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Trend analysis in all-India mackerel catches using ARIMA models

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ABSTRACT

Annual mackerel landings in India seem lo exhibit a 10-year cycle in long-term fluctuations. To find a suitable forecasting model for it, the annual catch data from 1950 lo 1989 were studied following Box-Jenkins method for lime series analysis, and ARIMA (1,0,0), was identified as the suitable one. Catch predictions by this also hinted at 10-year cycle but seemed to lack seasonal term.

Time series analysis is an economical method for forecasting catches which is essential for fisheries management. It describes the time structure of the catch data. Jensen (1985) applied time series analysis to forecast Menhaden catch and catch per unit effort. Saila *et al*. (1980) compared some methods of univariate statistical time series analysis for rock lobster *(Jasus edwardsii)* catch data and found Auto-Regressive Integrated Moving Average (ARIMA) models to behave better compared to other models. Mendelssohn (1980) used Box-Jenkins models to forecast fishery dynamics. Noble (1980) has already made an attempt to predict the trends in mackerel catches on the basis of a 10-year cycle seen with it.

The landings of mackerel exhibit annual and long-term fluctuations. Nevertheless, the catch of a year depends biologically on the spawning stock and spawning success in the previous year(s). So, simple regression analysis does not hold good for the mackerel data. To study the trend of landings of mackerel, Box-Jenkings method for time series analysis was hence applied to evolve a prediction system.

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MATERIALS AND METHODS

Estimates on the annual landings from 1950 to 1989 made by the Fishery Resources Assessment Division of the Central Marine Fisheries Research Institute, Cochin, by adopting multistage stratified random sampling, were used for the analysis, and the analysis was based on Box-Jenkins ARIMA models of Montgomery and Johnson (1976).

The procedure consisted of 3 stages.

(i) Identification of a suitable model with the help of 2 plots of auto-correlations *(ac)* and partial auto-correlations *(pac)* at different lags following Montgomery and Johnson (1976).

Auto-correlation of lag K, defined as r_k and given by equation (1), were tested using an approximate t test given by equation (2).

$$r_k = \frac{[1/(n-k)]\sum_{t=1}^{n-k}(y_t-\bar{y})(y_{t+k}-\bar{y})}{[1/n]\sum_{t=1}^{n}(y_t-\bar{y})^2} \qquad (1)$$

where $\bar{y} = [1/n]\sum_{i=1}^{n} y_i$ and y_t is the caich at lime i

$t = r_k/s(r_k)$ ...(2)

where s (rj)=(1 + 2 X^{r}j)/Vn^
j=i

The partial auto-correlation of lag k, given by equation (3), were tested by the t statistic (4).

k-l
ft-2- ric-ij ric-j
rkk=_J=L .(3)
k~l
1 - X ik-ij rj
i-i

where r =r, . . •^{r}tt^{r}k-l.k-i^{andr}il$^=r$i
kj k-l. J
t=lVk/(l/Vfi) •(4)

The auto-correlation function *(acf)* and partial auto-correlation function *(pacf)* of the resulting series were observed to decide the order of auto-regressive terms and moving average terms. Based on these preliminary analysis, an ARIMA (p, d, q) was identified for the series where p is the order of the auto-regressive terms in the model, q is that of moving average terms and d is the order of regular differences applied on the original series to transform it into a stationary series. The algebric form of the model is given in (5).

(1-B) y$_l$=^+J(piy$_t$-i-£e$_j$e$_H$-t€$_t$....(5)
i=i j=i

where \i, constant term and B, backward shift operator such that

^{Bk}y,=y$_{t-k}$

The important general characteristics of the model were

(i) a. The theoretical *acf* of the model tailed off to zero after the first q lags with either exponential decay or in a damped sine curve,

b. The theoretical *pacf* also tailed off to zero after the first p lags.

(ii) The p + q + 1 parameters of the model were estimated satisfying the conditions that the roots of the 2 polynomials (6 and 7) lie outside the unit circle and they have no roots in common.

f$_1$(B)=l-<p$_1$B-(p$_2$B^2-...-(p,)BP...(6)

f$_2$ (B) = 1 - GjB - 6$_2$B^2-...- e$_q$B"...(7)

(iii) The adequacy of the model was tested on residuals by the test criterion (8) which is Chi-square with K-p-q-1 d.f., where k is the number of auto-correlations computed for residuals.

Q=(N-d)£>;(e) (8)
i=l

RESULTS

The *acf* and *pacf* up to lag 24 worked out for the all-India annual mackerel landings

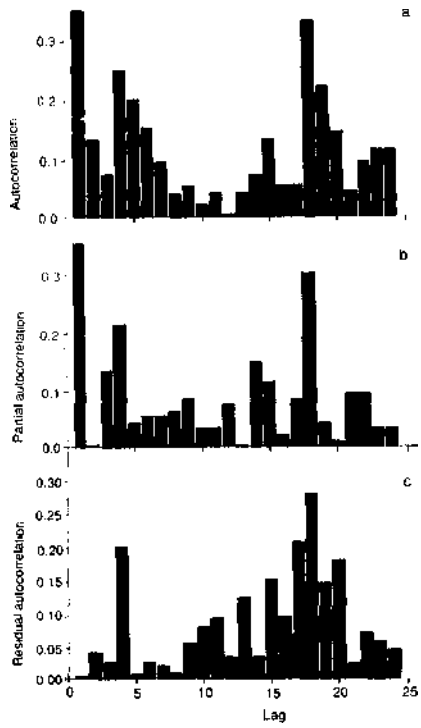

Fig. 1. Correlation series (absolute value) for mackerel 1950-89 catch.

and given in Fig. 1 a and 1 b respectively were found to be non-significant after lag 1. In *ad,* 13 out of 24 values, being below 0.10, were close to zero and in *pad* 18 out of 24 values were close to zero. Ignoring the value at lag 18, which was also non-significant, it was inferred that the *pad* cuts off after lag 1 and the *aqf* tails off towards zero. Hence the most suitable model for the mackerel data was chosen as ARIMA (1,0,0) expressed by (9).

$$y_t = \wedge + 9_1 y_{t-}, + e_t \quad -(9)$$

The estimated constant (fl) and the autoregressive coefficient (<p) were respectively 20661.15 and 0.7175 leading to the estimated model (10).

$$y_t = 20661.15 + 0.7175\, y_{,-}, + e_t \ldots (10)$$

where y_t, the catch in tonnes at any point of time t and e_t, the residual term. To test the adequacy of the model, the residuals were computed for the series using the fitted model and *ad* was plotted (Fig. 1 c) for these residuals while test statistic Q was found to be 11.173 with 22 d.f., which is non-significant. The identified model was, therefore, accepted to adequately fit the mackerel data. Using the fitted model (10) and keeping the initial value as the origin, predicted values for the period 1951 to 1990 were computed and plotted along with observed catch in Fig. 2 a. The predicted values also hint at a 10-year cycle in the long-term fluctuations, though the model lacks a seasonal term.

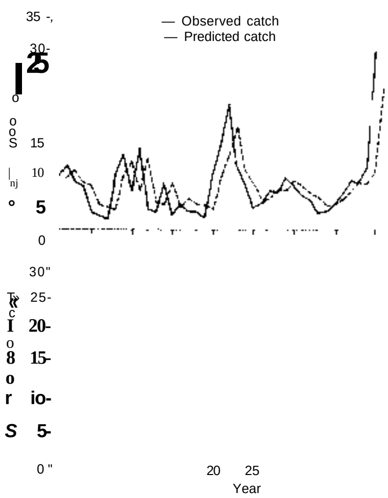

Fig. 2. ». Model ARIMA (1. 0, 0) fitted to mackerel 1950-89 catch data. b. Observed values of mackerel 1950-89 catch.

DISCUSSION

The mean of all-India annual observed mackerel landings for the 1950-89 period was 73 133 tonnes. The scatter diagram of observed values (Fig. 2 b) shows highly erratic nature of catches (standard deviation 52 150, c.v. 71.31%). Also, there were more disturbances in peak years which were found to vary with catches from 85 233 tonnes in 1978 to 291400 tonnes in 1989. In general, there was an increasing dimension in the quantity offish caught especially in the peak years. Among years of lowest catches in every 10-year period, the disparity was not that much as the landings in them ranged only between 16 431 tonnes (1956) and 37 462 tonnes (1974).

Only the first order values were significant in *acf* (Fig. 1 a) and pac/(Fig. 1 b). But in the illustrations, the seasonal term of recurring significant catches in every subsequent 10 years or so is lacking. In the case of mackerel, the data available, being only for 40 years, was probably inadequate to bring out a cycle of 10-year period. Possibly, data for 100 years or more, if and when available, may throw more light and statistically support better predictions of mackerel landings.

The ARIMA (1, 0, 0) model identified for the process, revealed that the catch in a particular year was more related to the catch one year immediately prior to it and was not significantly influenced by the catches of earlier year(s). But it does not explain why did the catch in a year, for instance in 1961, abruptly fell down from the one that was good in the previous year and how did the catches, for example in 1957 and 1969, suddenly and disproportionately elevated from the low values of respective preceding years. In fact, data on commercial catches alone do not serve as an index for predictions of the catch in succeeding year(s). Biologically, the strength of the spawning stock and the spawning success in any given year largely determine the abundance of the fish in the following season(s). Annual surveys of spawning population, spawning success, young fish abundance and recruitment to the fishable stock, if undertaken, provide a more dependable yardstick to measure the strength of the population. Probably, the ARIMA model may fit better with the spawning stock in making predictions. The 10-year cycle seen in the commercial landings may be dependent on the spawning stock and spawning success.

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