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INTERACTION OF PELAGIC FISHERIES WITH PHYSICAL AND BIOLOGICAL ENVIRONMENT OF THE WATERS OFF THE KERALA-KARNATAKA COAST

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ABSTRACT

The pelagic fishes and the zooplankton coexist in the same aquatic ecosystem which changes from season to season leading to interaction of each other.

The annual variations of the physical, chemical and biological characteristics of the waters and the pelagic fishery of the Kerala-Karnataka Coast are described. The amplitudes and phases of the relevant parameters in their annual variations are defined precisely. The fisheries of the pelagic domain are correlated in their seasonality with the zooplankton biomass and the upwelling index. Three biological seasons of different periods and characters are revealed by the analysis.

INTRODUCTION

THE CHAIN-LIKE reaction of the marine atmosphere, the physico-chemical characteristics of sea water, the phytoplankton, the zooplankton and the bacterial load of the pelagic realm will finally interact with the fishes and hence the fishery. In such a complex aquatic ecosystem, any attempt by simple means to forecast the fishery would not be accurate. However, attempts were made in the past to forecast the regional fishery from environmental factors. The best among such attempts in the recent times were those by Laevastu and Hela (1970) on herring and bottom temperature in North Sea, Cuhshing (1982) on the effect of El Nino upon the Peruvian anchoveta stock and Daniel Pauly and Navaluna (1983) on monsoon induced seasonality in the recruitment of Philippine fishes.

In the present paper an attempt is made to correlate the pelagic fisheries of the Kerala-Karnataka Coast with the physical and biological conditions prevalent in the aquatic ecosystem.

MATERIALS AND METHODS

The data from September 1971 to August 1973 presented in UNDP/FAO Pelagic Fisheries Project Progress Report No. 7, (1974) of zooplankton biomass of the EEZ waters of the Kerala-Karnataka region, as observed from four almost uniformly spaced transects—Quilon, Cochin, Kasargod and Karwar, were considered to determine the monthly mean variations of the zooplankton in the waters. Similarly, from the UNDP/FAO Pelagic Fisheries Project Progress Report No. 3 (1973) for the period, June 1971 to February 1973 the monthly mean temperature at 50 m depth and the monthly mean dissolved oxygen of the neritic waters not exceeding 50 m depth were determined. And the pelagic fish catches along the Kerala-Karnataka Coast (quarterly averages for 13 years from 1962 to 1974) published in CMFRI Bulletin No. 27 (Silas *et al.*, 1976) were treated conjointly with the above environmental factors.

Exploited marine fishery resources of India averaged for thirteen years (1962-74) in the form of their quarter-wise and species-wise landings were presented in the CMFRI Bulletin No. 27 (Silas *et al.*, 1976). Among those species, the following were considered to belonging to the pelagic group : oil sardine, other sardines, *Hilsa*, other clupeids, *Hemiramphus*, flyingfish, carangids, mackerel, seerfish and tunnies. The quarter-wise landings of the total pelagic species for the Kerala-Karnataka Coast were considered as they are fished from the same marine ecosystem.

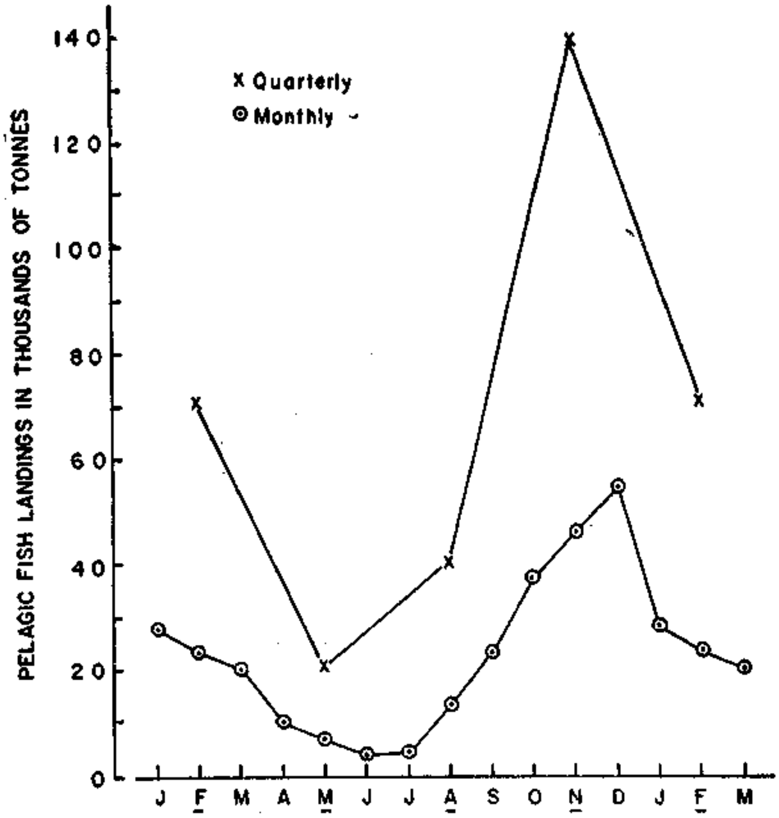

FIG. 1. The year-round pelagic fish landings from the Kerala-Karnataka Coast (The middle month of each quarter is underlined).

The following method is adopted in order to derive the monthly mean landings of the pelagic fish from their quarterly mean values. The quarter mean value of a particular quarter is divided by the total number of months (3) of the quarter and the value thus obtained by this division is allotted to the name of the middle month of the quarter. The remainder was shared by the rest of the months (2) one on either side of the middle month. In allotting the share of either of the month, the neighbouring quarter values on either side of the quarter under consideration was taken into account. Let the quarter value under consideration be Q_s and let ΔQ_l and ΔQ_r be the differential values of the left quarter and right quarter respectively to the value Q_s. The remaining two months of the quarter are given their share out of the $\frac{2}{3}$ Q_s value in the following manner :

The $\frac{2}{3}$ Q_s is divided into two parts namely $\frac{2}{3}$ $Q_s \times \triangle Q_l / (\triangle Q_l + \triangle Q_r)$ and $\frac{2}{3}$ $Q_s \times \triangle Q_r / (\triangle Q_l + \triangle Q_r)$ and the major part is allotted to one of the two months on whose side the neighbouring quarter value is higher. Thus, the values of each quarter are distributed over the three months concerning the quarter. The monthly mean distributions thus obtained of the pelagic fish catches are taken into consideration for analysis in this paper (Fig. 1).

occurrence of maximum or minimum in them. The biological parameter namely the zooplankton biomass of the environmental factors shows opposite trend of variation to that of the physico-chemical factors of the environment. The pelagic fishery data shows a considerable lag in its occurrence of maximum or minimum when compared to the zooplankton biomass in the waters.

Time functions of the parameters

In order to be more precise in the time of occurrence of maximum or minimum and the

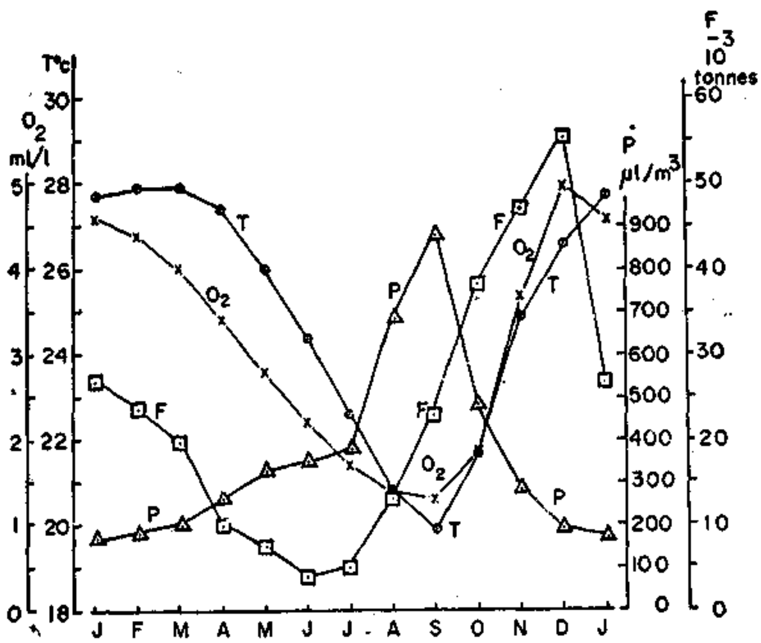

FIG. 2. Annual variations of parameters T-Temperature at 50 m depth (inverse index of upwelling). O_2-Dissolved oxygen and P - the zooplankton biomass of the pelagic waters. F — the pelagic fishery.

Results and Discussion

Annual march of parameters

Figure 2 shows the annual variations of the parameters of the environmental factors together with the variations of fish catch of the pelagic species. The variations of temperature at 50 m depth and the dissolved oxygen content of the nearshore pelagic waters vary during the year with very close timings of relative lead/lag of each parameter, the annual variations of all the parameters are subjected to harmonic analysis of single (annual) wave period in each of them.

General principles/equations

If y is the magnitude of any parameter at time t (in months of the year) then the parameter y as a function t is written as

$$y = a_0 + a \cos 2\pi \frac{t}{T} + b \sin 2\pi \frac{t}{T} \quad (1)$$

where t refers to the month of the year ($T=12$ months), $t=0$ refers to December, $t=1$ refers to January and $t=2$ refers to February and so on.

Constants

The average value of the parameter for the 12 months replaces the constant a_0. In order to determine the constants a and b the following method is adopted.

Harmonic analysis shows that

$$6a = \sum_{0}^{11} y \cos 2\pi \frac{t}{12} \quad \text{and}$$

$$6b = \sum_{0}^{11} y \sin 2\pi \frac{t}{12}.$$

Let the suffixes 0, 1, 2, ... of y refer to the corresponding month of the year starting with December with zero suffix. Arrange the ordinates (the monthly values of the parameter) as follows

	y_0	y_1	y_2	y_3	y_4	y_5
	y_6	y_7	y_8	y_9	y_{10}	y_{11}
q difference	q_0	q_1	q_2	q_3	q_4	q_5

Rearrange q's as follows

	q_0	q_1	q_2	q_3
		q_5	q_4	
v sum	v_0	v_1	v_2	v_3
w difference		w_1	w_2	

Tabulate the results as follows :

Multiplier			
0.5		w_2	v_1
0.866		w_1	v_2
1		v_0	v_3
Sum of column	=	$6a$	$6b$

Multiplying the terms in the 2nd and 3rd column by the corresponding multiples in the 1st column, the values of a and b are determined by summing up as shown in the above table. Thus the values a and b of each parameter are determined in addition to a_0. Thus after determining a_0, a and b, the equation of y as a function of t is written as

$$y = a_0 + a \cos 2\pi \frac{t}{12} + b \sin 2\pi \frac{t}{12}$$

in which the constants a_0, a and b are known.

The cosin and the sin terms of the above equation may be combined and expressed as

$$a \cos 2\pi \frac{t}{12} + b \sin 2\pi \frac{t}{12}$$
$$= r \cos \frac{2\pi}{12}(t - \alpha) \qquad (2)$$

where r is the amplitude of the wave form $r = (\sqrt{a^2 + b^2})$ and $\tan^{-1}\left(\frac{b}{a}\right) = \frac{2\pi}{12}\alpha$, the phase angle of the parameter.

Applying the above procedure to the data presented in Fig. 1, we get that

$$T = 24.94 + 0.97 \cos 2\pi \frac{t}{12}$$
$$+ 3.68 \sin 2\pi \frac{t}{12} \qquad (3)$$

or

$$T = 24.94 + 3.8 \cos 2 \frac{\pi}{12}(t - 2.5) \qquad (4)$$

where T is the temperature (°C) at 50 m depth.

$$O_2 = 3.03 + 1.14 \cos 2\pi \frac{t}{12}$$
$$+ 1.27 \sin 2\pi \frac{t}{12} \qquad (5)$$

or

$$O_2 = 3.03 + 1.7 \cos 2 \frac{\pi}{12}(t - 1.6) \qquad (6)$$

where O_2 is dissolved oxygen (ml/l) of the neritic waters.

$$P = 350 - 80 \cos 2\pi \frac{t}{12} \quad - 230 \sin 2 \frac{\pi t}{12} \quad (7)$$

or

$$P = 350 + 240 \cos \frac{2\pi}{12} (t - 8.4) \quad (8)$$

where P is zooplankton biomass in $\mu l/m^3$,

$$F = 22.53 + 20.14 \cos \frac{2\pi t}{12} - 3.55 \sin \frac{2\pi t}{12} \quad (9)$$

or

$$F = 22.53 + 20.45 \cos \frac{2\pi}{12} (t + 0.3) \quad (10)$$

where F is pelagic fisheries in thousands of tonnes.

Differentiating the equations 4, 6, 8 and 10 with respect to time t, we can determine the time of minimum or maximum of each parameter and the same are presented in Table 1.

TABLE 1. *Time of occurrence of maxima and minima*

Parameter	Time in months when the parameter is	
	Maximum	Minimum
T (Temperature at 50 m depth)	2.5 (Feb. — March)	8.5 (Aug.— Sept.)
O_2 (Dissolved oxygen ml/l of the neritic waters)	1.6 (Jan.— Feb.)	7.6 (July— Aug.)
P (Zooplankton biomass $\mu l/m^3$ of the pelagic waters)	8.4 (Aug.— Sept.)	2.4 (Feb.— March)
F (Pelagic fishery 1000's of tonnes)	11.7 (Nov.— Dec.)	5.7 (May— June)

Oxygen minimum occurred one month in advance to T minimum. Assuming that the lowering of T and O_2 are effected by upwelling in the waters, it may be seen that O_2 responded quicker to the peak influence of upwelling, while the parameter of temperature is influenced with one month delay. The plankton maximum occurred in August-September and its minimum in February-March. The occurrence of plankton maximum coincided with temperature minimum. The reduction of O_2 to its minimum in July-August has no reducing influence on the plankton abundance. Therefore, the plankton production appears to be more controlled by temperature rather than the dissolved oxygen of the waters. P is maximum when the temperature at 50 m is 19.8°C. Or P is above 500 $\mu l/m^3$ during the temperature below 21.5°C. The corresponding O_2 for $P >$ 500 $\mu l/m^3$ is 1.6 to 1.3 m/l.

The environmental relation of fishery

One can expect that the pelagic fishery would be influenced by the temperature at 50 m depth as the latter parameter, when it is of lower range represents the effect of upwelling. The fishery should be more when the zooplankton is abundant. Therefore, F should be proportional to P and inversely proportional to T.

The relation of fishery with the bio-physical parameter $\frac{P}{T}$ is illustrated in Fig. 3. Three distinct relations are notice d— June to September, October to December and January to May, with sharp discontinuity between the three curves representing the three main seasons namely the monsoon, post-monsoon and pre-monsoon respectively. These three regimes may reflect the three different interaction systems of the fishery with biophysical environment of the waters. During the monsoon regime low temperature and high plankton biomass are the prevailing conditions. During the pre-monsoon regime high temperature and low plankton production constitute the status of the environment, while during post-monsoon the conditions are moderate.

The slope of the curve is positive only during monsoon and in the rest of the seasons (post-monsoon and pre-monsoon) it is negative. Therefore, in the balance of rates of production and predation of the standing crop of plankton, there is a net production during monsoon which is upwelling period, whereas the predation exceeds production during the remaining two seasons. The pre-monsoon season with its progressive improvement of plankton production may serve as a link season between the net predatory season and the net productive season namely the post-monsoon and the monsoon seasons.

Apart from quantitative differences of plankton biomass, the three regimes may differ in their quality/variety of the plankton which includes fish eggs and larvae. In tropical waters fish eggs hatch out into larvae within a few hours of spawning and the location of fish eggs in quantities in any one area is therefore a clear evidence of fish spawning in the same area around that time. In the case of oil

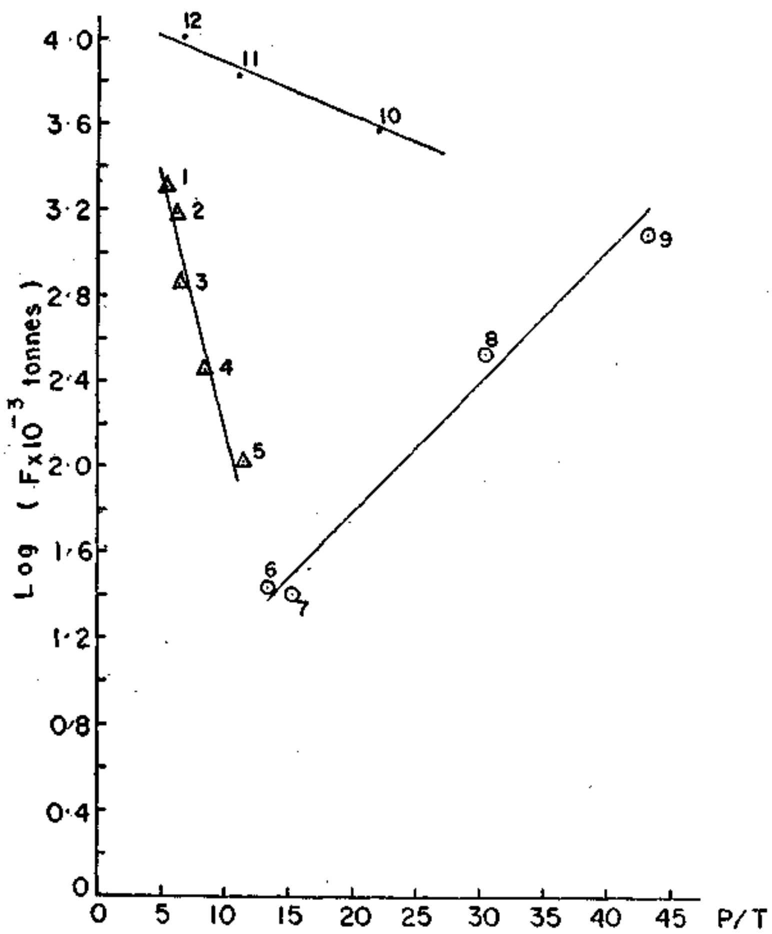

FIG. 3. The three-phase model of seasonality of the pelagic fisheries — environment system (The inserted numbers refer to the months of the year).

sardine which forms the major fishery, different ranges of periods of spawning were attributed by different workers — June to October by Devanesan (1943), June to November by Nair (1959). Antony Raja (1969) from his ten-year experience of oil sardine investigations, states that no instances of even ripening gonads, leave about spawning, were noticed beyond September. He concludes that June-October period can be safely assumed as the season of spawning, with the month of October as a rare possible extreme limit and with intense activity of spawning during the first three months *i.e.* June to August. Although different workers reported different periods of spawning of mackerel, in majority of studies it was June to September or April to September (Bal and Virabhadra Rao, 1984). Narayana Rao (1962) observed that the Indian tunas spawn between April and August. Therefore, it may be generalised that the period of spawning in these waters is mainly concentrated to monsoon season, although it is wide-spread from pre-monsoon to monsoon with occasional spawning in post-monsoon.

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