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Full Length Research Paper

Impact of environment variables on pelagic fish landings: Special emphasis on Indian oil sardine off Tiruchendur coast, Gulf of Mannar

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Results of the present study reported the correlation of various environmental variables such as dissolved oxygen (DO), chlorophyll 'a', primary productivity (PP), salinity, sea surface temperature (SST) and meteorological parameters such as air temperature (AT), air pressure (AP), relative humidity (RH), wind pattern, sunshine hours (SSH) and rainfall (RF) during January, 2008 to December, 2010 with that of the sardine fish landing along the Tiruchendur coast in Gulf of Mannar. The landings of the pelagic fishes like sardine, anchovy and Indian mackerel were high during south-west monsoon months extending from July to September in Tiruchendur coast. Sardines, which contribute 18.24% of the total fish catch, were recorded throughout the study period with a minimum occurrence during January and maximum in August. Large sized fishes were caught during October. It was found that, moderate temperature, high chlorophyll 'a' concentration and phytoplankton abundance are primary factors that enhance sardine fishery. Weather changes, influences fisheries through the modification of habitat characteristics, affecting the organisms to the extent that the physical, chemical and biological conditions that influence their productivity, development, nourishment and reproduction distribution are altered. Subtle changes in key environmental variables can drastically modify the abundance, distribution, and availability of fish populations.

Key words: Environmental parameters, meteorological variability, pelagic fish, salinity, Tiruchendur, Chlorophyll 'a', primary productivity, Gulf of Mannar.

INTRODUCTION

The clupeids comprise a major group among the pelagic resource. Among the clupeids, the Indian oil sardine (*Sardinella longiceps* Val.) (Valenciennes, 1847) is the most predominant species that forms the mainstay of the pelagic fishes of India and its stock is probably the widespread in the Indo-Pacific region. Presently, the west coast of India indicates a declining trend compared to an ascending pattern along the east coast of India. The Indian oil sardine (*S. longiceps* Val.), supports a neritic pelagic fishery contributing 2 to 33% of the annual marine fish production in India. However, due to the seasonal changes and changes in the meteorological variability, sardine-landing pattern has altered. Changes in habitat quality inevitably influence the spatial patterns of abundance of pelagic fish. The distribution of pelagic fish

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may be related to several interacting environmental factors, which also correlate with each other (Maravelias and Reid, 1997; Maravelias et al., 2000).

Pelagic fishery of the Gulf of Mannar

Several species of fish inhabiting the pelagic zone contribute to the fishery in the Gulf of Mannar (Raju, 2000). Sardines, anchovies, mackerel, carangids, tunas and seer fishes are important pelagic fishery caught in the Gulf of Mannar. Fishing folk of these regions are depending on this artisanal fishery (small scale) for their livelihood. Because artisanal fishers depend on the health of marine ecosystems for their subsistence, the added threat of climate change and sea level rise will not only threaten biodiversity, but human well being as well. Sardines comprising several species of *Sardinella* collectively contribute to a major share of the marine pelagic fisheries resource of India (Rohit and Bhat, 2003). Though several species of sardines supported the pelagic fishery in Tiruchendur coast, the oil sardine, *S. longiceps* alone comprised more than 90% of the catch (Total pelagic fish catch).

Status of Pelagic fishery in other regions

In the Sea of Oman, the sardine population is one of the major consumers of mesozooplankton. Sardine contributes 49% of the total landings in Muscat region and the annual landing of sardines in Oman ranges between 7000 and 18000 metric tonnes (Piontkovski et al., 2012). Due to the rising atmospheric temperature, sea surface temperature (SST), variability of the kinetic energy of eddies, frequency of fish kills and harmful algal bloom incidents, 40% decline in sardine landings were reported by Piontkovski et al. (2012).

The sardine *(Sardinops sugax)* fishery of the Gulf of California is among Mexico's most important fisheries, accounting for the largest catch and providing many productive jobs. During the early 1990s, this fishery collapsed to less than 3% of the production maximum. Surprisingly, after two years of very low catch the fishery recovered quickly. Comparative studies of fish habitat climatology have provided key clues to understanding mechanisms linking physical environment to biological populations.

Fuel consumption per fishing fleet, fuel price and market price are also determining fish catch in Norwegian fisheries rather than environmental parameters (Schau et al., 2009).

Peltonen et al. (2007) studied the pelagic fish abundance in relation to regional environmental variation in the Gulf of Finland, Northern Baltic Sea and documented the fish assemblage consisted of small sprat and herring, which together constituted about 99% of the yield. Sprat made up 83% of the yield, and it was numerically dominant in 19 of the 21 trawl catches. Trawl sampling revealed small differences in fish size distributions in different parts of the basin, but there were large local variations in fish abundance, as well as in the explanatory variables in the region studied by Peltonen et al. (2007).

The results indicate that the pelagic fish preferred regions with deepwater temperature of about 5°C to areas with warmer (especially) and with colder deep water. The avoidance of regions with deepwater temperatures,<4°C is in accordance with the findings of Parmanne et al. (1994), who stated that Baltic Sea sprat prefer temperatures <4°C. Correspondingly, the pelagic fish in the Gulf of Finland in September, 2002, avoided cold temperatures <3°C even though oxygen concentration, for example, was not a limiting factor (Peltonen et al., 2004). Moreover, North Sea herring avoided areas of cold bottom water in summer (Maravelias et al., 2000).

The most important pelagic fish stocks inhabiting Peru's relatively narrow continental shelf are anchoveta, chub mackerel (*Trachurus murphyi*) and Chilean jack mackerel (*Scomber japonicus*), which together represented 95% of the catch volume in 2006. Although historically the standing stocks have been subjected to sharp variations, apparently due more to environmental conditions than to fishing pressure, it is clear that these stocks are potentially large and generally able to recover from periodic declines. Of these, the anchoveta is the main species, comprising 92.5% stocks of the total catch, according to 2005 records.

Although fishing mortality has been a major force driving, the population collapse in Guaymas Basin. Holmgren-Urba and Baumgartner (1993) reported that, analysis of sardine scale deposits in anaerobic sediments off Guaymas Basin have shown large population fluctuations even in the absence of fishing activity because of the natural variability. It is likely that management of the species depends on the ability to differentiate between natural variability and fishing mortality.

Population of fish and other aquatic organisms are reported to be greatly influenced by physical, chemical, biological and meteorological parameters (Biswas et al., 2009). The global climatic changes are expected to affect marine fisheries productivity due to changes in water temperature, ocean currents and other oceanic conditions. This also can be affected by in changes food web structure and species distribution, influenced by the changes in oceanic condition. Among the marine fisheries, small pelagic fishes have undergone considerable variation in both their distribution and abundance over time (Kawasaki, 1984; Lluch-Belda et al., 1989; Navarez-Martinez et al., 2001); influenced by seasonal, inter-annual and decadal climate variations (Lluch-Belda et al., 1989; Bakun and Board, 2003;

de Young et al., 2004). Meteorological fluctuations are expected to affect marine fisheries productivity because of changes in water temperature, ocean currents and other ocean conditions (Pauly et al., 2002). The expected impacts of meteorological change will be seen first on the distribution and abundance of pelagic fishes (Hobday et al., 2006; Lanz et al., 2008). Among the meteorological variability temperature is the key factor, it will alter the SST. Water temperature is a key variable with regard to the distribution, abundance and metabolic activity of fishes. Since, fishes are poikilothermous, changing in water temperature will affect the physiological activity and it leads to decline of biodiversity of fishes. Marine fisheries productivity may be affected by changes in ocean conditions resulting from climate change including changes in food web structure and species distribution. Oceanic conditions were found to affect profoundly the distribution, year-chats production and yields of sardines. Among the pelagic fishery, oil sardine and other or lesser sardine alone contribute about 15% of the total marine fish production in India (Pillai, 1990). In this background, in order to understand the meteorological variability such as air temperature (AT), air pressure (AP), wind speed and wind direction, relative humidity (RH), rainfall (RF) and sunshine hours (SSH) and its effect on sardine fishery was studied for a period of 3 years from January, 2008 to December, 2010. Meteorological parameters and water quality parameters (variability) were correlated with sardine fish landing. In the present study, it is observed that fish landing (oil sardine and other sardine) were highest during South West monsoon seasons.

The metabolism activities and physiological behavior of fish is directly related to the SST and the fluctuation of SST is depending upon the AT, cloud cover and SSH. Changes in AT, cloud cover and SSH will lead to increase or decrease of SST and light penetration. Metabolic activity in fish increases by 10% for every 1°C rise in temperature of aquatic environment that is, fish need 10% of more oxygen for 1°C rise in temperature (Rahman, 1992). In all aquatic environments, phytoplankton acts as primary producer and their growth is an important process, which depends on the concentration of nutrients in water and in external factors such as temperature and light illuminations (Scavia and Park, 1976; Groden, 1977; Desormeau, 1978; Park et al., 1979; Jorgensen, 1980; Biswas et al., 2009; Ramos et al., 2011). The pelagic fishes are not particularly diverse; there are approximately 260 pelagic species, out of 12,000 marine species worldwide. ATs are expected to increase ocean warming, most significantly in the upper layer 500 to 800 m (Bernal, 1993). It causes a rise in sea level, higher SST and a weakened thermocline, which is associated with reduced primary productivity (PP) (Miller and Fluharty, 1992). Extremes in environmental factors such as elevated water temperature, low dissolved oxygen (DO) or salinity and pH can have deleterious effects on fishes (Moyle and Ceeh, 2004).

In this paper, attempt were made to correlate the meteorological parameters such as wind pattern, AP, AT, RH, SSH and precipitation with oil sardine landing at Tiruchendur.

MATERIALS AND METHODS

Tiruchendur is one of the main fish-landing centers town (Latitude: 8.29.19.1 and Longitude: 7.26.62) in Tuticorin District of Tamil Nadu, India. It is located in between Thoothukudi and Kanniyakumari and situated in the bank of Gulf of Mannar, Southeast Coast of India. Traditional sardine fishing grounds (SFGs) were chosen for the present study.

Here, we analyse temporal or seasonal patterns in pelagic fish landings in relation to regional environmental variation in the Gulf of Mannar. We focus mainly on meteorological variation and environmental variability, which can provide new insights into the relationships between sardine fish catch and the environment characteristics by decomposing the variation in response variable(s) into independent components that reflect the relative importance of the groups of predictors and their joint effects.

Meteorological parameters of AT, AP, RH, wind speed, wind direction and SSH were recorded from January, 2008 to December, 2010 in the SFG area. AT and AP were observed by standard mercury thermometer and handheld Aneroid barometer, respectively. RH was observed by whirling hygrometer, wind speed and direction were recorded by using Anemometer and wind vane, respectively. A small meteorological observatory was set up in the fishing boat especially for this study. Day light duration (SSH) and RF data were collected from the Meteorological Observatory of Kanchi School, Tiruchendur. Data on oil sardine and other sardine landings at Amali Nagar center in Tiruchendur in different seasons were collected on every day and pooled into season wise and SST was measured by standard mercury thermometer in the SFG (Traditional fishing ground) off Tiruchendur itself (Figure 1). Salinity was measured by Salinometer (Model E-2), and Chlorophyll "a" was estimated by spectrophotometry following the method of Parsons et al. (1984). Gross PP (GPP) was measured by adopting light and dark bottle method (Strickland and Parsons, 1972).

A simple spearman's correlation was done by using past statistical package. Meteorological parameters and oceanographic variables were correlated with sardine fish landing.

Fish landing data of oil sardine (*S. longiceps*) and other sardines were collected at fish auction center on weekly basis for the period of 3 years from January, 2008 to December, 2010.

RESULTS AND DISCUSSION

Atmospheric temperature at the study area was given (Figure 2) and it varied from 24.0 to 30.5°C in the 3 years. Maximum temperature at the study was uniformly recorded in the month of June during the study period. However, minimum temperatures were consistently recorded only in January, 2009 and 2010, and in 2008, minimum temperature was recorded in the month of December. Northeast monsoon and RF effect causes low temperature and direct solar heating and hot summer effect causes maximum temperature during the study period. Too little is known to even speculate on changes in physiology or morphology of the pelagic fishery that might be driven by elevated atmospheric temperature

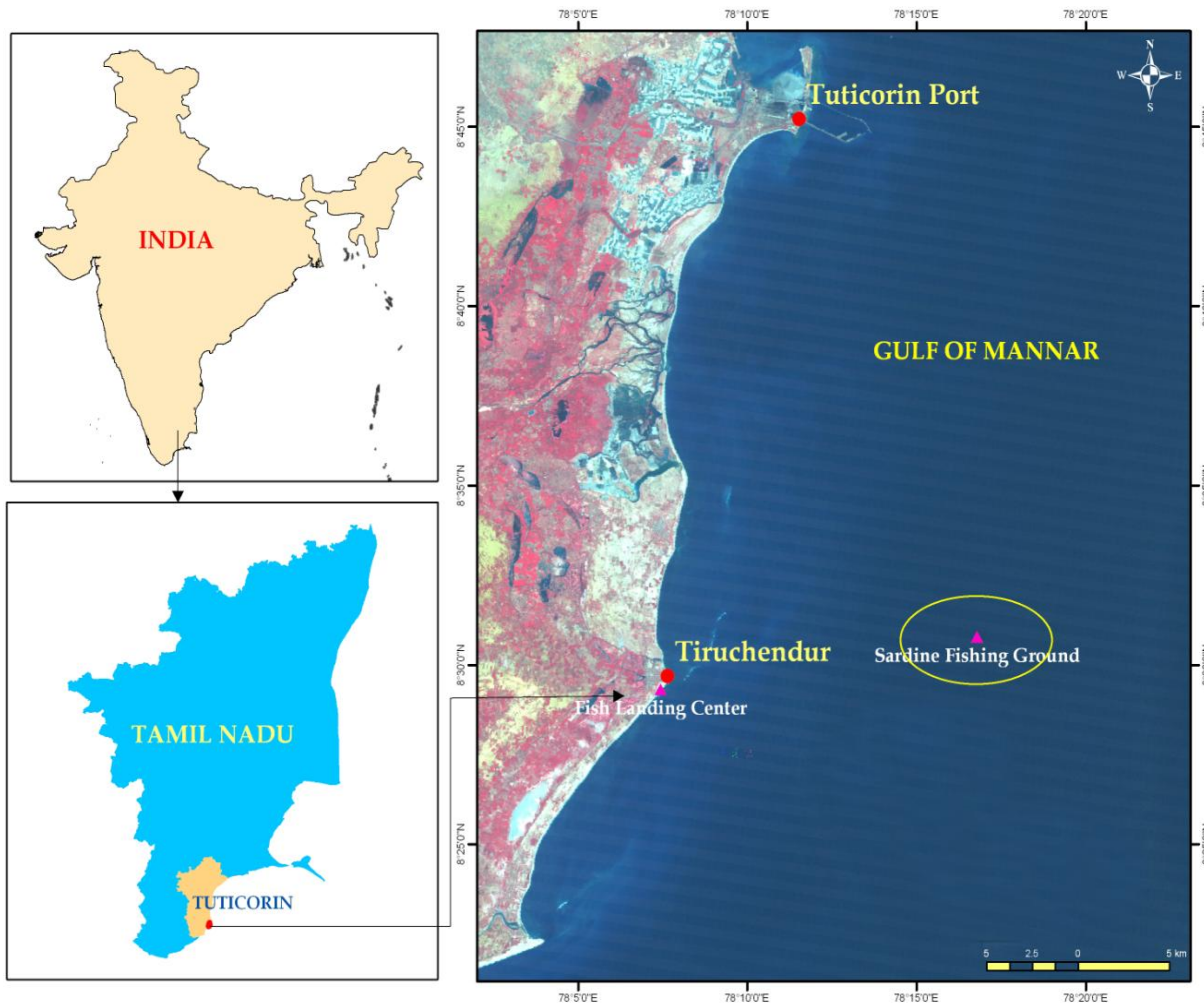

Figure 1. Study area.

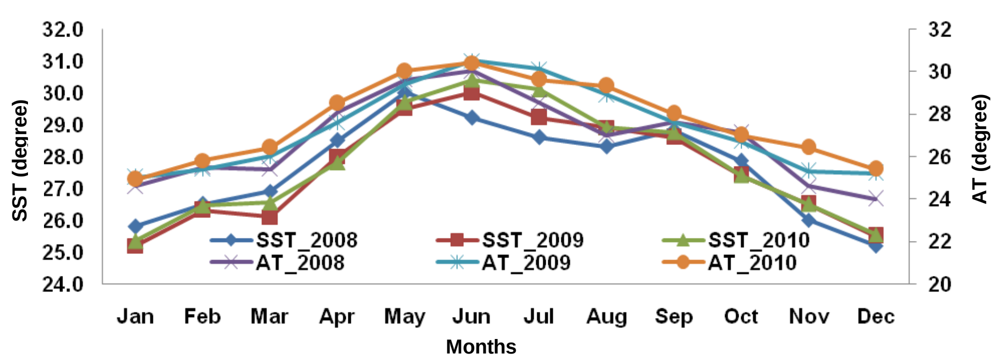

Figure 2. Monthly variation of SST and AT.

(Hobday et al., 2006). AT is directly influencing the SST of the oceanic water body and changes in the ocean temperature especially in the surface layers will have an impact on the distribution of pelagic species. In the present study, temperature is gradually rising from January to June and attaining peak value at June month,

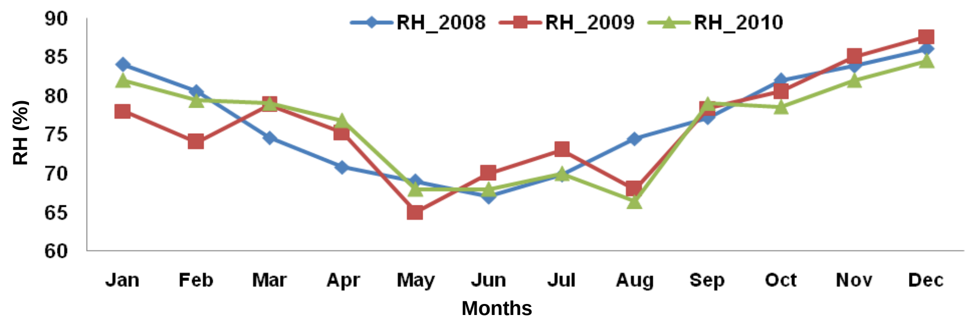

Figure 3. Monthly variation of RH.

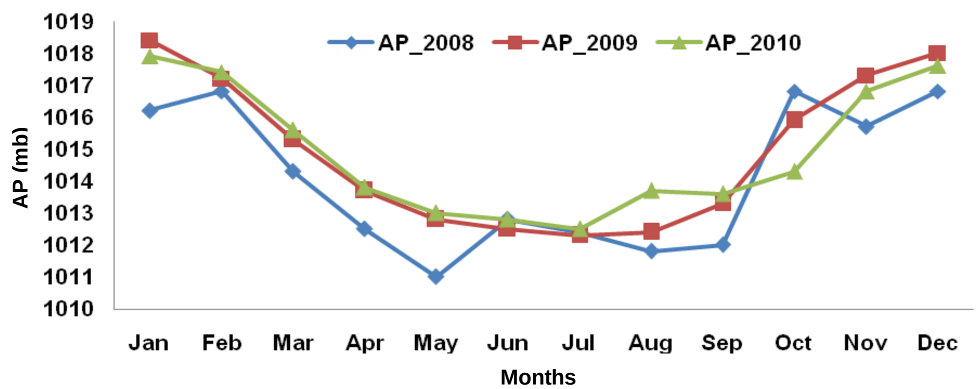

Figure 4. Monthly variation of AP.

thereafter decreasing till December. The same trend has been recorded throughout in the study.

RH was varied from 65 to 87.6% (Figure 3) during the study period and maximum and minimum were recorded in December and May, respectively during 2009 due to the summer effect. Maximum humidity was uniformly observed in the month of December in the 3 years due to the northeast monsoon effect.

Changes in the amount or timing of RF and the associated river runoff affect the salinity of the coastal waters; in the present study, period annual RF was varied from 681 to 1119.9 mm (Table 7). Maximum was observed in 2008 and minimum was observed in 2010. During the study period, maximum RF (786.2 mm) was recorded during monsoon season in 2009 and minimum (16 mm) was recorded during post monsoon in 2010; however, no RF was recorded during pre-monsoon in 2008. APs were varied from 1011 to 1018.4 mb (milli bar) during the study (Figure 4). Minimum value was recorded during summer season throughout the study period owing to the summer effect and high temperature. Maximum value was recorded during northeast monsoon due to the RF and cooling effect was found that pressure decreases during northeast monsoon (Selvin and Selvaraj, 2011). During the present study, AP shows the decreasing trend during summer season and increasing trend persists during northeast monsoon. In general, low pressure was recorded during summer months due to warm temperature, high pressure is always recorded during December due to winter effect, and it was found that a close relationship exists between AT and AP.

Wind indirectly influences pelagic species through mixing of the surface waters (Cury and Roy, 1989). Pelagic and coastal ecosystems are comparatively productive zone depending upon the availability of nutrients, sunlight and stability for phytoplankton production (Cury and Roy, 1989; Bakun and Weeks, 2004). Wind forcing could cause the upwelling in the coastal zone and enhancing the productivity of the coastal and pelagic fishery. In the present observation, wind speed was recorded to range from 3.2 to 15.8 km/h (Figure 5). High wind speed was recorded during June and July months owing to the southwest monsoon effect and during the southwest monsoon period, wind was flowing from southwest with high velocity and low speed could be recorded during March and April months. Northeast wind flow was observed during monsoon and post monsoon (Figure 6). During summer of June and July months, wind flow pattern changed and wind flow coming from Southwest direction due to the Southwest

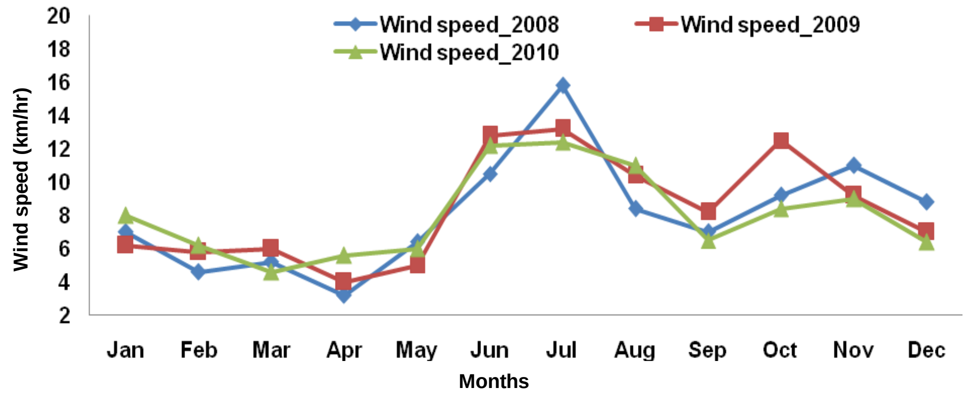

Figure 5. Monthly variation of wind speed.

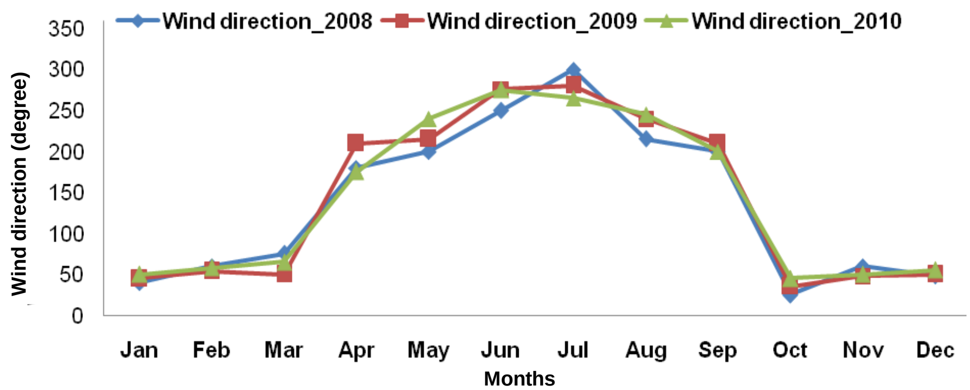

Figure 6. Monthly variation of wind direction.

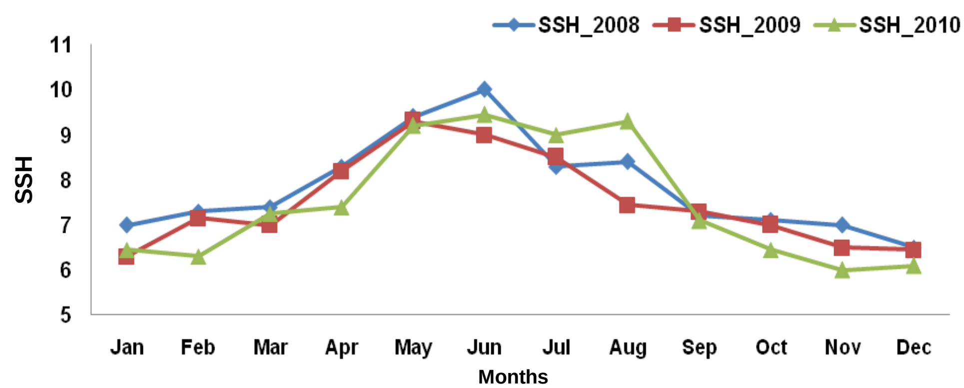

Figure 7. Monthly variation of SSH.

monsoon effect.

SSH could directly influence the salinity, SST and phytoplankton productivity. The intensity of the solar radiation and SSH are determining the euphotic zone of the oceanic ecosystem. SSH was recorded between 6 and 10 h/day (Figure 7) during the study; minimum was recorded in the month of November, 2010 and maximum recorded in June, 2008. SSH or day length is an important factor, which could affect the SST and sea surface salinity. In the present study, it was found that the annual SSH has been decreased from 2008 to 2010; it could be due to the stronger winds (Pant, 2003). Though

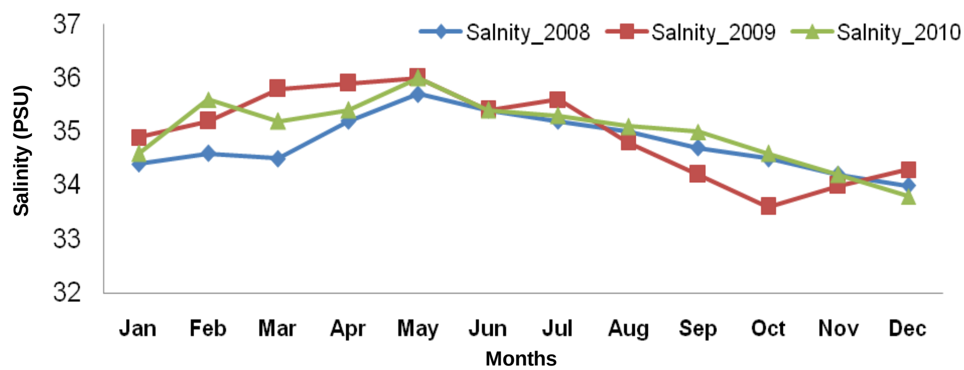

Figure 8. Monthly variation of salinity.

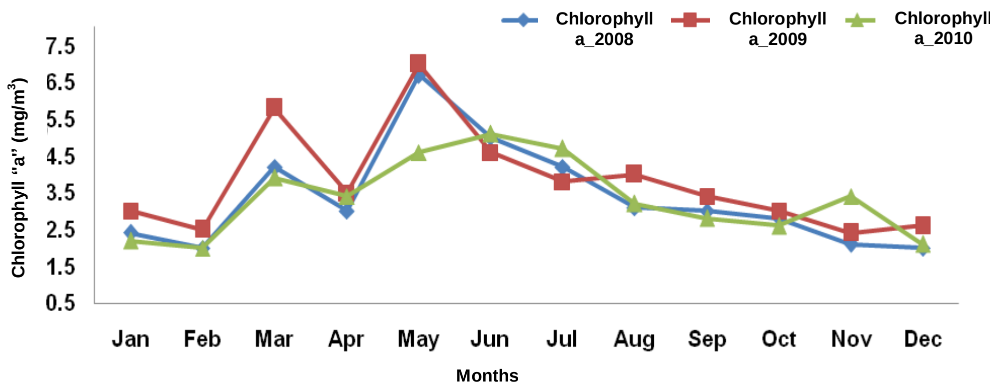

Figure 9. Monthly variation of Chlorphyll ''a''.

these weather parameters have been influencing the pelagic fishery, other factors like export price of the fish, fuel price, market value of the fishmeal and fish oil are playing important role in the oil sardine fishery. Therefore, these factors also influence the amount of fish caught in this fishery. The oil sardine fishery of the Gulf of Mannar also show declining trend as like other Coast and Gulf regions of the World (like Sea of Oman, Gulf of California and Finland). SST values rises from 25.2 to 30.4°C (Figure 2), maximum was recorded in the month of June, 2010 and minimum was recorded during December, 2008 and January, 2009. SST was greatly influenced by the atmospheric temperature (Asha and Diwakar, 2007) and it is one of the important physical factors, which affects the chemical and biological reactions in water. It will directly affect the pelagic fishery than other layers of the marine fishery and regulates the rate of photosynthesis in aquatic ecosystem. In the present study, it has been observed that high temperature is noticed in the months of May and June due to the longer SSH, bright sunshine and hot air. Low temperature in the months of October to December was due to cloudy sky northeast monsoon effect, resulting RF brought down in the temperature to the minimum range.

Salinity was varied from 33.6 to 36 PSU (Figure 8) during the observation and it has been observed that minimum value was recorded from October to December due to the heavy RF effect and salinity value were gradually increased from January to May and attained high value in the month of May due to the summer effect resulting high evaporation. After that, salinity value decreased up to December raised and reaches high value recorded during May month which might be due to the bright sunshine and hot air. It showed that salinity was negatively correlated with RF. The salinity fluctuated unimodally associated with northeast monsoon in Tuticorin waters. Similar trend in salinity values were also recorded from various parts in Gulf of Mannar (Jayaraman, 1954; Bapat, 1955; Asha and Diwakar, 2007).

Chlorophyll "a" varied between 2 and 7 mg.m^3 (Figure 9). Chlorophyll "a" showed distinct seasonal variation and close direct relationship with the primary production (Gopinathan et al., 1994). Maximum chlorophyll "a" value was recorded in the month of May, 2009 and minimum was recorded in February, 2008 and 2010. Chlorophyll "a" was positively correlated with SST, salinity and PP and negatively correlated with oil sardine. From this

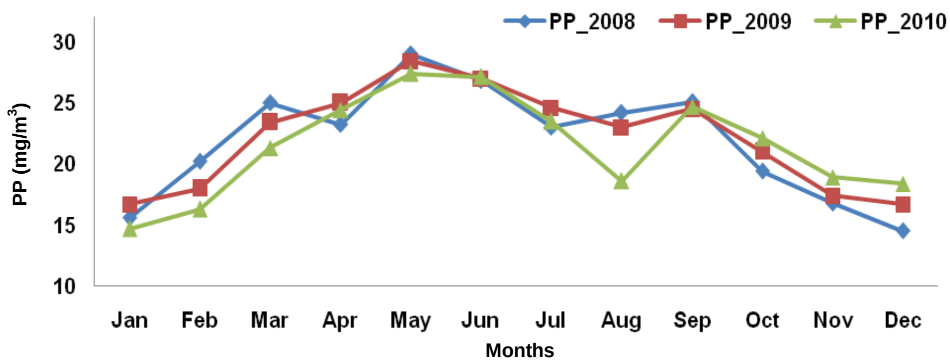

Figure 10. Monhtly variation of PP.

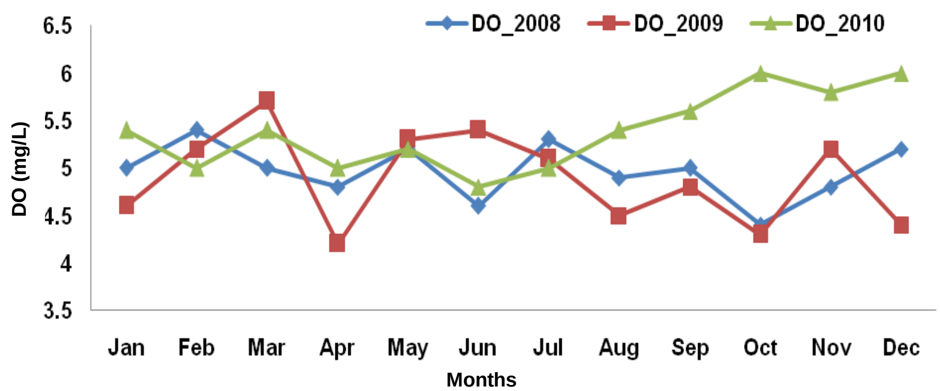

Figure 11. Monthly variation of DO.

study, it is understood that high Chlorophyll “a” was always recorded in summer (in the month of May). Vinayachandran et al. (2004) reported that, in the month of May, there is high Chlorophyll “a” along the Indian coast as well as along the southern coast of Sri Lanka. The Chlorophyll “a” value corresponded to the PP during the observation. The Chlorophyll “a” bloom is fully developed during June to July and there is high Chlorophyll “a” in the Gulf of Mannar, Palk Bay and along the southern coast of Sri Lanka (Vinayachandran et al., 2004), PP in the fishing ground was varied from 14.5 to 29.0 mh/m^3 (Figure 10). The peak value was recorded during summer and low value recorded in the months of December and January. Although photosynthesis is a key component of the global carbon cycle, its spatial and temporal variability is poorly constrained observationally. DO was recorded from 4.2 to 6.0 mg/L (Figure 11). Minimum DO was recorded in the months of April due to the summer effect and maximum was recorded in the months of October and December, 2010. The higher values of DO might be due to the cumulative effect of higher wind velocity coupled with heavy RF and the resultant fresh water mixing (Das et al., 1997; Mitra et al., 1990). The rate of gross primary production shows seasonal variation during the study period. Two distinct peak periods have been noticed, high value of production was observed in the month of May, 2008 and minimum was observed in December, 2008. It was observed that reduced light intensity due to the clouds formation during the study area has affected the PP during December and January in all the 3 years.

During this study period, maximum (total) sardine fish catch (290.87 MT) was recorded in 2008 and minimum (254.05 MT) was recorded in 2010 (Figure 12). Among the total sardine fish catch, oil sardine alone contribute about 200.32 metric tons and it was nearly 18.31% of the total fish catch during the study period. Oil sardine fish catch was high during the southwest monsoon season (mostly in the month of August). High Chlorophyll “a” contents recorded during observation has resulted in good amount of PP attributing to more fish catch. During southwest monsoon, nutrient rich Arabian Sea water brought to Gulf of Mannar by southwest monsoon current caused southwest wind flow. Owing to this process, PP was more during southwest monsoon particularly in the month of August. The probable life span of Indian oil sardine based on the scale studies is 2½ years (Chidambaram, 1950), but difficult to determine because the annual rings in their scales may be formed for several reasons than yearly changes in their environment.

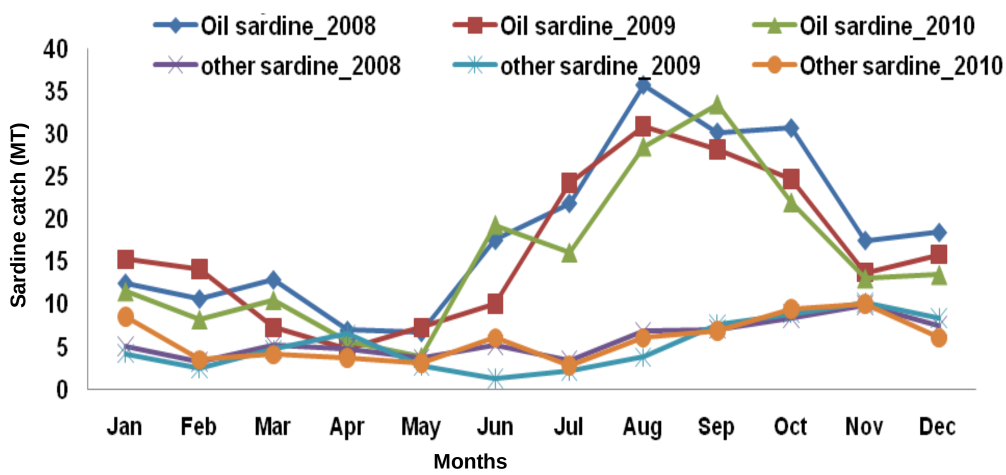

Figure 12. Monthly variation of Oil sardine and other sardine catch.

Table 1. Statistical analyses for weather parameter _2008.

2008	Oil sardine_2008	Other sardine_2008	AT_2008	RH_08	Rainfall_08	Sunshine_2008
Oil sardine_2008	1					
Other_sardine_2008	0.559389318	1				
AT_2008	-0.098398987	-0.459399682	1			
RH_08	0.224349205	0.684617239	-0.96118311	1		
Rainfall_08	-0.132362514	0.643554752	-0.82798808	0.893765099	1	
Sunshine_2008	-0.344211726	-0.605144888	0.967197139	-0.97289210	-0.76964252	1

Table 2. Statistical analyses for weather parameters_2009.

2009	Oil sardine_2009	other sardine_2009	AT_2009	RH_09	Rainfall_09	Sunshine_2009
Oil sardine_2009	1					
Other sardine_2009	0.297418259	1				
AT_2009	0.113677497	-0.496662571	1			
RH_09	0.192629261	0.893349488	-0.82934842	1		
Rainfall_09	-0.040534144	0.93083271	-0.42829032	0.789781192	1	
Sunshine_2009	-0.294754002	-0.606609388	0.915808193	-0.88075589	-0.4055338	1

Statistical analyses

SST was positively and significantly correlated with AT and salinity. Salinity was negatively correlated with fish catch (Oil and other sardine), DO, RF and had positive correlation Chlorophyll ‘‘a’’ and PP (significantly) (Tables 1, 2, and 3). SST had negative correlation with other sardine, DO and positive (insignificant) correlation with oil sardine catch. However, SST had positive and highly significant correlation with salinity, Chlorophyll ‘‘a’’ and PP. Oil sardine has been negatively (insignificant) correlated with RF and other sardine positively correlated with RF.

Fish catch and salinity showed negative correlation. Chlorophyll ‘‘a’’ and PP also showed positive correlation. Atmospheric temperature was negatively correlated with oil sardine and other sardine catch. RH had positive correlation with oil sardine (insignificant) and other sardine (significant). SSH was negatively correlated with fish catches, RH, RF and positive correlation with atmospheric temperature (highly significant). Wind speed was positively correlated with oil sardine and other sardine. Wind direction was positively correlated with oil sardine, Chlorophyll ‘‘a’’, PP, AT, SST, salinity, SSH and negatively correlated with other sardine, AP, RH and RF.

Table 3. Statistical analyses for weather parameters_2010.

2010	Oil sardine_2010	Other sardine_2010	AT_2010	RH_10	Rainfall_10	Sunshine_2010
Oil sardine_2010	1					
Other sardine_2010	0.16943423	1				
AT_2010	0.265871179	-0.62013225	1			
RH_10	-0.259508058	0.772538124	-0.96974815	1		
Rainfall_10	0.079008073	0.95202635	-0.41917228	0.622457829	1	
Sunshine_2010	0.238015242	-0.79872015	0.959667694	-0.99909362	-0.6544085	1

Table 4. Statistical analyses for oceanographic parameters_2008.

2008	Oil sardine_2008	other sardine_2008	DO_2008	SST_2008	Salnity_2008	Chlorophyll a_2008	PP_2008
Oil sardine_2008	1						
Other_sardine_2008	0.559389318	1					
DO_2008	0.043680929	-0.617581943	1				
SST_2008	0.008544102	-0.463567998	-0.082611656	1			
Salnity_2008	-0.247388998	-0.646940341	-0.008826775	0.963252063	1		
Chlorophyll a_2008	-0.416290136	-0.655581606	-0.09819944	0.905630276	0.980370012	1	
PP_2008	-0.181239324	-0.722279044	0.17014525	0.947422433	0.982278393	0.937121493	1

Table 5. Statistical analyses for oceanographic parameters_2009.

2009	Oil sardine_2009	Other sardine_2009	DO_2009	SST_2009	Salnity_2009	Chlorophyll a_2009	PP_2009
Oil sardine_2009	1						
Other_sardine_2009	0.297418259	1					
DO_2009	-0.528888072	-0.842078501	1				
SST_2009	0.13407414	-0.416576943	-0.121837485	1			
Salnity_2009	-0.567207563	-0.94309518	0.81695363	0.435675558	1		
Chlorophyll a_2009	-0.536720312	-0.846452098	0.599765821	0.654710641	0.950881293	1	
PP_2009	-0.147629869	-0.641035235	0.179032947	0.944281793	0.700428956	0.86699938	1

Table 6. Statistical analyses for oceanographic parameters_2010.

	Oil sardine_2010	Other sardine_2010	DO_2010	SST_2010	Salnity_2010	Chlorophyll a_2010	PP_2010
Oil sardine_2010	1						
Other_sardine_2010	0.16943423	1					
DO_2010	0.301388888	0.989944279	1				
SST_2010	0.372202587	-0.624169346	-0.5767589	1			
Salnity_2010	-0.250422816	-0.992601148	-0.9974845	0.633107992	1		
Chlorophyll a_2010	-0.032502423	-0.712032436	-0.7207545	0.914397536	0.760726144	1	
PP_2010	0.009271578	-0.506164645	-0.5224679	0.887669456	0.569962976	0.965888336	1

AP was positively correlated with RH and RF (Tables 4, 5, and 6). Generally, in Tiruchendur landing centre, oil sardine fish catch would be more during June and July. However, during this study period, more amount of sardine fish catch was recorded in the month of August. It could be due to the variability of meteorological characteristics implying climatic changes in coastal ecosystem. Out of the total pelagic fish catch, oil sardine contributed to 75% of fish catch. Low fish catch was recorded during April. Chidambaram (1950) found that

Table 7. Annual rainfall.

	Rainfall (mm)		
Season	**Year_2008**	**Year_2009**	**Year_2010**
Post monsoon	388.4	39.3	16
Summer	104	198	51
Pre- monsoon	0	18	45
Monsoon	627.5	786.2	569
Total	1119.9	1041.5	681

temperature of 26 to 28°C was favorable for inshore migration of oil sardine particularly juveniles and he reported that temperature over 29°C during March to May causes the offshore disappearance of the adult fish. This concept could be confirmed by the present observations.

Fishing season

On the southwest coast, the oil sardine fishery commences soon after the outbreak of monsoon in June and continues until March to April. Along the Kerala coast, catches are high throughout the year except during March to May, while in the Karnataka - Goa belt, the season starts in September/October with peak fishing during October to January period. On the southeast coast, the fishing season is from April to December with peak catches during April to June on the Tamil Nadu coast and July to October along the Andhra coast.

Conclusion

This study is the first to report on *S. longiceps* landings with respect to meteorological changes in Gulf of Mannar. Since no sufficient data on sardine fishery is available in this region, we used only 3 years data collected during the present study. Climate changes are expected to affect the marine fisheries productivity because of changes in water temperature; and other in Tiruchendur coast, *S. longiceps* is available throughout the year with minimum catch during April and maximum in August. Moderate temperature between 24.9 and 28.5°C could be considered as favorable for the sardine fishery. Analyses indicated that oil sardine catch have been decreasing from 2008 to 2010 and about 25 MT of oil sardine fish catch had decreased from 2008 to 2009. About 10.98 MT has decreased from 2009 to 2010. Like other parts of Gulf, oil sardine fishery in Gulf of Mannar also show declining trend. Though, these weather parameters have been influencing the pelagic fishery, other factors like export price of the fish, fuel price, market value of the fish meal and fish oil are playing important role in the oil sardine fishery. Therefore, these factors also influence the amount of fish caught in this fishery. The oil sardine fishery of the Gulf of Mannar also show declining trend like other Gulf regions of the world (like Sea of Oman, Gulf of California and Finland).

From the study, it was understood that July, August, September and October months are favorable for sardine fish catch. High fish catch was recorded during August; however, large size fishes were caught in October. The study result shows the similarity with fishermen opinion. Based on the opinion obtained from the traditional fishermen of the village, it was understood that, sardine fish catch is decreased in the traditional fishing grounds off Tiruchendur and about 20 to 30 years before, they used to get more fish catch than what they are getting now in the same fishing ground. Considering then, continuous monitoring is essential to understand the impact of meteorological variability (changes) on pelagic fishery. The wind pattern in the study area is found to influence the Northeast and Southwest monsoon currents. The currents could be considered as playing the major role in the fish growth and pelagic fish catch in Tiruchendur coast.

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