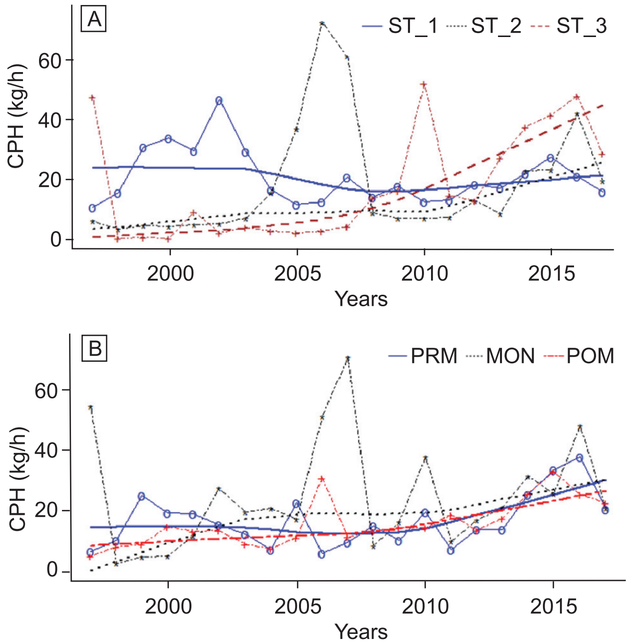

Fig. 4(A-B). Standardized CPH along strata (A) and seasons (B), where ST_1 = stratum_1, ST_2 = stratum_2 and ST_3 = stratum_3; PRM = pre-monsoon, MON = monsoon and POM = post-monsoon

in deeper water region in effect of global warming might be the reason for increasing of CPH in MTN. The migration of sardine in to deeper waters has observed by Chidambaram (1950). The CPH of MRS had increased continuously up to 2005, after that rate of upward running CPH for MRS had diminished. However, MPS also showed a continuous increase of CPH, which is mainly operated along ST_3 (Fig. 5a). The spatial extension of sardine population towards MPS operation area is the probable cause for continuously increasing CPH of MPS. However, the operational mechanisms for MPS and MRS are about similar, but CPH of MRS increased very fast only up to 2000. Similarly, CPH for OBRS is continuously increased rapidly up to 2007, and thereafter the rising rate for same has reduced. According to Marine fisheries census 2010 (Anon 2012), the operations of ring seines are mainly concentrated along central region in SW. Abdussamad *et al.* (2015) reported the effort of ring seines was declined because of low catch and catch rates, even though CPH of MRS could not regain its previous state rate of upward trend due to expansion of sardine population towards northern region. Among

Table 2. Correlation among stratum and season for standardized CPH along SW

	Spatial			Season	Temporal		
Strata	ST_1	ST_2	ST_3		PRM	MON	POM
ST_1	1.00	–0.26	–0.30	PRM	1.00	–0.05	0.47*
ST_2		1.00	–0.03	MON		1.00	0.22
ST_3			1.00	POM			1.00

where ST_1, stratum_1; ST_2, stratum_2 and ST_3, stratum_3 and PRM, pre-monsoon; MON, monsoon and POM, post-monsoon. *Significant at $P<0.05$.

Table 3. Correlation among gear-wise CPH

Gear	MPS	MRS	MTN	NM	OBGN	OBRS	OBTN
MPS	1.00	0.19	0.23	0.30	–0.10	0.28	–0.10
MRS		1.00	0.20	0.27	0.52*	0.74***	–0.49*
MTN			1.00	0.73***	–0.22	0.56**	–0.60**
NM				1.00	–0.03	0.39	–0.35
OBGN					1.00	0.34	0.01
OBRS						1.00	–0.53*
OBTN							1.00

where, mechanized purse seine (MPS), mechanized ring seine (MRS), mechanized trawl net (MTN), outboard ring seine (OBRS), outboard gill net (OBGN), outboard trawl net (OBTN) and non-mechanized gear (NM). ***Significant at P<0.001, **Significant at P<0.01 and *Significant at P<0.05.

outboard motor operated gears, the maximum CPH was noticed for OBRS over the study period with a continuous increasing trend. Therefore, the trend of CPH of both MRS and OBRS may also reveal the extension of sardine population from ST_1 to ST_2 with rising of SST over the time. The limitation in the operational depth of OBTN seems to show a decreasing trend in CPH for OBTN. Similar to OBTN, CPH of OBGN also showed a downward trend after 2010 (Fig. 5b). In case of correlation among CPH for different gears operated along the coast, a significantly negative correlation was observed between the CPH in two gears such as MRS and OBTN (–0.49), MTN and OBTN (–0.60) and, OBRS and OBTN (–0.53). Similarly, the positive correlation for CPH in two gears such as MRS and OBGN (0.52), MRS and OBRS (0.74), MTN and NM (0.73) and, MTN and OBRS (0.56) were found (Table 3). A significantly negative correlation between CPH of MRS and OBTN (–0.49) and, also MTN and OBTN (–0.60) in the study indicates the moving of sardine population to deeper water in search of optimum physiological temperature. According to marine fisheries act of maritime state along SW, mechanized fishing vessels are prohibited for fishing operation near coastal water. The combination of several gears in NM may be the reason for showing a significant correlation with mechanized trawl net, where NM may be dominated by bottom operated gears. The moving of sardine in deeper water also can be seen by CPH of mechanized trawl net, where the CPH has increased from 2010 onward. Similar observation was made by Vivekanandan *et al.* (2009), where the sardine has extended its distribution toward northern and deeper water along Indian coast due to impact of global warming.

Based on present finding, it has been concluded that the trend in the catch of sardine seems to exhibit the professed symptoms of the impact of global warming along SW. At intial phase of study, the standardized CPH was the highest along southern region, but later it was highest along northern region. In gear-wise catch study, even though having similar mode of operation, CPH rate of MRS was decelerated after 2005 compared to previous, while same in MPS operated along northern region has increased continuously. This is possible only when the extension in the distribution of sardine population towards nothern latitude might take place over the period under the influences of global warming. To cope up the suvival, sardine did not show only spatial extension, but also seasonal change in the trend of their catch has beeen noticed. Intially the standardized CPH was maximum during pre-monsoon and post-monsoon, while the rising of global temperature makes the favourable condition even in monsoon season, where CPH has noticed maximum during recent period.

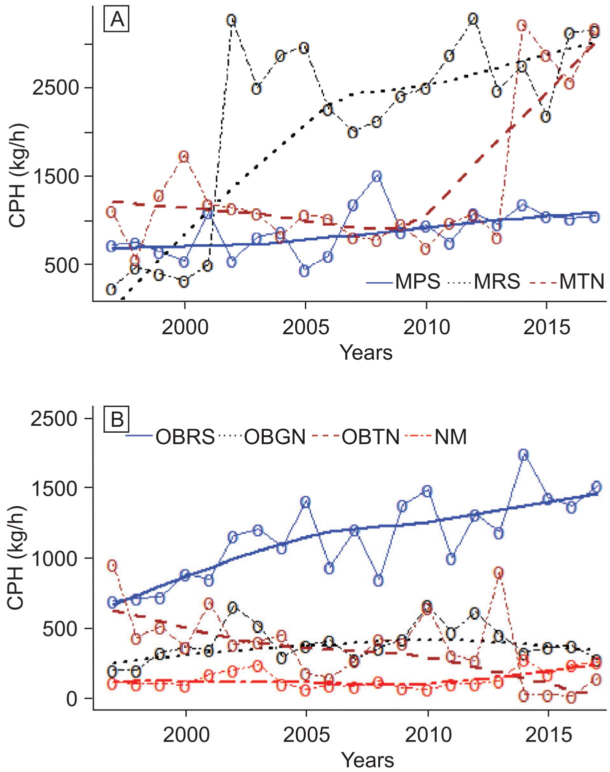

Fig. 5. Gear-wise CPH along SW (A and B) where, mechanized purse seine (MPS), mechanized ring seine (MRS), mechanized trawl net (MTN), outboard ring seine (OBRS), outboard gill net (OBGN), outboard trawl net (OBTN) and non-mechanized gears (NM)

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REFERENCES

Abdussamad E M, Ganga U, Said Koya K P, Prakasan D and Gireesh R. 2015. Ring seine fishery of Kerala: An overview. *Marine Fisheries Information Service: Technical and Extension Series* **225**: 3–7.

Anon. 2012. *Fisheries Census 2010 Part I India* Ministry of Agriculture, Krishi Bhavan, New Delhi and CMFRI, Kochi. pp. 98.

Anon. 2017. Report of the Working Group for revalidating the potential of fishery resources in the Indian EEZ. (In press).

Cheung W W L, Kearney K, Lam V, Sarmiento J, Watson R and Pauly D. 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* **10**: 235–51.

Chidambaram K. 1950. Studies on length frequency of the oil sardine *Sardinella longiceps* Cuv. & Val. on certain factors influencing their appearance on the Calicut coast of Madras Presidency. *Proceedings of the Indian Academy of Science* **31B**(5): 252–86.

FRAD, CMFRI. 2018. Marine fish landing in India 2017. Technical Report, CMFRI, Kochi. pp.10.

Francis R C and Hare S R. 1994. Decadal scale regime shifts in the large marine ecosystems of the North–East Pacific: A case for historical science. *Fisheries Oceanography* **3**: 279–91.

Goela P C, Cordeiro C, Danchenko S, Icely J, Cristina S and Newton A. 2016. Time series analysis of data for sea surface temperature and upwelling components from the southwest coast of Portugal. *Journal of Marine Systems* **163**: 12–22.

IPCC. 2007. *Impacts, adaptation and vulnerability summary for policy makers*. Intergovernmental Panel on Climate Change, Working Group II, Fourth Assessment Report pp. 16.

Jayaram C and Dinesh Kumar P K. 2018. Spatio-temporal variability of upwelling along the southwest coast of India based on satellite observations. *Continental Shelf Research* **156**: 33–42.

Nair P G, Joseph S, Kripa V, Remya R and Pillai V N. 2016. Growth and maturity of Indian oil sardine *Sardinella longiceps* (Valenciennes, 1847) along southwest coast of India. *Journal of Marine Biological Assessment of India* **58**(1): 64–68.

Perry A L, Low P J, Ellis J R and Reynolds J D. 2005. Climate change and distribution shifts in marine fishes. *Science* **308**(5730): 1912–15.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Rohit P and Bhat U. 2003. Sardine fishery with notes on the biology and stock assessment of oil sardine off Mangalore-Malpe. *Journal of Marine Biological Assessment of India* **45**(1): 61–73.

Sparre P and Venema S C. 1992. *Introduction to tropical fish stock assessment*. Food and agriculture organization of the United Nations, Rome. 306/1 pp. 376.

Srinath M, Kuriakose S and Mini K G. 2005. Methodology for the Estimation of Marine Fish Landings in India. *CMFRI Special Publication* **86**: 1–57.

Strussmann C A, Conover D O, Somoza G M and Miranda L A. 2010. Implications of climate change for the reproductive capacity and survival of New World silversides (family Atherinopsidae). *Journal of Fish Biology* **77**: 1818–34.

Sumaila U R, Cheung W W L, Lam V W Y, Pauly D and Herrick S. 2011. Climate change impacts on the biophysics and economics of world fisheries. *Nature Climate Change* **1**: 449–56.

Supraba V, Dineshbabu A P, Thomas S, Rohit P, Rajesh K M and Zacharia P U. 2016. Climate influence on oil sardine and Indian mackerel in southeastern Arabian Sea. *International Journal of Development Research* **6**(8): 9152–59.

Vivekanandan E. 2013. Climate Change: Challenging the sustainability of marine fisheries and ecosystems. *Journal of Aquatic Biology and Fisheries* **1**(1 and 2): 54–67.

Vivekanandan E and Krishnakumar P K. 2010. Spatial and temporal differences in the coastal fisheries along east coast of India. *Indian Journal of Marine Science* **39**(3): 380–87.

Vivekanandan E, Rajagopalan M and Pillai N G K. 2009. *Recent trends in sea surface temperature and its impact on oil sardine*, pp. 89–92. (Ed) Aggarwal P K. Global climate change and Indian agriculture. ICAR, New Delhi.

Wood C M and McDonald D G. 1997. *Global Warming: Implications for Freshwater and Marine Fish,* pp. 332. Cambridge University Press, Cambridge.