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Long term trends in rainfall, sea level and solar periodicity: A case study for forecast of Malabar sole and oil sardine fishery

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Abstract

The fluctuations in abundance of a demersal fish, the Malabar sole (*Cynoglossus macrostomus* Norman) and a pelagic fish *viz.*,oil sardine (*Sardinella longiceps*) in the Malabar upwelling ecosystem (MUE) were analysed in relation to long-term trends in rainfall in Kerala, onset time of the southwest monsoon, sea level off Cochin and solar periodicity. The abundance of these species showed a clear decadal trend comparable to such trends existing in rainfall, sea level and solar periodicity. The variations in the rainfall showed a 35-year rhythm in its intensity. A fishery forecast of Malabar sole and oil sardine fishery has been attempted based these trends and is *a posse ad esse*. The fluctuations in abundance of oil sardine, beyond doubt, are clearly influenced by the trends in rainfall during southwest monsoon. Periods of good rainfall have positive effect on its abundance and *vice versa*. There appear to be a decadal or long-term trend in the productivity of the upwelling zone itself. The spawning, recruitment, survival, feeding, growth, migration and the abundance of various organisms are influenced by rhythms exiting in this large marine ecosystem of the southeastern Arabian Sea.

Introduction

The ocean, though a single phase medium is not homogenous. The physical, chemical and oceanographic parameters and the biological characteristics vary regionally and seasonally. The currents and various hydrographic features represent a dynamic equilibrium between sea and the atmospheric conditions. The metererological factors are the main causes for changes in the hydrographic conditions. The conditions in the aquatic environment and their short and long-term variations exert a profound influence on the aperiodic and seasonal migrations, the spawning, recruitment, survival, feeding, growth, abundance and distribution of various fish species. An early or late onset of southwest monsoon or its failure affects our agricultural production, sometimes with disastrous consequences. This is true of the productivity in the sea and well reflected from the variations in abundance of various fishery resources. Further, the long period trends in climate and hydrography affect the distribution, changes in abundance and composition of all the species whether they are fished or not. There is continuous change in the numerical abundance and interrelations among the species inhabiting an environment showing a definite pattern of oscillation or rhythm. The sunlight is most important and ultimate source of energy for all life processes. Solar radiation, the source of energy for ecological cycle in the sea, varies daily, seasonally and geographically resulting in differential production, which again is influenced by the physical, chemical and biological characteristics of the given area.

The Malabar upwelling zone extending from Ratnagiri in the north to Cape Comorin in the south constitutes a large marine ecosystem in the eastern Arabian Sea. This hydro-climatic zone is characterised by annual cycle of upwelling associated with the southwest monsoon and the ensuing productivity sustains a number of commercially important finfishes, shellfishes and other organisms. The marine meteorological features here are more fascinating by virtue of the uniqueness of the monsoon non-existent elsewhere in the world. The rhythmic nature of climatic changes leads to fluctuation in abundance of the resources and their annual production in a similar manner. Such fluctuations have a direct bearing on the coastal economy, often giving anxious time for fishers, investors, exporters, planners and scientists, especially so at a time when the exploitation of many a resources from this ecosystem have reached saturation point. The fluctuation in abundance of oil sardine has been a subject of intensive research during the last century. So far, no satisfactory answer could be offered. The species is capricious. The need to evolve a fishery forecast model, therefore, assumes utmost importance in this predicament. A fishery forecast system in the existing multispecies fishery set up is a difficult task, as it requires time series data on a multitude of environmental parameters. We have a good knowledge of various physical, chemical and biological characteristics and their inter-play in the MUE, but the data sets on many of these parameters are not time series for attempting any meaningful correlation with fisheries. However, with some of the available data on the environment, a fishery forecast could be attempted. This would be of immense help to the fishermen and industry in planning strategies for exploitation. The present communication, therefore, is an attempt to forecast the fishery of a demersal fish like Malabar sole (*Cynoglossus macrostomus* Norman) and a pelagic species *viz;* oil sardine (*Sardinella longiceps* Val) in the MUE. The factors considered, here, are the time series data on the production trends of these two species, rainfall in Kerala, onset dates of the southwest monsoon, sea level off Cochin and the sunspot activity. The idea is to bring together and audit some of the available time series data to find out the log-term trends in these environmental factors and there by their influence on the abundance of these two species. This would help to identify the lacunae in our data system and plan future research programmes accordingly in the light of global warming.

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Material and methods

The following time series data have been considered.

1. Time series data on rainfall in Kerala during the southwest monsoon from 1901 to 1996
2. Time series data on onset dates of southwest monsoon in Kerala from 1956 to 1996

   (Items 1 & 2 collected from IMD and daily weather reports)
3. Sea level off Cochin during March from 1938 to 1987
4. Sea level off Cochin during April from 1938 to 1987
5. Sea level off Cochin during May to September from 1938 to 1987

   (Sea level data after Longhurst *et al.* 1990, PSMSL and Premchand *et al.*1988)
6. Time series data on the annual production of oil sardine
7. Time series data on the production trends of Malabar sole in Kerala and Karnataka (Data on items 6 & 7 were collected from FRAD,CMFRI)
8. Time series data on the sunspot activity from 1901 to 1996 (Solar Observatory, Rajasthan)

All these time series data were smoothened by five point moving average and comparison made between the trends lines in the various parameters considered here.

Results

Solar activity

The sunlight is vital to all life processes on earth. The rhythmic changes during day and night, during seasons and changes over longer period induce rhythms in the life cycle of all organisms. The sunspot activity is well known. The processes going on in the sun like the rhythmic 11 year cycle of solar activity minima and maxima related to sunspot also appear to exert influence leading to short and long term changes in the climate of our planet and thereby all the living organisms. The troughs and cliffs representing the sunspot minima and maxima respectively and the definite trend of oscillation (11 year) are indicated as (A) in Fig.1.

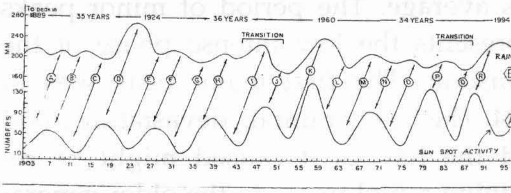

Fig.1. *Sunspot activity (A) and rainfall during S.W.monsoon in Kerala (B) from 1901 to 1996.*

Southwest monsoon

In India, the southwest (June to September) and northeast (November to February) monsoons control the agricultural/ fisheries production and thereby are closely webbed to the well being of the country's economy. The former is associated with the annual and periodic upwelling process in the MUE. Further, the timely onset and a normal southwest monsoon are also very important in terms of productivity. In the MUE the southwest monsoon (SWM) is associated with initiation and sustenance of a series of annual changes starting from upwelling, primary, secondary and tertiary productions.

The data on rainfall (SWM) over Kerala from 1901 to 1996 were analysed. The details are indicated as (B) in Fig.1. The graph looks like a wave with alternate cliffs and troughs that oscillate, as in solar activity, at regular amplitude. Figure 1B indicates that there are three major peaks and sandwiched between them are three minor peaks each. The normal rainfall in Kerala during SWM is 2130 mm. The major peaks represent a period with above normal rainfall and the minor ones below this average. The period of minor peaks represents the low intense phase of the monsoon. The first major peak was in 1924. The heavy rainfall, devastating flood and the havocs it caused might be remaining a nightmare to the older generation. The second and third major peaks are seen during 1960 and 1994 respectively. It is surprising to note that there is a time lapse of 34-36 years between these major peaks, probably indicating a rhythm of such duration in the rainfall in Kerala (perhaps the whole country).

Rainfall and solar periodicity

The solar periodicity (=SP), though a proxy, appears to induce climatic changes through interaction of a series of meteorological factors. Since rainfall is a manifestation of the interactions a comparison between rainfall (=RF) and (SP) has been attempted. Simple comparison between the two was attempted (Fig.1). Comparison between SP and RF indicated good correspondence up to a period and then changed to a different pattern. The first cliff in the solar cycle during 1905/1906 represented by 'B' corresponds to the cliff in the RF during 1914. Between these two peaks is a time lag of about 7 years. The trough in the SP during 1912 represented by 'C' corresponds to trough in the RF during 1917, again with a time lapse of 7 years. This continues until 1943 noted by the letter 'I' in the figure. A transition occurs from 1943 onwards wherein the troughs and cliffs of SP correspond with cliffs and troughs in the RF respectively indicated by letters from 'I' to 'P'. This trend also shows a transition from 1980 where in the correspondence is between cliff-to-cliff and trough-to-trough of both SP and RF. The transition also occurs during every 36-37 years or approximately three solar cycles indicating a rhythm of the sort.

Sea level

Time series data on sea level (1939-1987) off Cochin pertaining to March, April and May to September have been considered here. The smoothened graph along with the solar periodicity (SP) is indicated in Fig. 2. The troughs in the figure indicate upwelling. The sea level during March over the years showed that major upwelling occurred during 1953-54, 1960, 1965-69, 1975-77, 1982 and 1985-88.

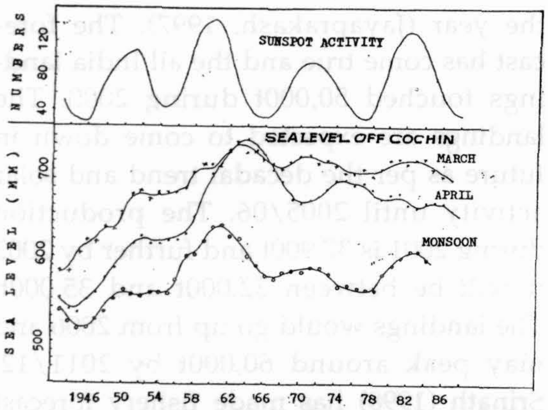

Fig.2. *Comparison of the mean sea level off Cochin during March, April and during the s.w.monsoon from 1942 to 1987.*

The April sea level over the period also showed an increase from the year 1943 to 1962/1963. There was a decline in the sea level up to 1970 and then increased till 1975 and further decreased with slight ups and downs.

The sea level during the southwest monsoon (May-September) showed an upward trend from the year 1946 to a peak in 1961 and in subsequent years decreased till 1966. Again it increased till 1970 and started decreasing up to 1976, but reached a peak in 1982.

Sea level and solar periodicity

A comparison of the sea level (SL) and solar periodicity (SP) showed good correspondence. The peaks and troughs in the SL almost showed point-to-point correspondence with that of SP. But the sea level during March and April has not shown such correspondence. It may be pointed out that the March and April SL represent the formative stage in the upwelling process compared to almost a settled condition (May-September) in the SL during the monsoon (Fig.2).

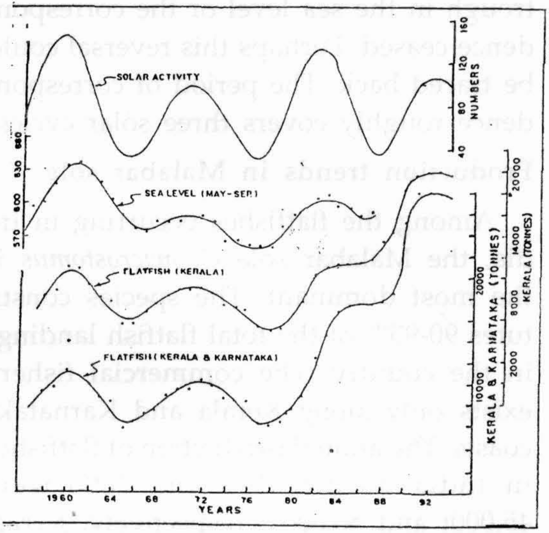

Fig.3. *Decadal trends in abundance of Malabar sole in relation to sunspot activity and sea level (s.w.monsoon) off Cochin during 1958- 1996.*

Monsoon sea level and rainfall

A comparison of the time series data on sea level (May to September) off Cochin and the rainfall during the same period showed good correspondence between troughs and cliffs in both these parameters (Fig. 4). It may be noted here that

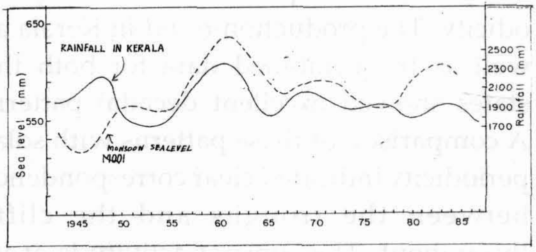

Fig.4. *Rainfall in Kerala and sea level off Cochin during the s.w.monsoon (1943-1987)*

prior to 1949 the pattern was different in that the cliffs in the RF were opposed to trough in the sea level or the correspondence ceased. Perhaps this reversal could be traced back. The period of correspondence roughly covers three solar cycles.

Production trends in Malabar sole

Among the flatfishes occurring in India, the Malabar sole *C. macrostomus* is the most dominant. The species constitutes 90-95% of the total flatfish landings in the country. The commercial fishery exists only along Kerala and Karnataka coasts. The annual production of flatfishes in India during 1999 and 2000 were 45,000t and 50,000 t respectively. Kerala and Karnataka contribute 46% and 14% respectively to all India production. In Kerala the average annual decadal production during the fifties to nineties respectively were 6694t, 7888t, 9868t, 12736t and 18785t. Mostly the trawls, mini trawls and purseseines exploit them.

Malabar sole fishery forecast

Time series data on the landings of Malabar sole in Kerala, and the pooled data from both Kerala and Karnataka were considered for the long-term trend analysis and comparison with solar periodicity. The production trend in Kerala as well as the combined data for both the states showed excellent decadal pattern. A comparison of these patterns with solar periodicity indicated clear correspondence between the troughs and the cliffs throughout. The sunspot activity is at its peak during 2000/2001 and the flatfish production is expected to go up during the year (Jayaprakash, 1997). The forecast has come true and the all India landings touched 50,000t during 2000. The landings are expected to come down in future as per the decadal trend and solar activity until 2005/06. The production during 2001 is 37,900t and further by 2002 it will be between 32,000t and 35,000t. The landings would go up from 2006 and may peak around 60,000t by 2011/12. Srinath (1998) has made fishery forecast of oil sardine based on the decadal trend in its abundance in relation to solar periodicity.

Sea level and Malabar sole production trend

Comparison of the time series data on the annual landings of Malabar sole from Kerala and the pooled data from Kerala-Karnataka with the sea level also indicated interesting results. There is point to point correspondence between troughs and cliffs in sea level to the trend in abundance of Malabar sole (Fig. 3).

Rainfall and trends in abundance of Malabar sole

Comparison between trend in production of Malabar sole in Kerala and south-west monsoon also showed point-to-point correspondence and similarity in the troughs and cliffs of both sets of data series (Fig.5).

Malabar sole fishery *vs.* onset dates of s.w. monsoon

Apart from a normal monsoon, its onset timings also influence production in the agricultural/fisheries sectors. The onset

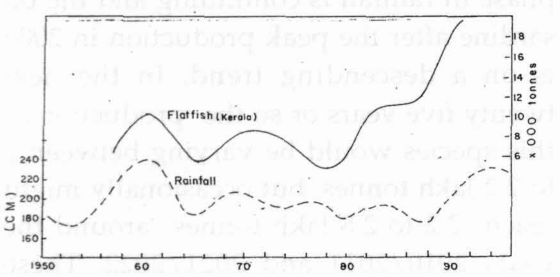

Fig.5. *Trends in abundance of Malabar sole and rainfall (s.w.monsoon) from 1985-1996.*

date and the intensity of the monsoon have special significance in the productivity of the MUE as well. The normal date of the arrival of the S.W.monsoon over Kerala is by second of June every year; however, there are inter annual variations. Time series data on yearly onset dates (1956 to 1996) and annual landings of Malabar sole were compared here (Fig. 6). An early onset of the monsoon

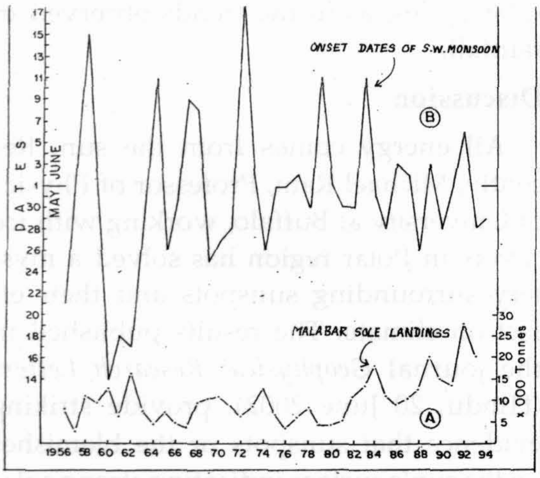

Fig.6. *Malabar sole fishery in relation to onset time of S.W. monsoon in Kerala from 1956-1994*

appeared to result in a good fishery of this species. The onset dates were 10 June, 3 June, 24 May, 30 May and 23 May during 1997 to 2001 respectively. The landings were good during 1998 to 2000.

An explanation to fluctuations in oil sardine fishery and a forecast

In the history of fisheries research in India, the fluctuation in abundance of oil sardine has been a subject of intensive research. For nearly a century or so, many workers from time to time have focused their attention in decoding the mystery surrounding the capricious nature of oil sardine. But the explanations offered were far from convincing. Jayaprakash and Pillai (2000) while presenting the status of oil sardine fishery have given a review of these aspects. The present study provides a concrete answer to these fluctuations. It is the rainfall, the causative factor. Rainfall during the high and low intense phases in the monsoon, beyond doubt, controls these fluctuations. However, there is a lag of 6 to 7 years between intensity of rainfall and oil sardine abundance as may be observed from the peak production of oil sardine during 1968 and 2000 (Fig.7). The correspondence between the trends in these two dissimilar data sets was remarkable as if they are made for each other. The intense phase in rainfall precedes the two highest peak production of oil sardine. The intense phases in the rainfall are indicated by letters A & B. The peak abundance of oil sardine was 3 lakh tonnes in 1968 and 3.6 lakh tonnes in the year 2000 and are indicated by the letters F &

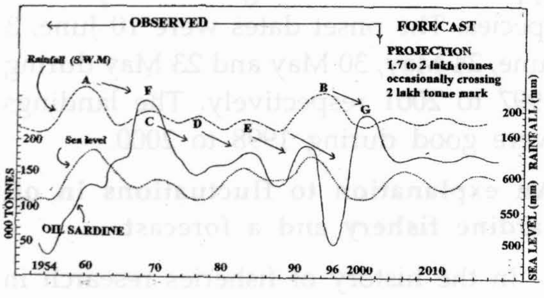

Fig.7 *Forecast of oil sardine fishery. Letters* ***A & B*** *represent the intense phase, and* ***C,D,E*** *the low intense phase of monsoon. Letters* ***F & G*** *represent peak production of oil sardine over 3 lakh tonnes during the year 1968 and 2000. The lag effect of intensity of rainfall on oil sardine fishery is indicated by arrows.*

G respectively. Between high intense phases in the rainfall and oil sardine peak (A & F and B & G), there is a lag of 6 to 7 years. Similarly, letters C,D,E represent the low intense phase in rainfall (or the 'dry spell'). The oil sardine abundance is clearly low during these periods. The period of the low intense phase in rainfall is higher than the intense phase. This long period of low intense phase has a negative effect on oil sardine abundance. Its continued effect leads to decrease in stock as happened in 1994 when oil sardine production slumped to 44,000t. Probably low rainfall might be affecting the fecundity, recruitment success and food availability. Response of the stock to intense phase in the monsoon was instant. Increase in stock size from 44,000t in 1994 to 3.6 lakh tonnes in 2000 was phenomenal. If we observe backwards, also this pattern in the rainfall and change in oil sardine abundance is recognizable, from mid sixties. Presently, the low intense phase in rainfall is continuing and the oil sardine after the peak production in 2000 is on a descending trend. In the next twenty five years or so the production of this species would be varying between 2 to 2.2 lakh tonnes, but occasionally might reach 2.2 to 2.8 lakh tonnes around the years 2010/2011 and 2021/2022. These ups in production would be during years of higher sun spot activity preceded by better rainfall. The next intense phase in the rainfall would start from around the years 2028 and 2033. Oil sardine production might cross 3 lakh tonnes during any of these years. It is a forecast and assumes importance especially in the context of global warming. It would be worthwhile to keep a close watch on these in the decades ahead. It is interesting to note here that the time lapse between the highest peak of oil sardine abundance in 1968 (3 lakh tones) and 2000 (3.67 lakh tones) is again 32 to 33 years or equals three solar cycles, as in the trends observed in rainfall.

Discussion

All energy comes from the sun. Recently, Michael Ram, Professor of Physics of University at Buffalo, working with ice covers in Polar region has solved a mystery surrounding sunspots and their effect on climate. The results published in the journal *Geophysical Research Letters* (Hindu, 20 June 2002), provide striking evidence that sunspots or the blemishes on the sun's surface indicating strong solar activity do influence global climate change. Drawing on climate data derived from ice cores, they determined the level of dust in the atmosphere for roughly 300 years, which is how far back sunspot data has been recorded. They assumed that a low level of cosmic rays on earth resulting from high sunspot activity would lead to less cloud cover and less rain, with resulting high dust levels. The correlation appeared true for the first 33 years from about 1930 to 1962, but reversed afterwards. According to the team the volcanic eruptions world over have a bearing on the correlation reversals. In the present study also there is good correspondence between sunspot activity and rainfall for about 36 years and the trend reverses continuing for another 36 years. Again, a period of correspondence ensues. It is interesting to note that all these events cover a period three solar cycles each indicating an alternate rhythm in correlations and reversals.

The annual rainfall in Kerala is around 3000mm; out of this the S.W.monsoon accounts for 71% (213 mm), the NE monsoon 16% and the summer rain 13%. The long-term trends indicate that there is an intense phase and a period of low intense phase in the southwest monsoon rainfall. These two phases together constitute a period equivalent to three solar cycles.

The normal onset date of monsoon in Kerala is mostly on 2nd June. There is considerable inter annual variability in this. The monsoon onset is delayed in years of *El Nino*. During, the last century (1901-2000) the earliest onset ever observed was on 11th May 1918 and in 1972 the monsoon was delayed by 17 days. During both the years severe draught conditions prevailed. The Malabar sole fishery was always good throughout the years whenever early onset of the monsoon occurred. The oil sardine abundance doesn't indicate any trend with onset timings of monsoon.

The present study indicates that the rainfall peaks in 1924 and 1994 correspond to the troughs, and that of 1960 to the cliffs of sunspot activity. Based on the trends observed the next major peak would be around the years 2028/2029. The three minor peaks expected between the major peaks in 1994 and 2028 represent the low intense phase of the monsoon and there is every possibility that years with below normal RF would be more than double indicating a 'dry spell' in the period ahead. This has been predicted in 1997 (Jayaprakash, 1997). The prevailing drought situation, the power shortage and, political and social concerns in Kerala are akin to this dry spell. During the first half of this century (1901 - 1950), the rainfall was below normal (20-51%) only for seven years. However, during the second half (1951-2000) rainfall was below normal for twelve years. The decade 1981-1990 witnessed less than normal rainfall (S.W) during four years. During the last decade (1991-2000) it was below normal (–25%) in 1999 and in 2000 the state received only 1780 mm (-18%). A drought condition is prevailing throughout India in the current year 2002. Normally the rainfall in Kerala during the season up to 20th August is about 1600.5mm, but the State received only 1222.9mm (less by 24%.). The total rainfall during June to September this year (2002) was less by 32% or more. All these corroborate the findings of the present study. Mining the data collected and applying them properly to reduce the sting in the natural disasters should be a priority in future studies. In addition, it is essential to know how nature draws up plans and patterns in drying or wetting the ground below.

According to Longhurst (1990) the mean sea level is highest (indicating least upwelling) during the northeast monsoon and lowest during the S.W.monsoon (strongest upwelling). Between the lowest values (May and September), there is a weak intermediate maximum during the highly developed monsoon conditions. Longhurst *et al* (1990) have also observed a decadal trend in the sea level and indicated that this required interpretation. The authors compared the variations in oil sardine abundance with sea level as an indicator of recruitment success.

A decadal (or 11 year to be precise) variations in the stock size have been observed in oil sardine (Longhurst *et al.* 1990; Srinath,1998) and mackerel (Noble, 1992) in India. Decadal to secular variations in the stock size of clupeids (*Clupea, Sardina, Sardinops and Engraulis*) have been reported by Soutar and Isaacs (1974), Kondo (1980), Cushing (1981), Belveze and Erzini (1983), Tanaka (1983) and Pauly and Tsukuyama (1987). Tameishi *et al* (1988) noticed that the stocks of sardine *Sardinops melanosticta* undergo 70 to 100 years long-term changes on a global scale. Their studies indicated a relationship between the stock of sardines and the velocity of earth's rotation (earth rate) whereby a positive correlation was detected. Further, the change in the stock of sardines is correlated with change in the ground temperature. In terms of change in phase, they agree strikingly well suggesting that the energy of the sun contributes significantly to the increase in phytoplankton and subsequent increase in the stock of sardines. We may recall here the relation between oil sardine in India and the diatom *Fragilaria oceanica*. Nair (1960) has indicated that the revival of oil sardine stock in 1949 and 1953 after the population crash of the forties coincided with the heavy blooms of this diatom. Unfortunately, no time series data on the blooms of this diatom are available.

How the variations in rainfall lead to fluctuations in abundance of oil sardine is a point to ponder. The clear correspondence between these two throughout indicates that the life cycle of oil sardine is attuned to the intense and low intense phase in the rainfall. The food availability, consequent increase in lipid content, conversion of lipid into gonadal tissue and recruitment appear to be related to rainfall. The epithet 'oil' is apt for this sardine. During July to September 1997, the beaches at Purakkad in Alleppey (Kerala) witnessed one of the rarest scenes. After a lapse of 20-25 years, the fishermen were engaged in large-scale extraction of oil from this sardine. Studies indicated active feeding by sardine, with stomach full of copepods, throughout the period. Further, examination of specimens during April-May 1998 showed fully-grown gonads with their outer edges folded, filling the entire body cavity. (This is not an aspect seen every year, especially during the low intense phase in rainfall). By July the beaches at Fort-Cochin and landing centres in the southern districts were strewn with putrefied young oil sardine (40-65mm) brought by the ring seine fleet. There were no takers. The recruitment was massive. It is history, that oil sardine landings reached the highest peak in the year 2000. We have to remember the landings were at its lowest (44,000 t) during 1994. The effect of intense phase in the rainfall on the stock was remarkable. The time lag between the intense phase in rainfall to peak production of oil sardine represents the period of rebuilding or resuscitation of a subdued but resilient stock. The same pattern could be seen during the earlier intense phase in rainfall and oil sardine peak (in the year 1968). There is higher energy investment in gonadal tissues during intense phase and *vice versa* during other times.

Decadal (to be precise 11 year) to secular variations in the stock size of pelagic fishes appear to be a common phenomenon. However, the occurrence of a perfect 'decadal' variation in the stock of a demersal fish like the Malabar sole is something interesting. The productivity of the sea is linked to the solar flux variability. Unfortunately, time series data on this aspect is lacking. The interannual variations in the primary, secondary and tertiary production lead to change in the abundance of fishery resources and finally result in variable biomass in the given ecosystem. Sharp *et al* (1983) while studying the stock recruitment relationship in sardine stocks have indicated that the cyclic pattern in the relationship between landings in successive years represents a surge of increasing recruitment, leading to an increased adult population, then followed by a decrease in recruitment and finally to a decreasing adult population. Longhurst *et al* (1990) have reported this cyclic pattern in oil sardine. It is interesting to note the striking similarity in the decadal scale trends in abundance of the Malabar sole and the oil sardine. The former is a demersal fish and the latter pelagic in habitat. Oil sardine is a grazer in the food web utilizing the benefits of primary production whereas the Malabar sole mainly a detritus feeder utilizes the suspended and settled detritus (Jayaprakash, 1997). Qasim (1972) grouped fishes based on their food and feeding habits as belonging to different trophic levels. The phytoplankton and attached or floating algae come under trophic level I; zooplankton and other filter feeding animals (mainly pelagic) under trophic level II; detritus, both suspended and settled – being a heterogeneous mixture and derived from plants, animals and bacteria – comes almost mid way between trophic level I and II. Since the Malabar sole is mainly a detritus feeder its position would be between trophic level I and II. Considerable quantities of planktonic organisms, dead and otherwise rain down the water column near and at the bottom on the shelf, constitute the food of a variety of organisms including detritus feeders like *Cynoglossus* spp. (Subramanian, 1973). This raining of organisms and its intensity depends on the primary and secondary productions, which again may show interannual or long-term variations, probably on a decadal scale. Hence, there appears some interlinking in the pattern in abundance exhibited by Malabar sole and the oil sardine, mostly akin to a probable decadal trend existing in the primary and secondary production as well. Presently it is not possible to confirm this as time series data are not available on these aspects. Colebrook (1988), while illustrating the seasonal and annual variations in the abundance of species of phytoplankton and zooplankton from 1948 to 1987 of the northeast Atlantic and North Sea, suggested that there is something about the marine environment which tend towards clear long term pattern in their abundance. A long-term decline followed by a recovery suggests control in the realm by climatic phenomenon. The physical mechanism has yet to be identified, though empirical relationship with atmospheric climatic variables has been established. Further, he stated that the dynamics of the whole system highlights the ocean as a red-noise system, a system in which variability increases with time scale to give large-scale amplitude change over long periods.

The trends in solar periodicity, rainfall, sea level and fluctuations in abundance of Malabar sole and oil sardine in the MUE appear rhythmic, synchronized and inter linked as if in an orchestra. Can the sun, the source of all energy, be the conductor of this orchestra? The net results of the interactions of various meteorological, physical, chemical and biological factors may vary in different ecosystems depending on the geographical location. According to sharp (1988) the kind of records, correspondence or associations, trends and rhythms posed will become more useful as they accumulate, as more in-depth understanding is developed relating cause and effect through the myriad processes that mediate and modulate from the initial solar radiance and planetary interactions, through to atmosphere-ocean-ecosystem dynamics. The *en masse* flowering of *Neelakkurinji (Strobilanthus kunthiana)* in the Nilgiri Hills of Kerala and the tropical tall grass bamboo (*Bambosa aurindenacea*) would be worth mentioning here. Strikingly, the periodicity in flowering is duo-decennial in the former (equal to 1 solar cycle) and 35 years in the latter (3 solar cycles). Oil sardine abundance reaches high peak at every 32-33 years, the rainfall has a periodicity of 33-35 years and the transition in the correspondence between sunspot activity and rainfall again is about 33 years. What do these entire phenomena mean? It is a subject matter for further intensive research. The trends discernible while analyzing some of the time series data would definitely be a reference point when we consider future changes, if any that might occur due to global warming.

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