Oil sardine landings and Revenue realization under a climate change regime in India

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Abstract

The present study probes to assess the distributional shifts in sardine landings across the states and its impact on the revenue realisation across the country. The secondary data related to the landings across the states were obtained from the National Marine Living Resources Data Centre (NMLRDC) of the Central Marine Fisheries Research Institute, Kochi for the period 1985-2017 and the primary data on the landing centre prices were obtained from Socio-Economic Evaluation Technology and Transfer Division (SEETTD) of CMFRI. Average landings showed a sturdy decrease after 2013 elucidating the price surges and regional shifts in distribution of oil sardines off the Indian coast. The prices showed an amplified growth rate in the Northwest coast of India stating the increased demand for sardines in the region during the recent decades. The surge in mean prices and mean landing quantity between the decades was computed using the Decomposition Model. An analysis of the landing centre prices of oil sardine along India showed the highest change in mean price which means that there is a higher price effect when compared to the quantity effect. The availability of sardine in non- traditional demand areas is due to shifts in habitat distribution (towards the latitudinal stretch) and the demand for import of sardines to the domestic markets and fishmeal industries. The study advocates the need for establishing affordable prices (minimum support and maximum ceiling prices) for sardines to provide sustenance to the fishers and fish food security to the consumers in the demand-rich regions.

Keywords: Sardine, fishery, Revenue, Price, Climate change, India

1. Introduction

The Indian oil sardine, *Sardinella longiceps*, is a major commercially important epipelagic fishery which accounts for 17-20% of the total marine fish landings in India. Sardine fishery productions are fluctuating from year to year and it is considered to be an important factor that determines the trends in total fish production of the country. Several studies relating the sardine catch variability to environmental conditions such as sea surface temperature, salinity, rainfall, upwelling (Madhupratap et al. 1994; Jayaprakash 2002; Krishnakumar et al. 2008), larval and spawning survival during the monsoon seasons (Bal and Rao 1990) and food availability (Devaraj and Vivekanandan 1999; Prathibha and Bhatt 2003) were carried out along the southern coast of India. In addition, more recently notable contributions on the oil sardine fishery and its relationship to habitat loss and climate drivers was studied by (Kripa et al. 2018; Menon et al. 2018). This clupeid fish spawns during the summer monsoon season (June to September) and the intensity in spawning is rapid in July and August months, which correlate with the upwelling months in the southwest coast of India. Oil sardine grows to about 15 cm (>1 year) attaining an early maturity stage within the life span of about 2.5 years. Oil sardines are planktivores feeds both on phytoplankton and zooplankton. Madhupratap et al., 1994 reported the correlation between the phenology of blooms of colonial diatom *Fragilaria oceanica* and the abundance of oil sardine.

Globally, average production of oil sardine production among the other sardine producing countries, India tend to be high with 65% (376,189 t) followed by Oman, Yemen, Iran, and Pakistan (FAO 2016). Oil sardine landings constitute to about 66-96% of the total global catch. Over the years, oil sardine catches of India collapsed eventually since 2012. The sardine famine was noted in the year 2013 with a decline of 0.39 million tons (2012) to 0.21 million tons in the year 2013. It further waned to about 0.15 million tons to 0.068 million tons in the years 2014 and 2015. This indicates a percentage variation of drop in sardine catch to about 46% to 82% since 2012. The southwest region, comprising the states of Kerala, Karnataka and Goa where oil sardine was abundant, experienced a major setback resulting in the overall reduction of oil sardine landings in the country with a maximum loss of nearly 3 lakh tonnes. Oil sardine catch along Kerala coast dropped drastically to 68431 t registering a sharp decline from an estimated 1.55 lakh t recorded in the previous year and a record of 3.92 lakh t during 2012.

However, these falloffs in the landings are not unusual, as the oil sardine stock has collapsed in a similar way in 1929, 1943, 1963, 1986 and as recently as 1994. These small pelagic fishes are highly influenced by the environmental conditions in the sea, the temperature, salinity, oxygen levels etc. There have been serious disruptions in the climatic conditions inducing variations in environmental events such as upwelling in the Arabian Sea. Besides, 2015 was a strong El Niño year with reduced rainfall and increased sea surface temperatures. These factors, coupled with excessive fishing on the stock beyond the maximum sustainable yield, and excessive capture of juveniles during 2010-2012, has led to a famine in the oil sardine stock in the Indian coast.

Sardines bolster the fisher folk’s economic state through their significance for increased consumption rate, strong demand and supply paradigm in marketing of the fish. Among the Indian maritime states, Kerala is the maximum fish consuming state leading to a recognized market demand. In addition, the supply pattern is met from the fish arrivals from the neighbouring states of Tamil Nadu, Karnataka, Maharashtra, and Goa (Salim et al. 2015). The southwest region, comprising the states of Kerala, Karnataka and Goa where oil sardine was abundant, experienced a major setback resulting in the overall reduction of oil sardine landings in the country with a maximum loss of nearly 3 lakh tonnes. Oil sardine is experiencing a surge in the price these years, probably due to its high demand and low supply. At the same time, there has been an increase in the share of the landings along southeast coast where there is less demand for oil sardine.

In this context, we investigate the economic factors influencing variability in a 33-year time-series of oil sardine landings across all the coastal states of India. This study will address the climate change driven fluctuations in the revenue dynamics of the sardine fishery. We made use of sardine landing data, landing centre value and landing centre price of each coastal state to ascertain the observed economic variability among each other. The study will elucidate the potential effects of an economic surge in sardine fishery with potential inputs for facilitating sustainable fishery management.

2. Data and Methods

2.1. Study site

Oil sardine distribution extends along both the east and west coast of India. Distribution off the west coast of India is confined to the 40 m isobaths with temperature ranging from 22-28^{0}C. Landing datasets for nine coastal states and one union territory was used for the present study. Figure 1 represents the coastal states and union territory of India used for the study.

2.2. Datasets

Annual sardine landing datasets of all the coastal states from 1985 to 2017 (33 years) were collected from the National Marine Living Resources Data Centre (NMLRDC) of Central Marine Fisheries Research Institute, Kochi. CMFRI was involved in the estimation of marine fish landings since 1920s' and in the latter years, the landing datasets were estimated using stratified multi-stage sampling method. We studied the annual landings of the oil sardines over a period of 33 years obtained from the more reliable source of information on the fishery. The Landing Centre Price (LCP) and Landing Centre Value (LCV) were collected from the Socio-Economic Extension and Technology Transfer Division (SEETTD), CMFRI. The price values were deflated using the Wholesale Price Index (WPI) from the WPI source release for the year 2011. The interannual/decadal variability within the landings and landing price value across all the coastal states were done using the Decomposition analysis (Hazells, 1982; Shyam et al. 2004). The coastal states were categorized into four regions: Southwest Southeast, Northwest and Northeast zones. This regional zonation was classified based on the dominance in the geographical distribution of major finfish groups in the Indian coast. Increase in landings and LCP of oil sardine along Southwest Southeast, Northwest and Northeast coasts of India during the two decades: Period 1(1985-2000) and Period 2(2001-2017) were studied.

2.3. Data Analysis

2.3.1. Deflation of Landing Centre Value and Landing Centre Price

To deflate the series of price values over the years, nominal price value and an appropriate price index is essential. The nominal landing price values and landing centre values are the values acquired from the SEETTD, CMFRI. The WPI index used here is from the source, http://eaindustry.nic.in/home.asp. The formula for obtaining the real value is obtained by taking the ratio of nominal values to the price index (decimal form) for that same period.

$$\boldsymbol{Real\backslash Deflated\ Value} = \frac{\textbf{Nominal Value}}{\textbf{Price Index (decimal form)}}$$

2.3.2. Growth rate

Growth rate on landings and Landing Centre Values of Oil Sardine for both the decades were estimated. This estimation was carried out to understand the past performance of the values across the time-scale. We used the exponential growth function (Singh et al. 2006) to find out the trends in landings and LCV over the two periods.

The exponential growth function is of the following form:

$$\boldsymbol{Y = ab^t\, e_t}$$

Where, Y=Dependent variable for which growth is estimated, a=intercept, b= Regression-coefficient, t=time-variable, e=error term. The above mention equation was used to estimate the growth rate of the variables, Landings and LCV. The linear form of the equation can be written can be obtained by natural log-conversion on both the sides as follows:

$$\boldsymbol{ln_e Y = ln_{e^a} + t\, ln_{e^b}}$$

2.3.1. Decomposition Model

To understand the source of growth and variability in the landings and landing centre prices, the Hazells, 1982, Decomposition model was used. The landing and LCP values were first detrended using the linear relations of the form:

$$\mathbf{Z_t = a + b + e}$$

Where Z_t, denoted the dependent variable (landing and landing centre price), t = time variable and e_t = random variable residual with zero mean and variance σ^2. After detrending the data, the residuals were centered on the export mean export quantity and export unit value resulting in the detrended time-series data of the form:

$$\mathbf{Z_t^{*}=e_t+z}$$

Where z = mean of landings/LCP, Z_t^{*}= detrended landings or LCP. The detrended values were subjected to the following analysis:

$$\mathbf{LCV = LAN.\ LCP}$$

Where LCV = the landing centre value of oil sardine, LAN = the landings of oil sardine, LCP = the landing centre price of oil sardines.

The description of the variable considered for calculating component of change in average landing centre value and component of change in variance of landing centre value are given in Table 1.

3. Results and Discussion

3.1. Inter-Annual Variability of Oil Sardine

In the present study, Oil sardine landings of the Indian coast for the period of 1985-2017 (33 years) were examined. Highest landing was recorded in the year 2012 to 7.3 million tonnes and lowest landing was from the year 1994 to 0.5 million tons. Oil sardine landings over the years showed an upward trend till the year 2012 and have started declining since 2013 till now. The total landings decline was 6 million tons in 2013 from the peak of 7.2 million tons in 2012. It further waned to 5.4 million tons in 2014, and continued to drop to about 2.9 million tons in 2015 and 1.7 million tons in 2016 (Figure 2). Kerala stands as a major contributor with 51% of oil sardine landings over the years followed by Tamil Nadu (19%)

and Karnataka (16%). The landing contribution from the states such as West Bengal, Gujarat and Orissa tend to be meagre in comparison to the other coastal states of India. Figure 3 represents the percentage variations of total landings over the years from each state.

3.1.1 Regional variability of Oil Sardine Landings

To understand the fluctuations and variability in landings of oil sardine off the Indian coast more in detail, the spatio-temporal scale was divided into four regions and two decades respectively. The first decade covers the first 16 years (1985 to 2000) of the time-series and the second decade includes the next 17 years (2001 to 2017). Nine coastal states and one union territory were classified into four regions such as: Southeast (Tamil Nadu, Pondicherry and Andhra Pradesh), Northeast (Odisha and West Bengal), Southwest (Kerala, Karnataka and Goa), and Northwest (Maharashtra and Gujarat). From examining the results on landings and percentage variations regionally and decadal-wise, it is evident that the Southwest coast immensely contributes to the overall oil sardine landings and it has drastically increased from 18.5 million tons (in the first decade) to 54.5 million tons in the second decade. Figure 4 represents the region-wise and decadal-wise landings of Oil Sardine in the Indian coast. Among the coastal states of the Southwest coast, Kerala registered to be the major contributor with 14 million tonnes and 35.85 million tonnes in the first and second decade, respectively. The next regional contributor is the Southeast coast, which showed a twofold increase in the second decade. The Northeast and Northwest coastal regions are the minimum contributors to the landing. However, the significant fact to be noted is the increase over the second decade in these regions. Both the coastal regions have shown a subsequent progress in landings during the second decade. In comparison, among the Northwest and Northeast region, the Northwest coastal regions have shown a greater increase from 0.4 in the first decade to 2.2 million tons in the second decade. Percentage contribution has increased from 71 to 75% in the Southwest coast and 2 to 3% in the Northwest coast. The fall in percentage variability was noted in the Southeast coast from 27 to 22% (shown in Figure 5.a. and 5.b.). The result of increased sardine landing enrouted towards the towards the higher latitudes (off Maharashtra and Gujarat) substantiates that the sardines are extending their habitat towards the Northwest coast of India due to feeble oceanographic conditions and climate change impacts on the ecosystem. In addition, the climate change studies revealed the distributional shifts of sardines towards the Northern latitudes across the West and East coast. These shifts resulted in the availability of sardine across the non-conventional consuming states leading to the usage of sardine for non-food purposes (Madhupratap et al. 1994; Vivekanandan and

Krishnakumar 2010; Salim et al. 2017). On the other side, two significant interventions during the study period was noted, trawl bans (since 1989) and introduction of outboard crafts (since 2010) was also described to be the cause of increase and waning sardine landings. Pre-ban periods (past 1988) and Post-ban (subsequent increase), since 2010 introduction of outboard crafts (ref, technical report – trawl ban). Though there are two significant interventions almost in the same period, namely the seasonal ban and introduction of outboard crafts, the resource mainly targeted by the second intervention is oil sardine and hence the impact on the series on total landings excluding oil sardine can be attributed to the effect of seasonal fishing ban (Mohamed et al. 2014; Essington et al. 2015).

3.2. Growth analytics between the Landings and LCV

The growth rate among the landing and LCV across the two decades were analysed using the growth rate model. Growth range and Standard errors of Sardine landings and LCV for each region is provided in the table 1. The level of significance was found to be higher (P value = 0.00) in the LCV in all the regions excluding Northwest coast in the first decade. Moreover, the less significant P values higher than 0.1 was noted from both the decades in the landings of Southwest and Northwest coast. This supplements that shrinkage in oil sardine landings does not have any stimulus on the rapidly growing LCP and LCV.

Growth rate of Oil Sardine landing over the decades has reduced in all the regions exhibited in Table 2 and Figure 6. This condition was prominent in the southwest coast in both the decades and off the northeast coast in the first decade. The increase in landings in the northwest was pragmatic from -6.4 to 4.5 over the two decades. In the Southwest coast, the growth rate shows a further negative increase from -1.7 to -2.1 Both the Northeast and Southeast regions bared relatively less ranges of discernments in oil sardine landings.

Although the landings were showing loud decreasing trend over the decades, the growth rate of LCV in the Northwest coast exhibited an increasing value among the consequent years. However, other regions showed a drastic decline in the growth rate of LCV. Figure 7 portrays the growth rate of landing centre Values of Oil sardine across the four regions and two decades.

3.3. Economic Evaluation of Oil Sardine Landings

3.3.1. Landing Centre Price

Landing Centre Price (LCP) is the unit value of the fish per kilogram expressed as Rupees/kg. The deflated LCP (with base year 2011) was used for the analysis (presented in the Figure 8). The gradual growth of real values (deflated LCP) from the minimum of Rupees 1.18 to the maximum of Rupees 92.38 was definite over the years. However, the rapid dips in real values were noticed in the year 2015 and 2017 conversely with an elevated peak during 2016. This increase in price proves the demand-supply price surges evidential from the years 2015 to 2017. The rise in real LCP values are due to the decline in the oil sardine landings from 2.9 million tonnes (2015) to 1.6 million tonnes (2016). Thus the demand for oil-sardine has improved its unit price value during 2016 and later settled down to its standard price rate in the year 2017. Several studies on decline in the oil sardine landings states that, the state of Kerala, the major contributor of the sardine fishery from the Southwest coast of India witnessed the catch decline incessantly to the low of 2.4 lakh tonnes to 0.45 lakh tonnes in 2016 (CMFRI 2017). This decline was attributed to the retarded growth of the species and diminished spawning in 2015-16 preludes to the onset of *El Niño*, following the rise in temperature along the coastal waters of India (Kripa et al. 2018). This state was revived to normal with the landings in 2017 at 3.33 million tonnes directing the real LCP values to well back to the standard price range. The linear trend line in the figures 6.a., 6.b and 6.c represents that, the increase in LCP over the years is 1.5 times (R^2=0.67) and comparison among the two decades states that the rise in LCP to about 3.5 times in the second decade. However, 99% significance in the LCP is noted in the first decade, which foresees the positive relationship of LCP with quantity in the first decade.

3.3.2. Landing Centre Value

Landing centre value is defined as the estimated economic value based on the landing price/ kg. The values may oscillate with the factors such as size of the fish, species and market efficiency. Landing centre values were deflated with the base year 2011 (Figure 9.a.). Based on the real LC Values, the average LCV over the years is noted to be in upward trend from the year 1985 to 2013 and encountered a sudden dip in the year 2015. The maximum LCV was 186.65 lakhs in the year 2010 and the minimum was noted to be 5.05 lakh in the year 1987. The trend line displayed in the figure 9.a. projects a positive outlook for the future. This is a linear type with correlation coefficient R^2 is 0.80, it indicates that 80% of the changes in LCV have correlation with the landings. The trends in landing centre values are completely dependent on the landings as a driving factor is ascertained using the linear estimation. Comparisons on the two decades appear that the 66% of the LCV only correlates with the quantity, whereas during the second decade LCV contribution is to about 19%. The insignificant relationships between the LCV and Landings during the second decade may be due to the uncertainties in landings during the period.

3.3.3. Spatio-temporal economic variability of Oil Sardine landings

The region-wise observations on average Landing centre values were noted to be high, (177 to 999 lakhs) in the Southwest coast in both the decades. The deflated LCV for the Southeast coast of India upturns from 127 lakhs to 278 lakhs in the second decade. The Northwest coast of India has amplified to about twenty time increase from both the decades i.e. from 2.19 lakhs to 50 lakhs. This trend of LCV is similar to the region-wise landings of oil sardine fishery. Percentage variability among the two decades showed a decline in the southeast coast from 41% to 21%. In contrast to this, Southwest and Northwest showed a price value surge from 58 to 75% and 1% to 4%, respectively. The Northeast coast does not contribute much to the landings, so does not realise any LCV value in the sardine fishery economy. Figure 10.a. and 10.b.represents the regional and temporal variations of LCV and portrays the percentage variability among the regions and two decadal extents of the LCV of the oil sardine. With emphasis on understanding the relationship between the growth rate of increasing LCV and deceleration in landings across the southern and northern coastal regions of India, growth analytics on these two parameters were executed.

3.4. Decomposition Analysis of the Components of change in the mean Oil Sardine Landings and variance Landing Centre Values

From the overall analysis, the implicit relationship between quantity (landings) and the economic value of the fishery resource is tacit to be significant to each other. In addition, the decomposition model was executed for decomposing the sources of growth on the mean landings and variance LCV of the Oil sardines across all the coastal states and the two periods. The results are furnished in the Table 3 and Figure 11. The components of changes in the oil sardine landings and LCV in terms of change in mean landings and mean Landing Centre Value and their variability besides the interaction effect were set out in Table 3.

The result affirms that the contribution of change in mean landing quantity was the highest among the other components of change, i.e., the increase in mean landing centre Value. It accounted for 88.8 per cent of the increase in Andhra Pradesh (Southeast coast) followed by 86.99 in Karnataka (Southwest coast). This trend explains the fluctuating growth rates in sardine fishery among the coastal states and regions over the decades. The mean landing centre value has relatively lesser percentage shares in comparison with the mean landing quantity. The lowest change in mean LCV was noted in the states such as West Bengal (3.59%), Karnataka (6.28%) and Gujarat (8.56%). Kerala stands with higher percentage of change in mean LCV with 39.79% . Tamil Nadu and Pondicherry from the Southeast coast and Maharashtra from the Northwest region has shown increased percentage shares of mean landing centre values. The changes in the covariance values could be influenced by the changes in the variance of mean landings and landing centre values. With reference to the interactions between the two factors, the change in mean landings tend to be the significant source of driver to intervene alteration in mean landing centre values and landing centre price. This demonstrates that the economic realisation values of oil sardines are mostly relied upon the quantity and the realised values.

Conclusion

The present study indicates that Oil Sardines play a vital role in coastal economy of the fisher folks of India. However, Oil Sardine fishery is known to be a fluctuating fishery resource affected by both the physical and biological interactions of the marine environment. The historical records of depletion and decline of sardine fisheries were reported off the Konkan and Malabar regions (Southwest coast) in the year 1943. Climate change persuaded environmental changes and unfavourable niche alterations have created huge impacts on the abundance of oil sardines and thus a distributional shift of sardines towards the higher latitudes were observed and reported post 2014. With backdrop of these instances, we developed an interest in studying the impact of climate induced deviations on oil sardine landings and their effect on disparities in economic values with orientation to landing centre price and landing centre values over 33-years. The study indicates that in the viciousness of different climate change induced factors; the economy of sardine fisheries is tremendously driven by the landings. The climate change shifts have created an impact over the landings which have taken over on the demand-supply transferals since 2014. Growth rates among the landings and LCV was noted to be significant in the LCVs' among the two decades and the less significant relationships were noted in the landings especially constricted to the Northwest and Southwest coast of India. The decomposition analysis also supplements that economic realisation of sardine fishery is bound to the landings. This is an initial study in understanding the time-series of sardine landings and the economic values. Future works will flag a way to arrive at meticulous conclusions on the impact of climate change on the economics of the major fishery resources.

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Tables

Table 1. Components of change in average mean landings and LCV

S. No.	Source of change	Symbol	Components of change
1.	Change in mean landing centre value	Δ LCP	LAN, ΔLCP
2.	Change in mean landings	ΔLAN	LCP. ΔLAN
3.	Interaction between changes in (1) and (2)	Δ LCP Δ LAN	ΔLCP ΔLAN
4	Change in EQ-EUV covariance	ΔCOV(LAN, LCP)	ΔCOV(LAN, LCP)

Table 2. Growth rate and Standard errors of Oil Sardine Landings and Landing Centre Value

Coastal Regions	Landings				Landing Centre Value			
	1985-2000		2001-2017		1985-2000		2001-2017	
	Growth rate	Std. Error	Growth rate	Std. Error	Growth rate	Std. Error	Growth rate	Std. Error
Northeast	32.0****	1.3	10.9***	0.9	60.2****	2.2	21.8****	1.7
Southeast	25.3****	2.4	6.6***	1.2	39.7****	3.1	10.9****	2.0
Southwest	-1.7*	-0.1	-2.1*	-0.4	15.8****	1.0	7.0****	1.8
Northwest	-6.4*	-0.3	4.5*	0.3	10.1*	0.4	25.9****	1.6

**** P value < 0.01, *** P value < 0.05, * P value > 0.1

Table 3. Decomposition Analysis of the Components of change in the Mean Oil Sardine Landings and variance Landing Centre Values

Source of Change	Percentage share (%)									
	Northeast		Southeast			Southwest			Northwest	
	WB	OR	AP	TN	PDY	KER	KAR	GOA	MHR	GUJ
Change in Mean Landing Quantity	70.93	55.47	88.8	51.88	70.31	52.06	86.99	54.47	45.14	60
Change in Mean Landing Centre Value	3.59	10.12	10	19.73	15.75	39.79	6.28	25.81	15.12	8.56
Interaction between changes in (1) and (2)	10.23	39.93	12.71	30.77	26.05	16.29	61.46	24.2	23.24	20.23
Change in EQ-EUV covariance	15.25	-5.52	-11.51	-2.38	-12.11	-8.13	-54.72	-4.49	16.5	11.21