ON THE RELATION BETWEEN THE INTENSITY OF THE SOUTH-WEST MONSOON AND THE OIL-SARDINE FISHERY OF INDIA

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Introduction

The problem of fluctuations of marine fish populations and commercial stocks is a great concern of the marine fishery industries. The fluctuations depend upon the biological features of the individual species and the environmental factors. It is not possible to solve the problem without understanding both the aspects. The abundance of fish depends mainly upon the feeding conditions especially in larval and juvenile stages. And the feeding conditions depend upon the primary production which conditionally depends on the available nutrient salts in the sea. The availability of nutrients will much depend upon the vertical and horizontal circulations in the sea. The circulation of the sea in turn depends upon the atmospheric conditions due to the air-sea interaction. Thus the studies of the atmospheric conditions over the sea throw light upon the total influence of the various factors on the fishery. Dr. Izhevskii (1961) made an extensive analysis of the physical and biological marine processes and established the principal patterns governing the changes in marine environmental factors on which the changes in the biological productivity of the sea primarily depend. His principal methods are inspirations to the authors in their present work.

The oil-sardine is of great commercial value of the Indian pelagic fishery. There are great fluctuations in this fishery. The study of the causes of these fluctuations is an important problem. Many attempts were made to correlate these fluctuations with oceanographical factors and among them the investigations of Chidambaram and Menon (1945) may be mentioned. Their observations revealed that the catches depend upon the rainfall amounts. This indicates the influence of the monsoon intensity upon the fishery. It is difficult to adopt rainfall as index of monsoon intensity because of the orographical influences upon it. The field of pressure would reflect the

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monsoon intensity to the utmost degree of accuracy. The pressure gradients at the surface during monsoon are one of the best and simplest expressions of the intensities of the monsoon in different years. Hence the studies of temporal variations of monsoons in terms of pressure gradients would offer an explanation of the fluctuations in the abundance of the fish. Such studies may further lead to forecasting the fishery. Unfortunately, no data are available of the stock assessments of the oil-sardine which are essential for such studies. The data that the authors utilised in the course of their investigations are the estimated landings of the fish concerned. The relation between the landings of oil-sardine and the monsoon intensity would pave the first step of studies in this direction.

Data

Monthly mean values of station level pressures for 02.30 hrs. GMT for a set of coastal stations in India have been obtained from the records of the India Meteorological Department. The data were reduced to sea-level observations by using the tables for the reduction of meteorological observations in India (1947). Such sea-level pressures for each station have been selected for the months of July and August each year. These two months (July and August) are selected to represent the monsoon conditions over the West Coast of India. The average condition of pressure at a particular station during the monsoon period of a year is thus determined by averaging the pressure values for the above two months of the year.

The published data (Nair, 1959) of estimated landings of oil-sardine in South Kanara and Malabar Coast (West Coast of India) have been utilised in the present investigation. The data of oil-sardine estimations on all-India basis (also published, Nair, 1959) have also been utilised in the present paper.

RESULTS AND ANALYSES

One could clearly understand the nature of the pressure field over the Peninsular India by referring to the *Climatological* Atlas for Airmen (1943). The distribution of isobars at the surface during July and August is such that the pressure difference between Cochin and Madras represents approximately the pressure gradient over the Peninsular area and the pressure difference between Cochin and Bombay is a close representation of the pressure gradient vector over the Arabian Sea area adjacent to the western edge of the Peninsula. This condition of pressure (isobaric) distribution provides an easy means to study the year-to-year fluctuations of the intensity of monsoon over the Peninsular region or the West Coast waters of India.

The values of the pressure differences during the individual monsoons between Cochin and Madras and Cochin and Bombay and the oil-sardine landings are subjected to iterated averages (Kendall, 1946) taking seven successive terms into consideration at a time and representing the iterated average value in the position of the middle term. In other words, the trends have been determined in the monsoon intensities and the oil-sardine landings. The relation between the trend of sardine fishery and the trend of monsoon intensity as expressed by the pressure difference between Cochin and Madras is shown in Fig. 1 *a*. Figure 1 *b* represents similar relation when the intensity of monsoon is expressed by the pressure difference between Cochin and Bombay. The relation is similar in both the figures. The later figure exhibits much more linearity in both the branches of the figure. The figures indicate that there is a critical value of monsoon intensity above which the catches improve with increasing monsoon activity and below the critical value the catches decrease with increasing monsoon intensity. The following explanation may be offered to this characteristic influence of monsoon over the fishery. The last quarter in a year is the best period of the oil-sardine fishery. Therefore, the fishery follows the monsoon during each year. No doubt the influence of a strong monsoon is to enrich the nutrient supply to the surface and sub-surface layers of the sea by causing a corresponding upwelling over the West Coast of India, but at the same time the lower layers of poor oxygen would be brought upward creating thus an unfavourable condition for the fish to thrive. Hence is the fall of catch with increasing monsoon. When the monsoon is above its critical strength, the depletion of oxygen of the top layers due to upwelling would be much more compensated by addition of oxygen by the action of strong winds and waves. Thus the intensity of monsoon over and above its critical value is favourable not only for enrichment by nutrients but also by dissolved oxygen. Thus, an increase in the strength of the monsoon over its critical limit would be favourable for abundance of fish and hence for a good fishery.

It is to be noted here that the data for the years 1947 to 1955 in Figs. 1 *a* and 1 *b* involve not only the Kanara and Malabar Coasts but also the East Coast of India as the available estimations of oil-sardine during these years are on all-India basis. Nevertheless, they are incorporated here because of the reason that the oil-sardine is restricted in its distribution to the West Coast and it occurs very rarely along the East Coast (Indian Fisheries, 1951).

It is interesting to note that the first portion of the data of Fig. 1 *a* is governed by the simple regression equation $Y = 148 \cdot 6 - 1 \cdot 53X$ (for $X < 97$)

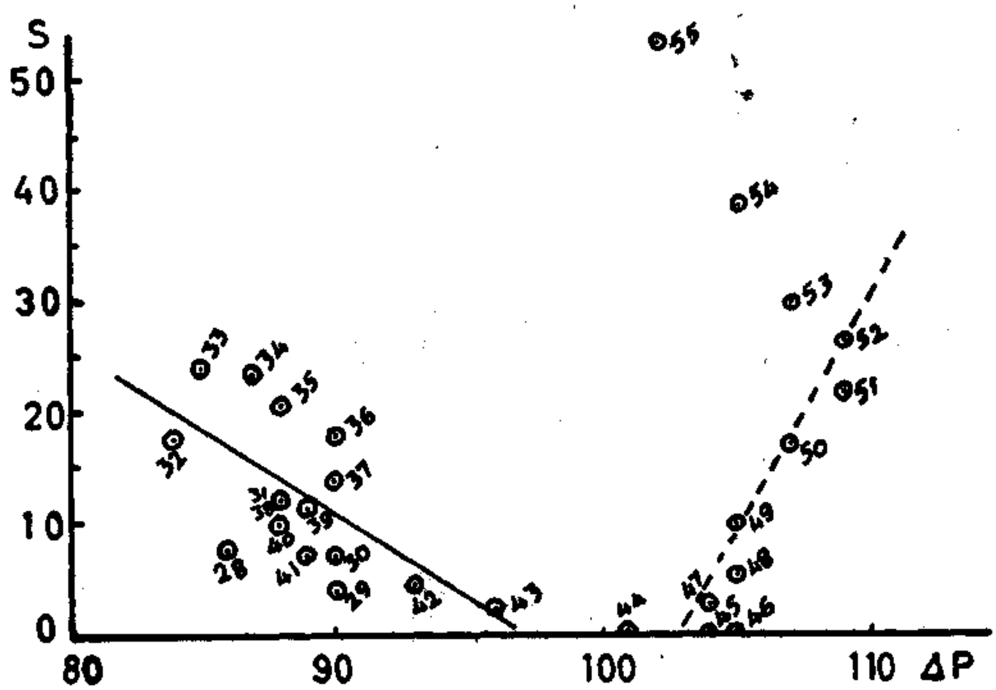

FIG. 1a. RELATION OF SARDINE CATCH AGAINST PRESSURE DIFFERENCE BETWEEN COCHIN AND MADRAS.

(S- Sardine catch in thousands of tons
ΔP- Pressure difference in units of 1000ths of in. of Hg.)

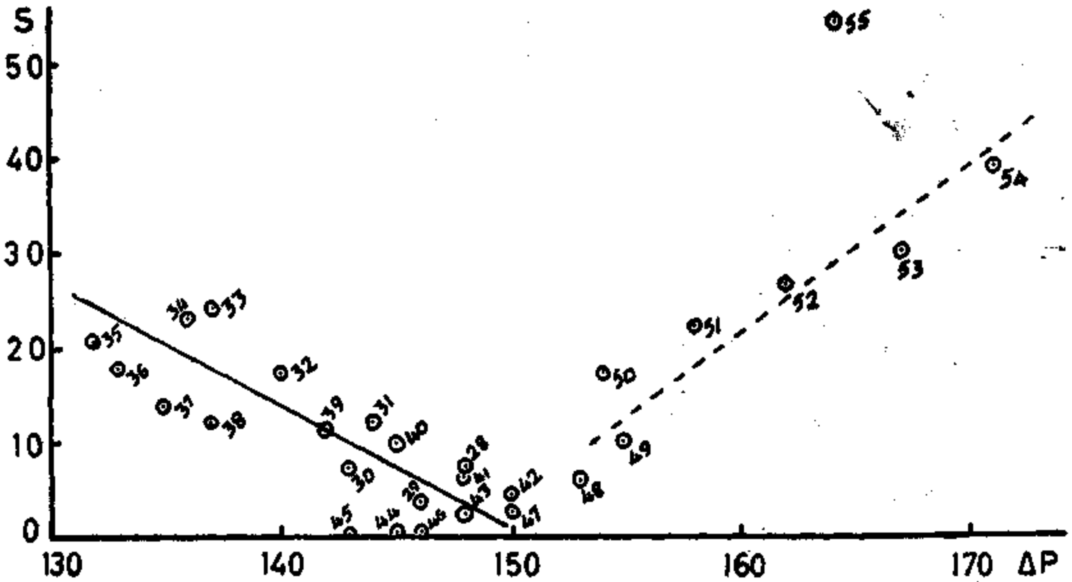

FIG.1b. RELATION OF SARDINE CATCH AGAINST PRESSURE DIFFERENCE BETWEEN COCHIN AND BOMBAY.

(S- Sardine catch in thousands of tons, ΔP- Pressure difference in units of thousandths of in. of Hg.)

with coefficient of correlation $-0 \cdot 64$. Here Y is the catch of oil-sardine over the South Kanara and Malabar Coasts in thousands of tons and X is the pressure difference between Cochin and Madras in units of thousandth of an inch of Hg. If one uses the pressure difference between Cochin and Bombay, the equation is $Y = 151 \cdot 9 - 0 \cdot 986\,X$ (for $X < 154$). In this case the correlation coefficient is appreciably about 84%. Figure 2 illustrates the comparison between trend of oil-sardine catch and the theoretically derived catch using the above-stated equation. The agreement between the two is rather appreciable. This helps for forecast of trends of the fishery based on the field of atmospheric pressure.

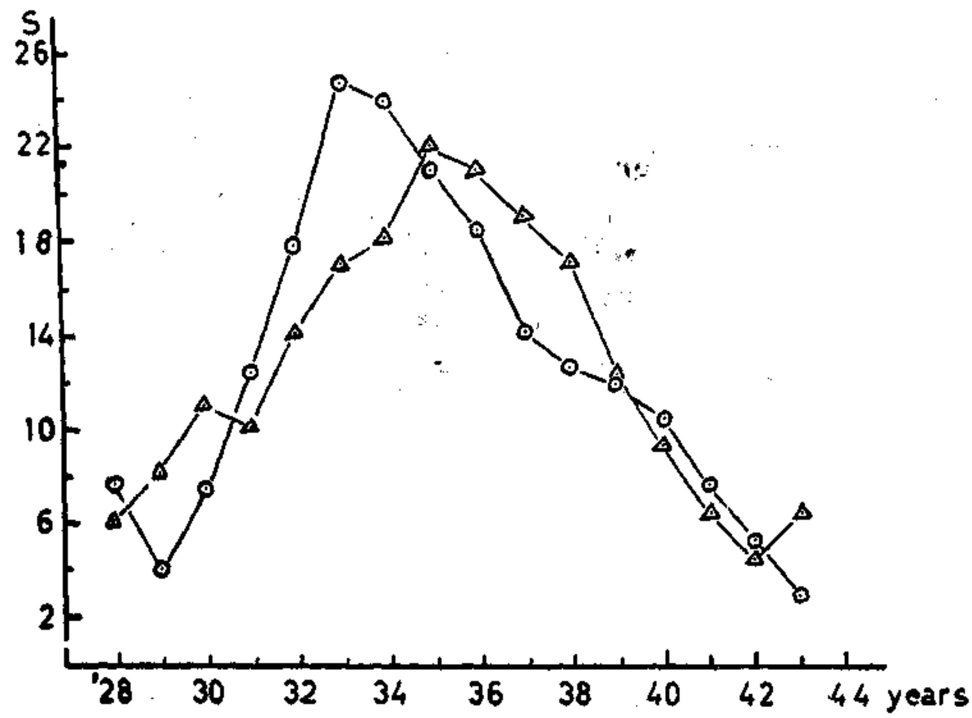

FIG. 2. COMPARISON OF TRENDS OF CATCH

(Δ - Theoretical; ⊙ - Observed; S- Catch in thousandths of tons)

Though the correlation is high, no regression equation is attempted for the rising portion of the curve because of the limited data and also due to the suspicion that increase of effort may be partly responsible for the rise of the curve from year to year.

HARMONIC ANALYSIS

As a first step to understand the periodic nature of the fluctuations of pressure, the data of trends of the pressure difference between Cochin and Bombay from 1925 to 1948 are treated for harmonic analysis. The analysis was done following Runge's twelve-ordinate scheme (Salvadori, 1948). Accordingly, the pressure difference $\triangle P$ (in thousandths of inch of Hg) during any year t ($t = 0$ at 1925) is given by

$$\begin{aligned}\triangle P = {} & 144 \cdot 42 + 7 \cdot 92 \cos \frac{\pi}{12} t + 0 \cdot 17 \cos \frac{2\pi}{12} t + 3 \cdot 17 \cos \frac{3\pi}{12} t \\ & + 1 \cdot 83 \cos \frac{4\pi}{12} t + 0 \cdot 41 \cos \frac{5\pi}{12} t + 0 \cdot 08 \cos \frac{6\pi}{12} t \\ & - 2 \cdot 66 \sin \frac{\pi}{12} t + 3 \cdot 46 \sin \frac{2\pi}{12} t - 1 \cdot 00 \sin \frac{3\pi}{12} t \\ & - 0 \cdot 58 \sin \frac{4\pi}{12} t - 0 \cdot 34 \sin \frac{5\pi}{12} t.\end{aligned}$$

The major harmonic components are shown in Fig. 3. The harmonically computed values of pressure difference (trends) agree very closely with the original trend values of pressure. It is, therefore, possible to forecast the trend of pressure for any year and then to find out the trend of fishery using the regression equation of the fishery with the pressure.

Having more and more data in the future, accurate estimates could be made which would be utilised for better forecasts of fishery. For accurate forecasts the data of stock assessments are needed instead of the estimated landings of the species.

SUMMARY

The long-term fluctuations of the Indian oil-sardine fishery are related with the strength of the summer monsoon over the Peninsular region of India. The sea-level pressure difference $\triangle P$, between Cochin and Bombay as an expression of monsoon intensity over the Arabian Sea adjacent to the West Coast of India, reveals good correlation with the fishery. Certain range of monsoon intensity is found to be unfavourable to the fishery and certain other range favourable. Regression equation is developed between the trends of fish catch and the monsoon intensity (expressed by pressure difference). The pressure data are also analysed for their harmonic components. These analyses may be useful for forecasting the main trend of

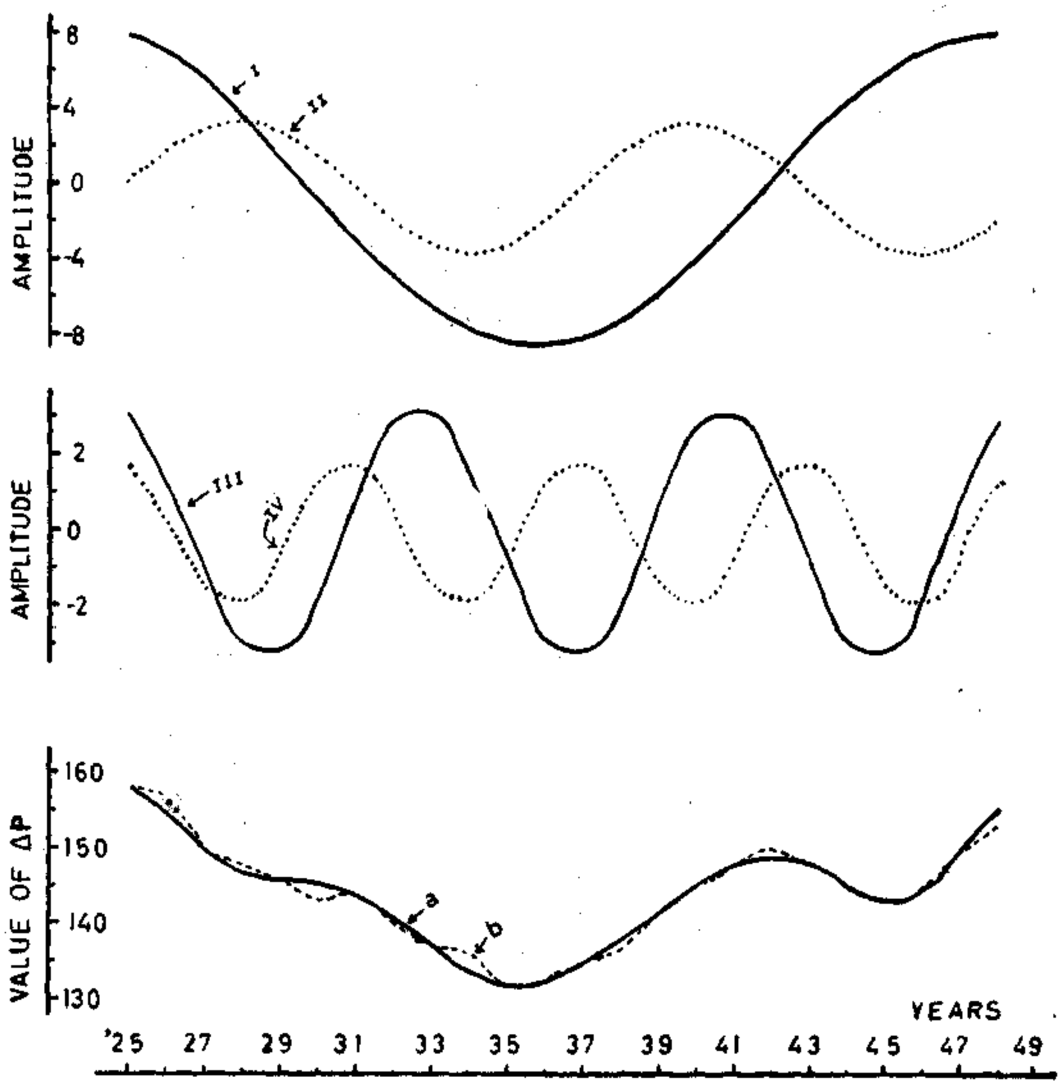

FIG. 3. HARMONIC COMPONENTS OF PRESSURE DIFFERENCE BETWEEN COCHIN AND BOMBAY OVER 24 YEARS FROM 1925 TO 1948.
(I- First harmonic; II- Second harmonic; III- Third harmonic; IV- Fourth harmonic. a- Theoretical trend of pressure difference based on the harmonic analysis. b-Observed trend.)

the fishery based on observations of field of atmospheric pressure over the Peninsular region of India.

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