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Exploratory analysis on the predictability of oil sardine landings in Kerala

M. SRINATH

Central Marine Fisheries Research Institute, Cochin – 682 014, India

ABSTRACT

In recent times, the oil sardine fishery along the west coast especially off the coast of Kerala shows signs of decline coupled with its year to year variability. In this study an empirical model is given to describe the oil sardine fishery along the Kerala coast using the time series approach and also examine its relationship with the climatic factors such as the rainfall, mean sea level pressure and solar activity. The analysis has revealed, *albeit* tentatively, the possible factors causing short-term and long-term variations in the catches of the oil sardine. Predictive models based purely on the autocorrelations and cyclic trend suggest possibility of generating forecasts which can be validated taking into consideration the long-term and year to year concomitant variations in the correlated factors. The present study is only a beginning in the search for a suitable predictive system for the small pelagics such as the oil sardine.

Introduction

The Indian oil sardine (*Sardinella longiceps)* is one of the commercially important pelagic fin fish resources occurring along the Kerala coast. Like the pelagic fish communities of other upwelling coasts that include a sardine, an anchovy and a mackerel, the pelagic fish assemblage of the coast has suffered wide fluctuations in the abundance of the individual components, of which, oil sardine is an important resource. The variability in oil sardine landings was noted as back as in 1865 which discouraged a planned industrial expansion based on oil sardine fishery. The periodic failures of the oil sardine fishery was mentioned as early as in 1900 by Thurston (as quoted in Longhurst and Wooster, 1990). the variability in the landings of oil sardine continues to baffle the research workers.

In recent times, the oil sardine fishery along the west coast especially along the Kerala coast is causing concern showing signs of decline coupled with its year to year variability. The biological characteristics of the oil sardine stock have been thoroughly researched and well documented. Attempts were also made to evaluate the effect of fishing and estimate the stock size. However, the stock assessment studies have revealed no more information than what is already available and some of the studies (Kurup *et al.*, 1989, Annigeri *et al.*, 1992) have given conflicting harvesting options depending upon the data series. Some workers have also tried to explore the periodic or cyclic variability in the oil sardine stock in the context of physical, chemical and biological oceanographic parameters either singly or in combination with the climatic and other ocean related phenomena (Murty and Edelman, 1970; Longhurst and Wooster, 1990; Kumaran *et al.*, 1992; Madhupratap *et al.*, 1994).

In this study an empirical model is given to describe the oil sardine fishery along the Kerala coast using the time series approach and also explain the inter annual variability in the landings through the relationship with the climatic factors such as the rainfall, mean sea level pressure and solar activity.

Database and methodology

The data on estimated landings of oil sardine and the fishing effort are obtained from the various reports, bulletins and publications of the Central Marine Fisheries Research Institute. Two data sets were used for analysis. The first pertains to the estimated annual oil sardine landings from 1961 to 1995 and the other data set is the quarterwise landings alongwith the fishing effort from 1975 to 1995 (covering 84 quarters). For estimation of fishing effort (in terms of actual fishing hours) only those gear in which oil sardine formed a significant portion of the total catch and those primarily directed towards exploiting small pelagics were considered. The data on annual mean sunspot number was obtained from the Internet. The data on the meteorological and other climatic parameters such as rainfall, atmospheric temperature, mean sea level pressure for the coastal stations of Trivandrum, Quilon, Alleppey, Cochin, Calicut, Canannore and Kasaragod from 1961 onwards were obtained from the Indian Meteorological Department.

Only those stations where there was continuous data from 1961 onwards were considered. The total rainfall from the coastal stations was calculated and assumed to be an index of the rainfall along the Kerala coast. Data smoothing algorithm of Velleman (1980) was used to understand the trend and also to identify possible periodic cycles. The ARIMA methodology as given in Pankratz (1983) was used for analysis of the data. Estimation of model parameters was according to the algorithms in SPSS/PC Ver. IV.

Time series modelings

Modeling the fish catches through the time series approach especially of Box-Jenkins (1976) type is gaining importance. Following the methodology in identification, fitting and diagnostic checking of the ARIMA given by Pankratz (1983), the following models could be chosen as the tentative models to describe the oil sardine landings in Kerala during 1961-'95. The models are (i) ARIMA (0,1,0), (ii) ARIMA (1,0,0), (iii) multiplicative seasonal model (1,0,0) $(1,0,0)_4$ and (iv) multiplicative seasonal model ARIMA (1,0,0) $(1,0,0)_5$ in the log scale of which the last mentioned model was found to be the most adequate and fitting. The autocorrelation function (acf) and the partial autocorreclation function (pacf) of the log transformed series are presented in Fig. 1 and 2. The estimated autoregressive term was 0.8986, the seasonal autoregressive term was 0.5893, and the constant term was 4.3175. The acf of the residual series

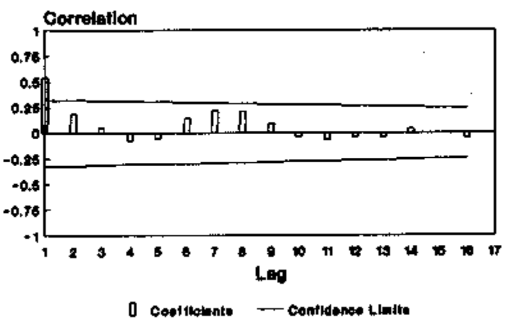

Fig. 1. Autocorrelation function of oil sardine landings 1961-'95.

obtained from the last model is given in Fig. 3 which clearly indicates that the residual is white noise process. The fitted curve along with the estimated

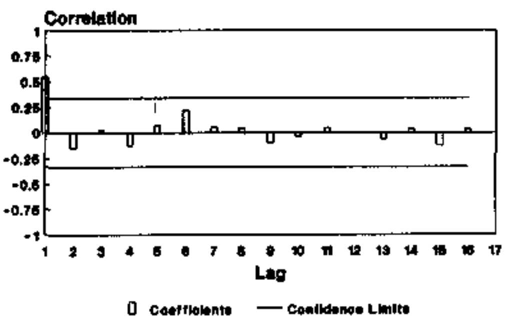

Fig. 2. Partial autocorrelation function of oil sardine 1961-'95.

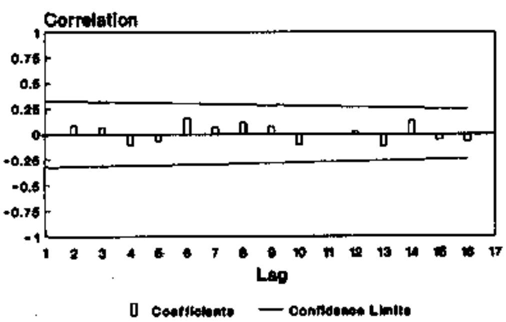

Fig. 3. Autocorrelation function of the residuals of oil sardine 1961-'95.

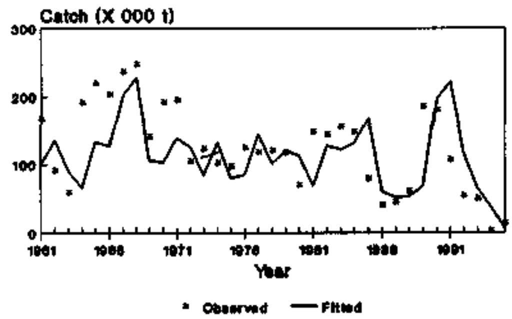

Fig. 4. Observed and fitted values of oil sardine 1961-'95.

landings are given in Fig. 4.

The analysis was also carried out on the quarterly data from 1975 to 1995 and the acf and pacf of the quarterly landings are depicted in Fig. 5 and 6. The model ARIMA (1,0,0) $(0,1,1)_4$ was tentatively identified and fitted. The residual from the fitted series were found to be of white noise process as evidenced by the plot of acf of the residuals (Fig. 7) justifying the above seasonal multiplicative model as an adequate fit for the data. The estimated autoregression term was 0.5131 and the moving average term was 0.6420. The fitted data is given in Fig. 8.

If the observations tend to show

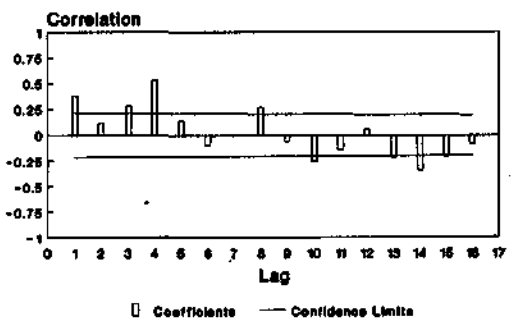

Fig. 5. Autocorrelation function for the quarterly data.

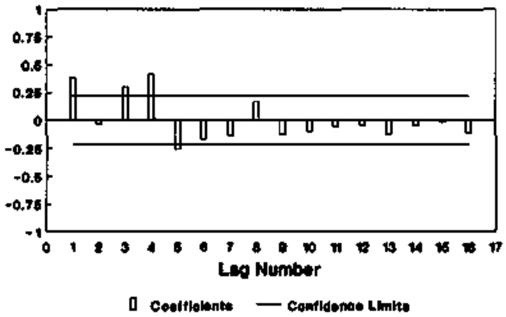

Fig. 6. Partial autocorrelation function for the quarterly data 1975-'95.

strong cyclical or periodic variations it is tempting to fit a model with sine and cosine terms (Saila *et al.*, 1980). Although harmonic regression analysis has been widely used in agriculture and other ecological studies its applications to fisheries has been minimal. In the earlier section, the oil sardine landings in Kerala were identified to be a multiplicative seasonal process. According to Pankratz (1983) "not every ARIMA model with significant estimates is a suitable one.... We strive for parsimonious models which fit the data adequately with significant coefficients but we should also temper on statistical results with insight into the nature of the underlying data". Stergiou and

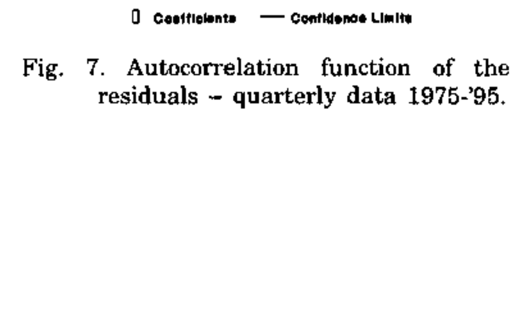

Fig. 7. Autocorrelation function of the residuals - quarterly data 1975-'95.

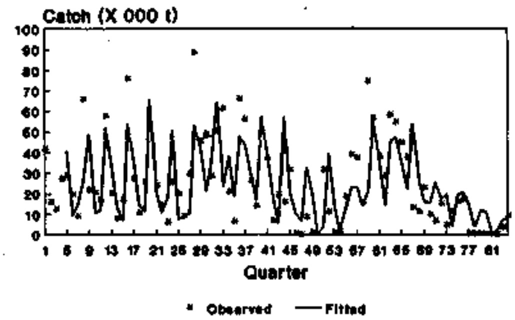

Fig. 8. Observed and fitted values of quarterly data : 1975-'95.

Christou (1996) pointed out that ARIMA models were not found among the best performers because the yearly data were not characterised by strong autocorrelations. Because of this, ARIMA could not possibly recover ample information from the data and this necessitated application of other techniques such as the harmonic regression to the data which yielded satisfying results. In the light of the above remarks, the data on oil sardine landings in Kerala was further explored.

Before attempting the harmonic analysis a clear cyclic pattern should be identified. Sometimes there may be some embedded minor cycles also. However, when the underlying pattern is obscured by noise as is the case with that of fisheries data, non-linear data smoother provides a practical method of smooth traces of data confounded with probably long tailed or occasionally spikey noise. Velleman (1980) proposed a suite of data smoothers of which the technique of 4253H exhibited best characteristics.

The smoothed data, along with the general trend line and the unsmoothed data on the landings are plotted (Fig. 9). The mean annual sunspot activity was

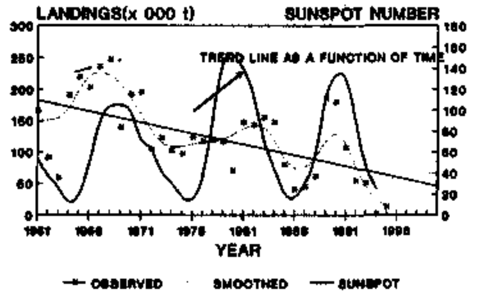

Fig. 9. Oil sardine landings in relation to solar activity (Kerala).

also drawn on the same graph. The following observation could be made from the graph.

There was a general declining trend in the landings as evidenced by the trend line (straight line in the Figure).

The smoothened data (dotted lines) showed periodicity of about 10 to 11 years.

Although the years of higher sunspot activity, in general, coincided with higher oil sardine landings, there seemed to be "leads" in the landings with respect to the sunspot activity.

Thus, it was obvious from the above observations that the data smoothing algorithm did, in fact, help in highlighting the underlying periodic trend. It was observed that the periodic trend was confounded with the linear trend in the original series. To determine the periodicity the data was detrended. The declining trend in the landings may also be due to increase in fishing effort since 1961. Thus, indirectly, the effect of fishery dependent factor (fishing effort) is removed from the series. Implicitly, it is assumed that the trend in fishing effort since 1961 is approximately linear.

A straight line relationship with time was found to fit the data better as determined by r^2 value (0.279). The second degree polynomial did not significantly contribute to r^2 (0.293). The series was detrended by subtracting the expected values of the fitted line from the observed values.

To determine the periodicity the residuals (the detrended series) was subject to spectral analysis. The periodogram and the spectral density of the residuals with a window width of 5 showed the evidence of significant periodicity of 11 years and 6 years.

Thus there was justifiable ground to carry out harmonic analysis with linear trend on the oil sardine landings of Kerala. Initially, only 6 year periodic terms along with linear component was considered which yielded R^2 value of 48.06 %. Inclusion of only 11 year periodic terms with a linear trend yielded R^2 of 51 %. By adding 6 year and 11 year periodicity with linear trend yielded a R^2 of 64.6 % . Thus the fitted equation was:

$$y = 191.365 - 3.782\ t - 36.196 \cos(2\pi t / 11) - 31.437 \sin(2\pi t / 11) - 1.707 \cos(2\pi t / 6) - 17.273 \sin(2\pi t / 6)$$

where y is the oil sardine landings and t the year.

The fitted harmonic regression curve along with the observed value and the seasonal ARIMA are plotted in Fig. 10.

Solar activity and oil sardine landings

The relationship of sunspot activity (measured as annual mean sunspot numbers) with oil sardine landings was studied with cross correlation function and cross spectra. The cross correlation

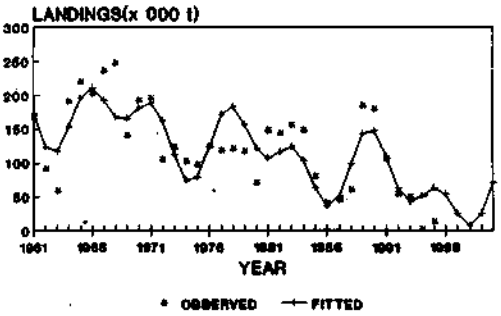

Fig. 10. Observed and fitted values of harmonic analysis 1961-'95.

of sunspot activity with oil sardine landings indicated that, although higher landings seemed to occur during higher solar activity, the sunspot activity was found to lead the oil sardine landings. This meant that higher sunspot activity at present might lead to higher oil sardine landings in 4 to 6 years. Hence the cross spectra (Fig. 11) of residuals of the linear trend with sunspot activity exhibited a significant periodicity of 11 years.

These analyses indicated that the oil sardine landings or abundance of oil sardine along the Kerala coast displayed a significant 11 year cycle which corresponded with the 11 year solar

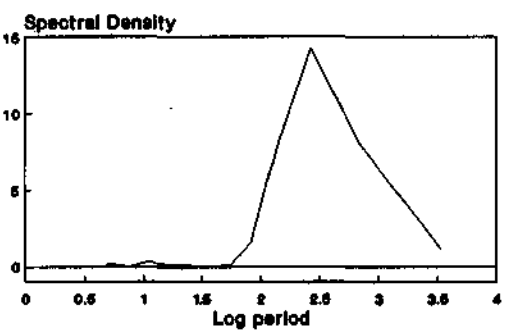

Fig. 11. Cospectral density of oil sardine landings with the sunspot activity.

activity. Hence, it may be concluded that the abundance of oil sardine along the Kerala coast, perhaps is governed by the solar activity. The general declining trend in the landings may be attributed to the increase in the fishing effort since 1960's. The periodic fluctuation in the abundance is probably caused by the periodic variations in the recruitment. The periodic variation in recruitment might have been induced by factors dependent on solar activity.

Climatic factors, fishing effort and oil sardine landings

The effect (including the lag effect) of the mean sea level pressure, total rainfall and the fishing effort from 1975 to 1995 on the landings of oil sardine is estimated with the help of cross correlation coefficients. Significant cross correlations of total rainfall with the oil sardine catch at lags 4, 3, 2, 1 and 0 were found, the values being –0.251, 0.229, 0.244, –0.325 and –0.269 respectively. Significant cross correlation of the mean sea level pressure (–0.403) with the oil sardine catch was observed at lag 2. At lag 0 it was 0.247. Highly significant correlations of –0.708, 0.668 and –0.833 at lags 4, 2 and 0 respectively were observed between mean sea level pressure and the total rainfall. The fishing effort had a positive correlation of 0.343 with the catch at lag 0 only.

Although no clear picture emerges from these correlations, generally, the climatic events in the preceding time periods seemed to have some effect on the landings during the ensuing periods. Higher amount of rainfall during July-September is probably indicative of higher landings during the post-monsoon season. However, higher amount of rainfall during the early phase of the monsoon, in April-June was found to result in lower landings.

The quarterly values of catch, effort, rainfall and the mean sea level pressure were annualised. To depict a comparable annual trend, the data were smoothed and normalised. The normalised data are plotted in Fig. 12. From the figure, the decadal periodic trend in the oil sardine landings and that of the mean sea level pressure could be observed, which agrees with the observations

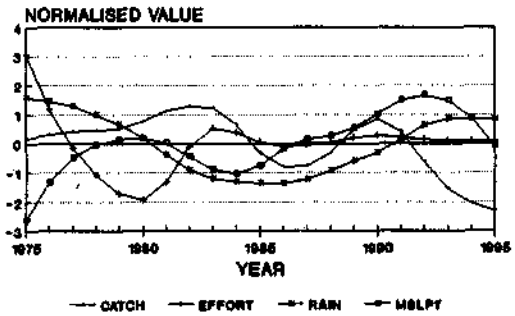

Fig. 12. Normalised values of catch, effort rainfall and mean sea level pressure.

made by Longhurst and Wooster (1990). As mentioned by Kumaran *et al.* (1992) there does not seem to be direct relationship between oil sardine landings and the total rainfall on the annual basis. It is also observed that the effort got more or less stabilised from 1985 onwards.

Discussion

The observation made and conclusions drawn in this study are more or less in close agreement with the studies conducted elsewhere. Murty (1965) envisaged the possibility of evolving a prediction system for forecasting the trend of pelagic fisheries of the west coast based on their relationship with the coastal current patterns. He also observed that changes in oil sardine landings seemed to be related to the long-term changes in the wind drifts. Murty and Edelman (1970) investigated the relationship between the intensity of the southwest monsoon and the oil sardine fishery. They contended that the field of pressure would reflect the monsoon intensity to the utmost degree of accuracy than the amount of rainfall. The pressure gradients at the surface during the monsoon, according to them are better indicators of monsoon intensities for the different years. Their analysis also revealed that there was a critical value of monsoon intensity above which the catches improve with increasing monsoon activity. They also offered an explanation to this characteristic influence of the monsoon.

Longhurst and Wooster (1990) gave a detailed account of oil sardine fishery and the literature related to the effect of fishery independent factors on the oil sardine catch variability. They observed that oil sardine landings data clearly indicated decadal trends. According to them the cyclic pattern of oil sardine probably reflected density dependence rather than response to fishing. While explaining the environmental variables which could have caused the variations in the oil sardine landings they have established a relationship of variations in the mean sea level with fluctuations in the abundance. Kumaran *et al.* (1992) observed that eventhough the rainfall and oil sardine landings at Calicut during different seasons did not show any direct relationship, the oil sardine landings were better two or three months after fairly heavy rains. The analysis of oil sardine landings and rainfall data at Cochin showed that fairly good rain during the monsoon probably had some positive impact on the abundance of juvenile oil sardine during the succeeding post-monsoon months. They inferred that the reduced rainfall intensity might have an adverse impact on the shoal formation at the surface. Antony Raja (1969) had also studied the effect of monsoon on the spawning success and the fishery. Madhupratap *et al.* (1994) questioned the validity of the precision of the data of the earlier period and also the observed relationship. They also stressed the importance of impact of climatic and other ocean related parameters on the oil sardine stock.

Regner and Gacic (1974) concluded that long-term fluctuations of the sardine catch on the eastern Adriatic coast could be approximated by the sum of harmonics which includes the 11 year cycle that coincided with the 11 year sunspot cycle. Southward *et al.* (1975) illustrated close agreement with curves of annual mean sunspot numbers and the annual mean SST's of certain stations in English Channel through spectral and autocorrelation analysis. The study revealed the presence of major cycles of the order of 10-11 years but longer and shorter harmonics were also present. Similar results were obtained for number of pilchard eggs in the plankton, the catch of demersal fishes and proportion of barnacle species in the intertidal zones. Driver (1978) analysed the annual landings of shrimp (*Crangon crangon)* in the Lancashire and the Western Sea Fisheries District (UK) and found that the abundance of shrimp could be correlated with mean sunspot number. Maximov *et al.* (1972) found out a phase relationship between the sea surface temperature and the sunspot activity. According to Love and Westphal (1981) dungeness crab catches and sunspot numbers both varied approximately in 11 year cycle. High sunspot numbers in a particular year seemed to be a predictor of relative low crab catches five years hence.

Reid (1987) analysed the influence of solar variability on global sea surface temperature. The secular variation in globally averaged SST over the past 130 years has been found to show a certain amount of similarity to the corresponding variation of the solar activity as revealed by the envelope of the 11 year sunspot cycle. Zigiang Li and Ma Shengchu (1995) observed a relationship between *El Nino* events and 11 year solar cycles. Chen *et al.* (1994) investigated the roles of vertical mixing, solar radiation and wind stress in a model simulation of the SST seasonal cycle in the tropical Pacific Ocean. Shevnin (1994) found significant correlation between the solar and magnetic activities with the Caspian sea level. Terauchi *et al.* (1991) while explaining environmental factors for variations in the stock of Yellow tails in its Pacific sub-population observed that periods of peak catches corresponded to the minimum point in the sunspot number. Kawasaki and Omori (1988) suggested that the variations in solar radiation lead to variation in primary productivity and therefore in availability to sardines of suitable food item. Anderson (1989) documented apparent correspondence between sunspot cycles on both eastern Pacific SST departures and *El Nino* frequency and intensity. This would imply that there is some threshold level of solar input which affects (modulates) the ENSO process and below which sunspot frequencies are nearly irrevelent to the apparently inherent upper ocean temperature changes around the Pacific Ocean. Sharp and Csirke (1984) reviewed many of the world's neritic resources variations and their relationships to climate-driven physical processes. Decadal scale trends in some of the climatic parameters were found to influence the cyclical patterns observed in some fisheries. Rothschild (1991) gave detailed account on the causes for variability of fish population. He observed that to circumvent the difficulty it is necessary to understand the relationship between population dynamics and the physical environment.

Kawasaki (1991) observed that three sardine populations in the Pacific Ocean and the European pilchard in the North Atlantic have undergone long-term coincident change in their abundance like the Pacific and Atlantic herrings with a phase different from that of the sardine populations. He also observed a high positive correlation between trends in abundance of the sardine populations and a secular change in anomaly of the global mean surface temperature. He concluded, "We are perhaps now standing at a turning point for the structural change in the pelagic fish community in the world ocean which may be caused by a global climatic change".

The mechanism or process of interaction of oil sardine abundance (or landings) along the Kerala coast and the solar activity is too complex to explain and it is not a direct process. Oil sardine abundance, typical of pelagic stocks elsewhere in the world is governed not only by the fishery dependent factors but also by the various fishery independent factors. Some of the factors such as the sea surface temperature or *El Nino* phenomenon might be directly or indirectly influenced by the 11 year solar activity. This in turn would have induced a 11 year cycle in the abundance. It is believed (Longhurst and Wooster, 1990) that oil sardine fishery mainly comprised of 0-year class only. Thus fluctuations in the landings could be ascribed to recruitment variability. The success or failure of the recruitment in pelagic stock by and large is governed by the environmental factors, the air sea interactions and the ocean dynamics. The literature cited earlier did have references of relationship of solar activity with the ocean parameters or phenomenon such as *El Nino*. Thus it may be concluded that solar activity would perhaps serve as indicator of variations in oil sardine fishery in Kerala, on the long-term basis.

The foregoing analysis has revealed, *albeit* tentatively, the possible factors causing short-term and long-term variations in the catches of the oil sardine from the Kerala coast. Predictive models based purely on the autocorrelations and cyclic trend suggest possibility of generating forecast which can be validated taking into consideration the long-term and year to year concomitant variations in the correlated factors. From the fitted models, there seems to be cause for alarm in the future trend in the landings, if the present mode of exploitation continues without any regulation. Srinath (1996) has indicated a perceptible change in the pelagic fish assemblage in Kerala, especially with ring seines dominating the fishery. If the present trends were to persist, the oil sardine is less likely to be a dominant group in the small pelagic fish assemblage of the Kerala waters. The general decline in the landings of small pelagics may suggest that these stocks may be in danger of recruitment over-fishing. As the stock sizes and catches depend alomst completely on one or two year classes, assessing the long-term effect of exploitation is extremely difficult because when the estimates of year class strength are available from the catch data the year class is often already out of the fishery. Because of the high natural mortality, usually associated with the small pelagics, any surplus which is not taken in one year will only be available to a minor extent to the fishery next year, thereby making any regulation of effort and mesh size of the small pelagic fishery untenable. Thus, it is extremely difficult to understand the dynamics of small pelagics such as the oil sardine based on catch and effort data alone. We may have to explore the factors other than fishing which induce year to year variations. The present study is only a beginning in the search for a suitable predictive system for the small pelagics such as the oil sardine.

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References

Anderson, R. G. 1989. Solar cycle modulations of ENSO : a mechanism for Pacific and global change. Presented at the Sixth Annual Pacific Climate (PACLIM) Workshop. Asilmar, CA, March 5-8, 1989.

Annigeri, G.G. *et al*. 1992. Stock assessment of oil sardine *Sardinella longiceps* Val. off west coast of India. *Indian J. Fish.*, **39**(3,4) : 125-135.

Antony Raja, B.T. 1969. The Indian oil sardine. *Bull. Cent. Mar. Fish. Res. Inst.*, No. 16, 128 pp. (Mimeograph).

Box, G.E.P. and G.M. Jenkins 1976. *Time Series Analysis : Forecasting and Control*, 2nd edition, San Francisco, Holde-Day.

Chen, D., A.J. Busalacchi and L.M. Rothstein 1994. The roles of vertical mixing, solar radiation and wind stress in a model simulation of the SST seasonal cycle in the tropical Pacific sea. *J. Geophysical Res. (C Oceanus)*, **99** (10) : 345-359.

Driver, P.A. 1978. The prediction of shrimp landings from sunspot activity. *Mar. Biol.*, **47** : 359-361.

Kawasaki, T. 1991. Long-term variability in the pelagic fish populations. *In: Long-term Variability in the Pelagic Fish Populations and their Environment. Proceedings of the International Symposium, Sendai, Japan,* 14-18, Nov. 1989. Pergamon Press.

Kawasaki, T. and M. Omori 1988. Fluctuations in three major sardine stocks in the Pacific and global trend in temperature. *In: Long Term Changes in Marine Fish Populations.* T. Wytt and G. Larranta (Eds.), p. 37-53.

Kumaran, M. *et al.* 1992. Present status of exploitation of fish and shell fish resources – Oil sardine. *Bull. Cent. Mar. Fish. Res. Inst.*, No. 45, p. 92-110.

Kurup, K.N., V. Balan., P. Vijayaraghavan and M. Kumaran 1989. Stock assessment of the Indian oil sardine (*Sardinella longiceps*) off the west coast of India. *In: Contributions to Tropical Fish Stock Assessment in India.* Papers prepared by the participants at the FAO/DANIDA/ICAR National Follow-up Training Course in Fish Stock Assessment, Cochin, India, from 2 to 28 Nov. 1987. FI: GCP/INT/392/DEN/1. S.C.Venema and Van Zalinge (Eds.).

Longhurst, A.R. and W.S. Wooster 1990. Abundance of oil sardine (*Sardinella longiceps*) and upwelling on the south west coast of India. *Can. J. Aquat. Sci.*, **47** : 2407-2419.

Love, M.S. and W.V. Westphal 1981. A correlation between annual catches of dungness crab *Cancer magister* along the west coast of North America and mean annual sunspot number. *Fish. Bull. US,* **79** : 794-796.

Madhupratap, M., S.R. Shetye, K.N.V. Nair and R. Sreekumaran Nair 1994. Oil sardine and Indian mackerel : Their fishery problems and coastal oceanography. *Curr. Sci.*, **66** : 340-348.

Maximov, I.V., E.I. Sarukhanyan and N. P. Smirnov 1972. Long-term variations of the North Atlantic currents and possible cause. *Rapp. P.V. Reun. C.I.E.M.*, **162** : 159-166.

Murty, A.V.S. 1965. Studies on the surface mixed layer and its associated thermocline off the west coast of India and the inferences thereby for working out a prediction system of the pelagic fisheries of the region. *Indian. J. Fish.*, **12** (1) : 118-135.

Murty, A.V.S. and M.S. Edelman 1970. On the relationship between the intensity of south-west monsoon and the oil sardine fishery of India. *Indian. J. Fish.,* **13**(1) : 142-149.

Pankratz, A. 1983. *Forecasting with univariate Box-Jenkins Models. Concepts and Cases.* John Wiley & Sons, 562 pp.

Regner, S. and M. Gacic 1974. An attempt to long-term forecast of sardine catch along the eastern Adriatic coast. *Rapp. Comm. Int. Mer. Medit.*, **24** : 77-79.

Reid, G.C. 1987. Influence of solar variability on global SSTs. *Nature,* **329,** 6135 : 142-143.

Rothschild, B.J. 1991. On causes for variability in fish populations – the linkage between large and small scales. *In: Long–term Variability in the Pelagic Fish Populations and their Environment. Proeedings of the International Symposium,* Sendai, Japan, 14-18 Nov. 1989. Pergamon Press.

Saila, S.B., M. Wigbout and L. Lermit 1980. Comparison of some time series models for the analysis of fisheries data. *J. CIEM,* **39** : 44-52.

Sharp, G.D and J. Csirke (Eds.) 1984. Proceedings of the expert consultation to examine the changes in abundance and species composition of neritic fish resources, San Jose, Costa Rica. 18-29 April, 1983. *FAO Fish, Rep. Ser.,* **291**(2&3) : 1-1294.

Shevnin, A.D. 1994. Long-term variations in solar and magnetic activities and the Caspian Sea level. *Water Resour.*, **21** (4) : 372-376.

Southward, A.J., E.I. Butler and Linda Pennycuick 1975. Recent cyclic changes in climate and in abundance of marine life. *Nature,* **253**: 714-717.

Srinath, M. 1996. Markov chain application to the dynamics of the pelagic fishery along the Kerala coast, India. *Indian J. Fish.*, **43**(2) : 115-120.

Stergiou, K.I. and E.D. Christou 1996. Modeling and forecasting annual fisheries catches : comparison of regression, univariate and multivariate time series methods. *Fisheries Research,* **25**(2) : 105-138.

Terauchi, M., H. Shinomiya, T. Higashi, S. Iwata and T. Kobata 1991. On the variations of the stock of yellow tails *Serola quinqueradiata* Temminck Schlegel in its Pacific sub-population. *In: Long-term Variability in the Pelagic Fish Populations and their Environment. Proceedings of the International Symposium, Sendai, Japan,* 14-18 Nov., 1989, Pergamon Press.

Velleman, P.F. 1980. Definition and comparison of robust non-linear data smoothing algorithms. *J. American Stat. Ass.*, **75** : 609-615.

Zigiang, Li and Ma Shengchu 1995. Relationship between EL Nino events and 11 year solar cycle. *Mar. Forecast/Haiyang, Yubao*, **12**(1) : 19-25.