

THEORETICAL YIELD STUDIES ON THE LARGE-SCALED TONGUE SOLE, *CYNOGLOSSUS MACROLEPIDOTUS* (BLEEKER) FROM THE ARABIAN SEA

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Theoretical yield values of *Cynoglossus macrolepidotus* were computed from a simple Beverton and Holt type model using informations on growth and mortality rates. The effects of various fishing mortality rates (F) and ages of exploitation (T_p) on yield were considered at three different natural mortality rates, $M=0.4$, 0.5 and 0.6 , since the calculated natural mortality was found to range from 0.4 to 0.575 . The conclusion drawn from the simple model is that the population is at present underfished and considerable increase in the yield is possible by increasing the fishing intensity. The yield values clearly indicate that when $M=0.4$, fish of 2 years and older may be fished at F greater than 0.5 ; when $M=0.5$, fish older than 1 year may be fished at F less than 1.15 and when $M=0.6$ fish of 1 year and older may be fished up to $F=1.8$. A precise estimate, however, of a T_p required to give the maximum yield for a given F can be determined from the eumetric fishing curve. The yield of *C. macrolepidotus* has been found to be low in relation to the fishing intensity. This may be because of high M and low W_∞ . The optimum age of exploitation is also low in this fish probably because the growth is largely confined to the first few years and M is high.

INTRODUCTION

The large-scaled tongue sole, *Cynoglossus macrolepidotus* (Bleeker) is a widely distributed fish of the tropical region. It is found in the Arabian Sea, the Bay of Bengal, around Ceylon and as far as Malay Archipelago (Day 1878; Munro 1955). On the Malabar Coast it is readily caught in trawls along with several other soles which constitute the sole fishery of the west coast of India. This fishery has been referred to earlier as of considerable local importance (George 1958). During the fishing season which lasts from October to May, the soles, besides trawl, are also caught in various other types of indigenous gears including the shore siene, boat siene and cast net, often very close to the shore during the peak fishing season. Soles have been reported to disappear from the inshore waters with the onset of south-west monsoon and reappear in late September or early October. The fish is either consumed fresh or in a sun-dried or cured state. As compared to the other closely related species, *C. semifasciatus*, the large-scaled tongue sole is of lesser commercial importance and is subjected to very little fishing. Its exploitation is however consistently on the increase because of a steady increase in the number of trawlers in this area.

Practically no information is available on any aspect of the biology of *C. macrolepidotus*. Among the Indian soles, the species which is relatively better studied is the Malabar sole, *C. semifasciatus* (Seshappa and Bhimachar 1951, 1954, 1955). In a recent communication on *C. macrolepidotus* it has been shown that

fairly accurate estimates of growth and mortality could be made (Krishnan Kutty 1967). Using these informations and assuming that the same natural mortality operates in all the size groups, the reaction of the population under various fishing mortality rates and ages of exploitation has been analysed in the present paper.

MATERIAL AND METHODS

Scales of *C. macrolepidotus* which show clear annulations were used to study the growth rate, while mortality was calculated by the method given by Ricker (1958), i.e. from the catch curve obtained by plotting the log frequency against the length of the fish on the assumption that the annual increase in length is more or less uniform (see Krishnan Kutty 1967). The estimated total mortality rate (Z) was found to lie between 0.4 and 0.575 and mainly corresponds to natural mortality alone, for there is very little fishery of this species and consequently fishing mortality (F), if any, would be almost negligible. The three parameters of the von Bertalanffy growth equation, K , T_0 and L_∞ were obtained by fitting the von Bertalanffy growth equation to the mean growth data of the two sexes up to age 5. The asymptotic weight (W_∞) corresponding to L_∞ was calculated from the length-weight relationship.

The material which formed the basis of the present study came from the small meshed trawls operating in the Arabian Sea, off Cochin. These nets are mainly used for the capture of prawns and seem equally efficient in catching fish of all sizes. Hence there seemed no mesh selection. Since fish of one year and older are readily caught in the trawl, the first age of full exploitation was taken as 1 for calculating the yield in weight per recruit (YW/R). The maximum exploitable age (T_λ) was taken to be 12 years which seemed reasonable, for 8-year-old fishes were not very uncommon in the samples. Moreover, since we suspect that the back-calculated lengths from the scales might be an underestimate of the actual lengths, particularly of higher age groups, we tended to keep T_λ slightly on the higher side for reasons of greater accuracy in YW/R values.

LENGTH-WEIGHT RELATIONSHIP

In *C. macrolepidotus* previous studies have shown that although there is a sexual difference in the growth rate, this difference is not too well marked. This would probably indicate that both sexes will have similar mortality rates (Qasim 1966). The length-weight data of the two sexes were therefore pooled to find a common relationship. This is shown in Fig. 1 and the estimated relationship has been found to be :

$$\text{Weight (g)} = 0.001107 L^{3.4148} \quad \dots \quad (1)$$

where L = length in cm

It can be seen from equation (1) that the exponential value is greater than 3. This may be because the weights taken were of un-gutted fish. For all our calculations the exponential value was taken as 3.375 instead of the estimated value of 3.4148 to avoid interpolation in the calculation of yield from the table of Incomplete Beta Function prepared by Wilimovsky and Wicklund (1963).

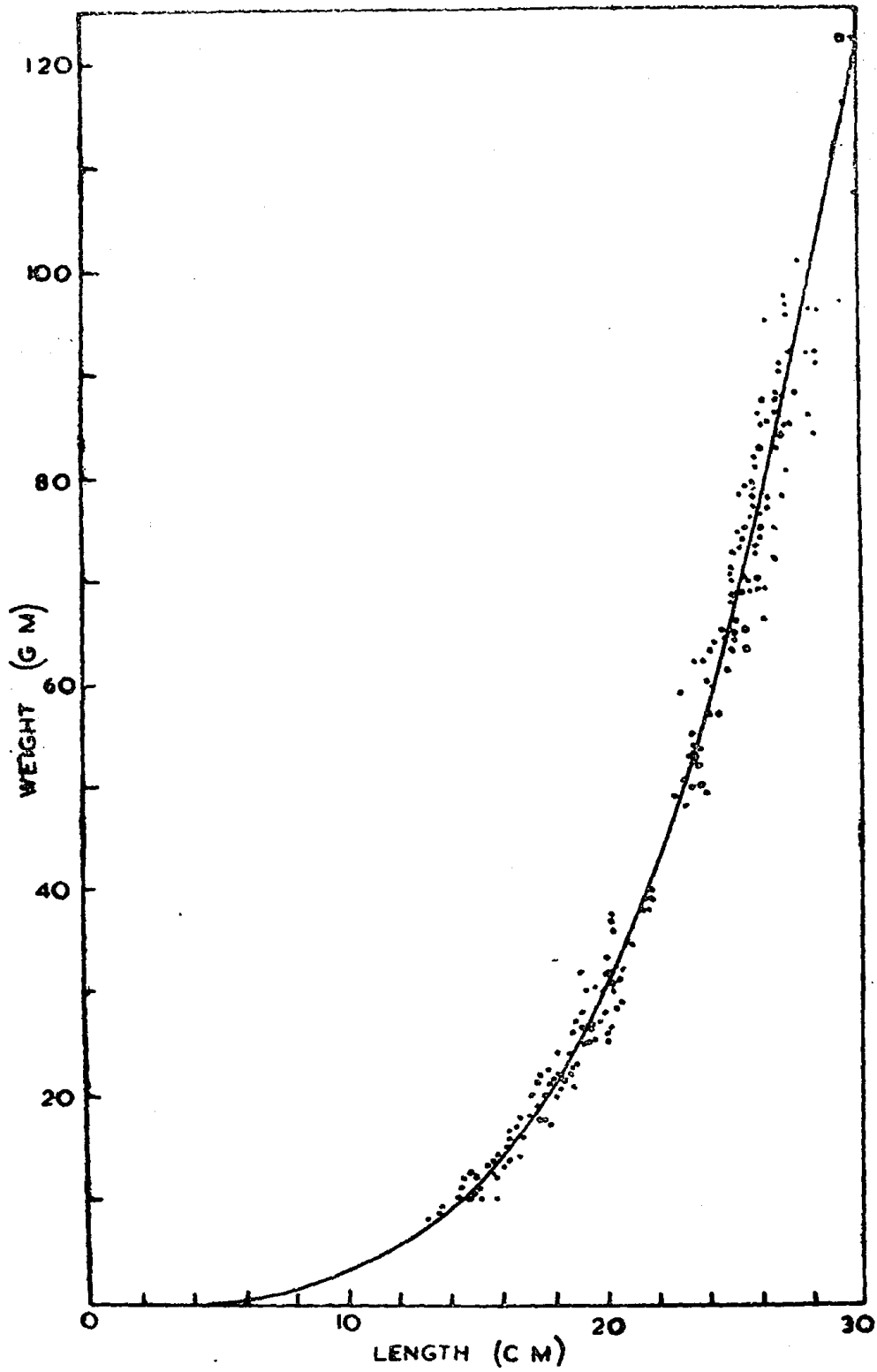


FIG. 1. Length-weight relationship of *Cynoglossus macrolepidotus*: The points refer to the observed values through which the curve has been fitted.

MATHEMATICAL MODEL USED

Out of the different types of equations used in dynamical studies, the ones described by Beverton and Holt (1967) and Ricker (1958) are the most complete in the sense that they incorporate into the model the main population parameters. Krishnan Kutty (1963) found that both are equally accurate in estimating the yield per recruit provided that the Ricker's model makes use of an exponential average of the biomass during each time period.

In the present study the yield equation of Beverton and Holt as modified by Jones (1957) was used because of its equal accuracy and relative ease in calculation. The use of Jones's equation became even more necessary as in the present case the length-weight relationship was not exactly cubic. Jones's modified equation reads :

$$YW = \frac{F}{K} R' W_{\infty} \frac{Z(T_p' - T_0)}{e} \left\{ \beta [X, P, Q] - \beta [X_1, P, Q] \right\} \dots\dots(2)$$

where YW = yield in weight, F = instantaneous fishing mortality coefficient, Z = instantaneous total mortality coefficient, K, T₀ and W_∞ are the parameters in Bertalanffy's growth equation, R' = number of recruits entering the fishery, T_p' = age at which fish become fully exploitable, X, X₁, P and Q are the parameters for the Incomplete Beta Function where $X = e^{-K(T_p' - T_0)}$, $X_1 = e^{-K(T_p - T_0)}$, $P = \frac{Z}{K}$

Q = one + exponent of the length-weight relationship. In equation (2)

$$R' = R e^{-M(T_p' - T_p)} \dots\dots(3)$$

where R = number of recruits first entering the fishing ground, M = instantaneous natural mortality coefficient and T_p = age at which fish first enter the fishing ground. If the fish are liable to be captured as soon as they enter the fishing ground, i.e. where T_p' = T_p, then in equation (3) R' = R and hence no correction in equation (2) is required to account for the natural mortality during the pre-exploited phase (T_p' - T_p). If, on the other hand, the fish are only liable to be captured sometime after they have entered the fishing ground, then a decrease in the population due to natural mortality during the pre-exploited phase has to be accounted for.

Hence after substituting $R e^{-M(T_p' - T_p)}$ for R' in equation (2) and dividing both sides by R, the equation for yield in weight per recruit (YW/R) becomes :

$$\frac{YW}{R} = \frac{F}{K} W_{\infty} \frac{Z(T_p' - T_0) - M(T_p' - T_p)}{e} \left\{ \beta [X, P, Q] - \beta [X_1, P, Q] \right\} \dots\dots(4)$$

The authors of the table of Incomplete Beta Function (Wilimovsky and Wicklund 1963) have pointed out that for calculating YW/R values, linear interpolation of values is rather inaccurate, particularly when the values of X and P are low. In the present study, values had to be obtained mostly by linear interpolation, for there was no other ready reference available on the method of precise interpolation. The linear interpolation was therefore thought to be better than no interpolation at all. Moreover, any error arising from this procedure will be only slight and will not significantly affect the YW/R values.

The yield in number per recruit (YN/R) was calculated from the equation of Beverton and Holt (1957) which states:

$$\frac{YN}{R} = \frac{Fe^{-M(T_p' - T_0)}}{F+M} \left\{ 1 - e^{-(F+M)(T_\lambda - T_p')} \right\} \dots\dots(5)$$

RESULTS

Yield per recruit

The yield in weight per recruit (YW/R) at natural mortalities (M), 0.4, 0.5 and 0.6 have been shown in Fig. 2 (a), (b) & (c) as a function of fishing mortality (F) at various ages of exploitation (T_p'). Since M was found to range from 0.4 to 0.575, it was thought best to calculate the yield for the above 3 sets of natural mortalities.

It can be seen from Fig. 2(a) that when M is 0.4 and $T_p' = 1$, maximum YW/R is reached when F is 1. Thereafter, it decreases with a further increase in F. When $T_p' = 2$, maximum yield is obtained at $F = 1.5$, where an indistinct mode appears. At this T_p' the yield is greater for $F = 0.5$ and above than that of the $T_p' = 1$. When T_p' is 3, 4 or 5 the yield progressively decreases and the yield curves get devoid of modes and become asymptotic within the range of fishing mortalities examined. This agrees well with the deduction made on plaice (Beerton 1954) that when F is increased the highest yield is obtained only at a higher T_p' and that beyond the optimum T_p' at the yield curve becomes asymptotic. Since the yield decreases and the curves become asymptotic when T_p' is 3 or more it appears that the optimum T_p' for *C. macrolepidotus* is about 2 years.

In Fig. 2(b) when M is increased from 0.4 to 0.5, all the yield curves for T_p' ranging from 2 to 5 become asymptotic. Fishing mortality in the range of 0.2 to 1.15 gives a greater yield for $T_p' = 1$. But when F is higher than 1.15 a T_p' of 2 gives a greater yield than that of $T_p' = 1$.

When M is increased to 0.6, the yield is further reduced (Fig. 2c) and even the equilibrium yield curve corresponding to $T_p' = 1$ becomes almost asymptotic and the mode representing the highest yield gets indistinct and shifts to $F = 1.5$. Fig. 2(c) also shows that a greater yield is obtained at $T_p' = 1$ for values of F up to 1.8. It is therefore clear that at a higher M to obtain the same yield either the age of exploitation has to be reduced or the fishing mortality rate has to be increased.

Figure 3 shows the YW/R values as a function of age of exploitation (T_p') at constant fishing and natural mortalities. It can be seen from Fig. 3(a) that when F is low (0.2 = 0.4) maximum yield is obtained at a T_p' less than 1. With an increase in F, maximum yield also increases but this is obtained at a T_p' greater than 1. Beverton (1954) has shown that with progressive increase in F the corresponding optimum age of exploitation and the maximum yield also increase. This may be because the optimum T_p' corresponding to the potential yield (Ty) is low and lies between 2 and 3 years. Hence lack of sufficient number of T_p' values between 1 and 3 years has failed to demonstrate the shifting of modes with increase in F in the yield-mesh curves of Fig. 3(a).

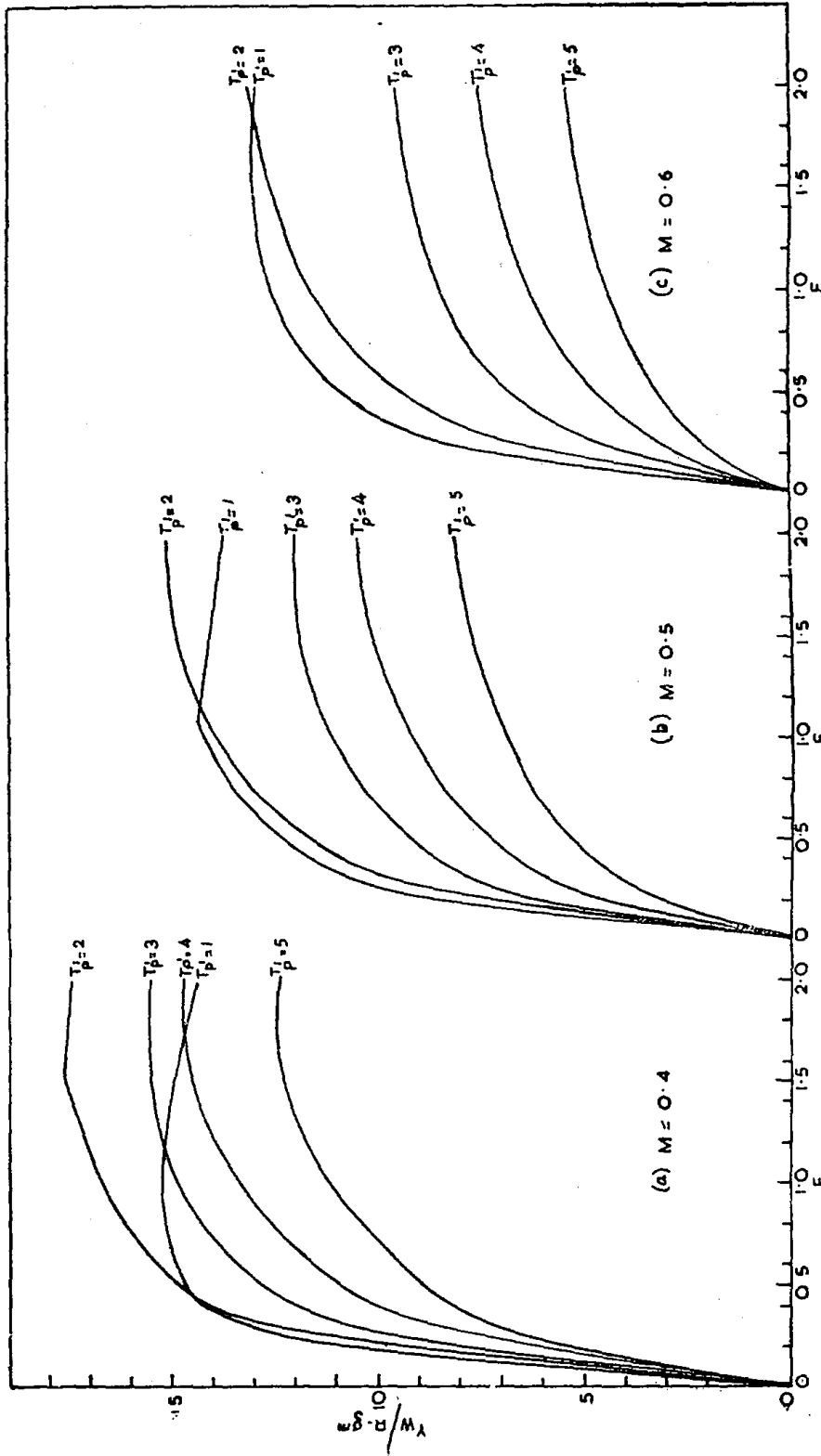


FIG. 2. Yield per recruit (YWR) in relation to fishing mortality (F) at fixed ages of exploitation (T_p) and natural mortalities M .

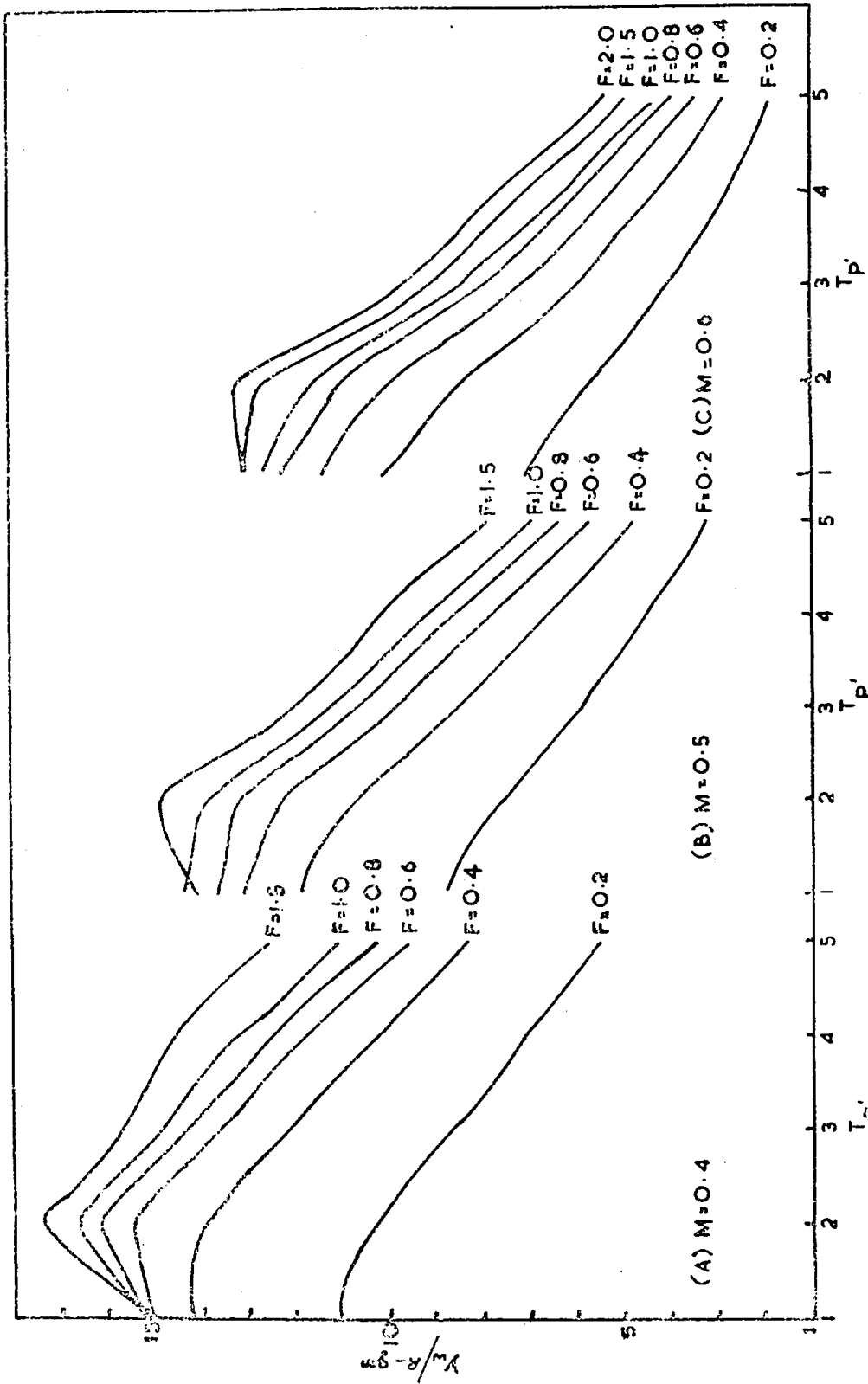


FIG. 3. Yield per recruit (Y_w/R) in relation to ages of exploitation (T_p) at fixed F and M .

With an increase in natural mortality ($M = 0.5$), all the equilibrium yield curves corresponding to $F = 0.2 - 1.0$ have their modes at $T_p' = 1$ or less (Fig. 3b) and when M is 0.6 all the yield curves except for $F = 2$ have their modes shifted to $T_p' = 1$ or less (Fig. 3c). From these analyses it seems clear that with an increase in M the optimum T_p' decreases and the maximum yield is also reduced. In other words when M is high the population has to be fished more intensively at a lower age.

Yield in number and in weight

Figure 4(a) shows the yield in number per recruit (YN/R) and yield in weight per recruit (YW/R) as functions of the age of exploitation (T_p') at a constant fishing mortality $F = 1.5$. It can be seen from the figure that YN/R decreases progressively with an increase in T_p' . The yield in weight, on the other hand, rises to a maximum when T_p' is 2 and then decreases with a further increase in T_p' . This signifies that at this F the mean weight of the exploited phase of the population will be greatest when the T_p' is about 2 years.

If the age of exploitation is kept constant then an increase in F results in an increase in YN/R values (Fig. 4b), but the curve describing YW/R either reaches a mode and then decreases or reaches an asymptotic value, depending upon whether the T_p' chosen is below or, above the optimum T_p' (T_y).

Yield isopleth

Following Beverton and Holt (1957) the yield in weight by simultaneous changes in F and T_p' has been examined by drawing the yielding isopleth diagrams (Fig. 5). Figure 5(a) shows that the same yield can be obtained by various combinations of F and T_p' and hence is of use to minimise F and still obtain the same yield. The latter will correspond to the modes in the isopleth contours which also indicate the maximum yield for a particular F . The eumetric fishing curve, i.e. the line joining the modes of the contours, has been drawn in Fig. 5(a). From this curve for any given F , T_p' required to give the maximum yield can be read off.

As has been noted earlier, with an increase in natural mortality, $M = 0.5$ and 0.6 (Fig. 5b and c), the yield decreases and the same yield can be obtained either with a higher F or at a lower T_p' . This can be clearly seen by following the same yield contour in Fig. 5(a), (b) and (c) and noting the corresponding values of F and T_p' .

In an earlier communication it has been shown that growth in *C. macrolepidotus* is largely confined to the first two years (Krishnan Kutty 1967). It is therefore apparent that much of the population biomass is contributed by fish of age groups 1 and 2. This is particularly so when the natural mortality is high. It can therefore be expected that the optimum age of exploitation is attained fairly early in life. This may be one of the reasons why the eumetric fishing curve could not be drawn in the yield isopleth diagrams representing natural mortalities 0.5 and 0.6 (Fig. 5b and c). The chief characteristic of the eumetric fishing curve is that the highest YW/R value for a given F lies along this line flanked on either side by lower values.

The maximum yield or the potential yield (y) is obtained only at the optimum T_p' (T_y) and this age of weight of the brood is greatest (Holt 1958). Since potential

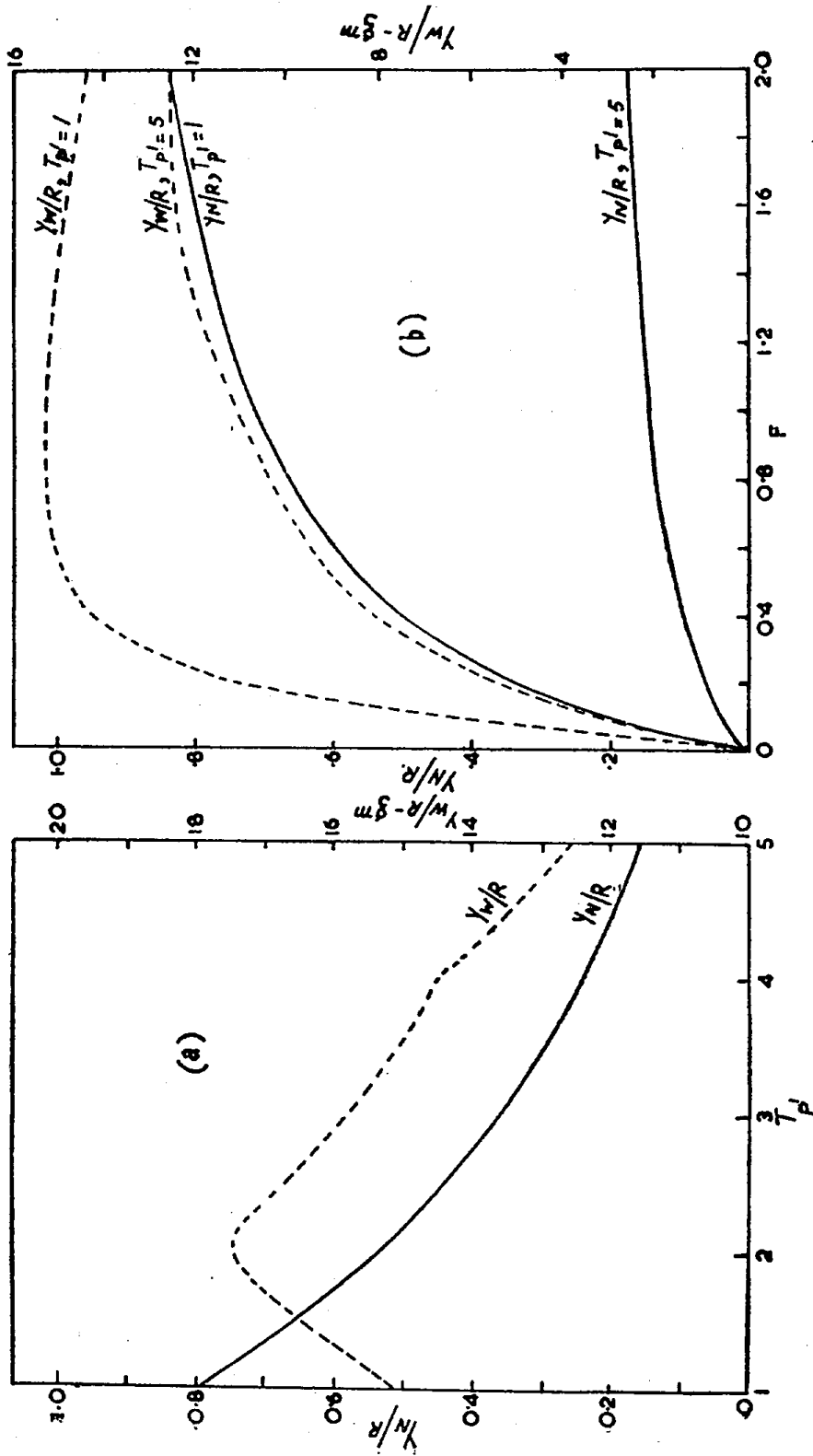


FIG. 4. Yield per recruit in number (Y_N/R) and in weight (Y_W/R): (a), as a function of T_p' at constant $M=0.4$ and $F=1.5$. (b), as a function of F at constant $M=0.4$ and taking two extreme $T_p' = 1$ and 5.

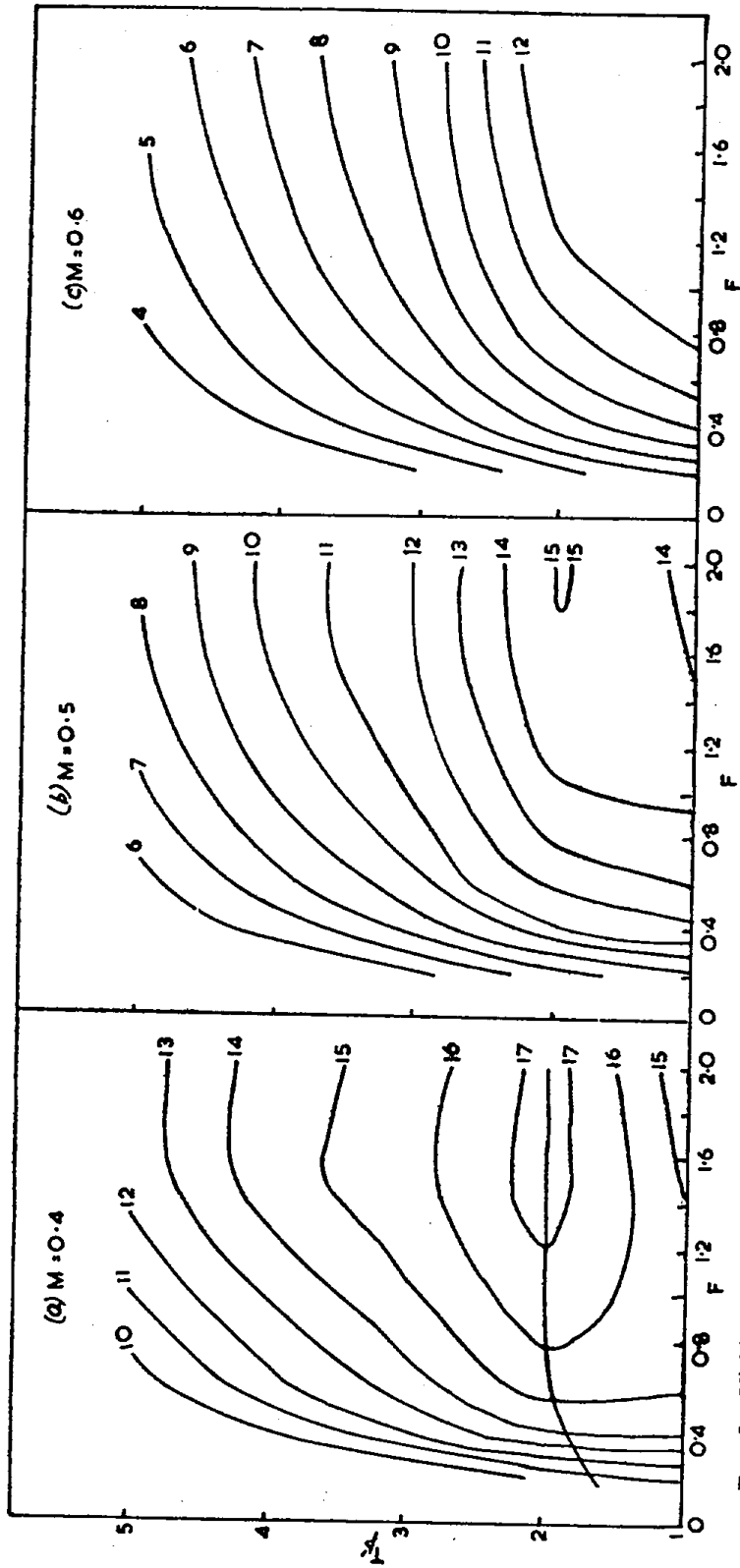


FIG. 5. Yield isopleth diagrams for $M=0.4$, 0.5 and 0.6 . The numbers against each contour refer to yield per recruit in grams.

yield is obtained only when $F = \infty$, which is not economically feasible, the desired T_p' to obtain the maximum yield at a given F can be read from the eumetric fishing curve.

DISCUSSION

Regulatory measures to conserve a population is often observed through changes in F or T_p' . An estimate of either of these or both can be made by studying the changes in YW/R values instead of total yield in weight since recruitment is seldom known (Beverton and Holt 1957). As has been noted earlier the estimated total mortality range, 0.4 - 0.575 is largely due to M , for F is very small. Hence the actual yield curves for *C. macrolepidotus* will be of the same shape as drawn in Fig. 2 for $M = 0.4, 0.5$ and 0.6 and the present yield from the fishery will be very near the origin of these curves. A large increase, therefore, in the yield is possible by increasing the fishing intensity (Gulland—Personal communication). But to maximise the yield for a given F , the age of exploitation has also to be considered. The analysis of YW/R values indicates that when $M = 0.4$, a T_p' of 2 seems desirable for $F = 0.5$ and above. Similarly when $M = 0.5$, a $T_p' = 1$ gives the maximum observed yield at F less than 1.15, and when $M = 0.6$, a $T_p' = 1$ gives the maximum observed yield at F less than 1.8.

Although it has been suggested that if $M = 0.4$ for a greater yield of *C. macrolepidotus*, fish of 2 year and older may be exploited, this may affect the yield of other fish and prawns which are caught along with *C. macrolepidotus* in the same trawl. Hence a change in the trawl mesh to catch larger and older *C. macrolepidotus* can only be adopted after a study has been conducted as to how such a change will influence the yield of trawl fishes in general of the Cochin area.

In *C. macrolepidotus*, the yield isopleth diagrams clearly indicate that the yield per recruit is very low in relation to the fishing intensity. This may be due to a number of factors. In the first place, a high M seems to be the most important factor in this particular species. Secondly the fish does not grow to a large size and hence the asymptotic weight is low, $W_\infty = 147$ gm. A high rate attaining the asymptotic length ($K=0.23866$) results in small growth increment in older fish. And, M being large, any contribution to the yield from the older year classes would be small despite the T_λ which is 12 years. In this particular case when the values of M , W_∞ and K are taken into consideration the effect of T_λ on yield would be negligible, for a precise estimate of T_λ as close to the age at which the fish disappears from the fishery would be very important when M and K are low and W_∞ is high. In such cases if T_λ is taken as ∞ , yield will be overestimated, particularly at low F values (Beverton and Holt 1957).

In *C. macrolepidotus*, the optimum T_p' is also low. This is because the optimum T_p' largely depends upon growth and mortality. This particular fish attains considerable growth in the first year which also becomes evident from the high T_0 value which is — 2.2883. After the first year, growth slows down considerably and in subsequent years very little growth occurs. It is therefore less surprising to find

such a low optimum T_p' value, for it is obvious that the age at which the increment due to growth will balance the loss due to M will be attained fairly early in life.

In the present study we have assumed the population to be in a steady state and all population parameters to be constant. Beverton and Holt (1957) while extending the simple yield equation on plaice have released the assumption that the population is in a steady state and have calculated the effect of changes in annual recruitment, growth and natural mortality on yield. Since such studies require intensive data and are therefore slow in producing results, our understanding of the dynamics of tropical fish populations at least in the beginning, can be enhanced considerably by using simpler models than those of the analytical ones.

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