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An assessment of ring seine fishery in Kerala through surplus production model

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ABSTRACT

Outboard ring seine is one of the major gears operated in Kerala which contributes about 37% of the total landings in the State. Oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) are the two species that account for about 84% of the ring seine catch. The ring seine fishery began in the State by mid eighties and grown into a major fishery over the years. An assessment of the ring seine fishery in the state through nonequilibrium surplus production model was made in this study by using time series data on catch and effort of ring seine in Kerala during 1986-2004. An index of relative biomass a_t and an index of net production rate m_t were computed, apart from fishing mortality rates F_t, maximum sustainable yield (MSY), effort corresponding to MSY and biomass corresponding to MSY. Results revealed that the ring seine fishery in Kerala is close to the state of equilibrium. Behaviour of m_t and F_t were almost similar showing characteristics of fully developed fishery and the pattern of their difference m_t-F_t indicated that the status of ring seine fishery in Kerala is close to the optimal level at present.

Introduction

The introduction of outboard motors to the traditional crafts, in the early eighties made conspicuous impact on the marine fisheries sector in Kerala (Balan *et al.*, 1989). With the introduction of outboard motors, the erstwhile boat seine units with 15-18 crew members were replaced by the outboard motor fitted, large sized plank built boats enhancing the crew capacity to 30-35. Motorization helped the development of innovative high catching gears like ring seine on par with purse seine.

Ring seines were first reported during 1985-86 in the Alleppey region and picked up fast to the central and northern Kerala (Balan *et al.*, 1989). The ring seine, a major gear used in Kerala is a fine meshed encircling net used mainly to harvest pelagic fishes like oil sardine and mackerel and contributed to 21.4% of the marine fish landings of Kerala in 1994 (Balan and Andrews, 1995). Over the years, its share increased and attained a level of 36.7% during 2000-2004. The size and CPUE of ring seine had changed over years (Edwin and Hridayanathan, 1998). The impact of ring seine and minitrawlers used in the artisanal fisheries in Kerala was examined by D'cruz (1998) and reported as harmful to the fishery. Vijayan *et al.* (2000) recommended outboard engines with less than 50 hp engine power for effective operations of ring seines.

Oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) are the two species that account for about 84% of the ring seine catch. From 1990 onwards, about 75% of the oil sardine landings and about 60% of the mackerel landings in the State are from ring seine operations. In the present study an attempt is made to assess the status of oil sardine and mackerel stocks off Kerala coast using time series data on catch and effort of ring seines in the state by fitting nonequilibrium surplus production model and a linear version of the model suggested by Schaefer (1954).

Materials and methods

Time series data on ring seine catch in Kerala and effort expended in terms of hours of operation of ring seines during 1986-2004 obtained from the National Marine Living Resources Data Centre (NMLRDC) of the Central Marine Fisheries Research Institute, Cochin was used for the study. The model used is the nonequilibrium surplus production model (Schaefer, 1954) given by

$$\frac{dB_t}{dt} = rB_t(1-\frac{B_t}{K}) - F_tB_t \qquad (1)$$

This leads to the calculation of biomass as

$$B_{t+1} = \begin{cases} \dfrac{\alpha_t \exp(\alpha_t)\, B_t}{\alpha_t + \beta(\exp(\alpha_t)-1)\, B_t}, & \alpha_t \neq 0 \\[2ex] \dfrac{B_t}{1+\beta\, B_t}, & \alpha_t = 0 \end{cases} \qquad (2)$$

where $\beta = \frac{r}{K}$, $\alpha_t = r - F_t$ and $F_t = q\, f_t$

Here F_t is the fishing mortality rate, f_t is the fishing effort, K is the carrying capacity, r is the intrinsic rate of increase of the stock, B_t is the biomass at time t (year) and q is the catchability coefficient. Based on this model, yield is calculated as

$$Y_t = \begin{cases} \dfrac{F_t}{\beta} \ln\left[1 - \dfrac{\beta\,(1-\exp(\alpha_t))\, B_t}{\alpha_t}\right], & \alpha_t \neq 0 \\[2ex] \dfrac{F_t}{\beta} \ln[1+\beta\, B_t], & \alpha_t = 0 \end{cases} \qquad (3)$$

Parameters of this model to be estimated, using the time series data on catch and effort, are (i) the initial biomass B_0, (ii) carrying capacity K, (iii) intrinsic growth rate r and (iv) catchability coefficient q. For estimation of these parameters, the method suggested by Wang (2002) was adopted. A brief outline of this procedure is presented below.

a) The catch per unit effort (suitably scaled) U_t is first calculated, which is an abundance index of average biomass at year t.

b) The abundance index is calculated at the beginning and end of year t as $U'_t = (U_{t-1} + U_t)/2$ and $U'_{t+1} = (U_t + U_{t+1})/2$ respectively.

c) Using the derived equation $U_t = qK + \frac{qK}{r}\ln(\frac{B_t}{B_{t+1}}) - \frac{q^2K}{r}X_t$ and replacing $\ln(\frac{B_t}{B_{t+1}})$ with $\ln(\frac{U'_t}{U'_{t+1}})$, estimates of r and q are obtained through a regression of U_t on $\ln(\frac{U'_t}{U'_{t+1}})$ and X_t, where X_t is the effort.

d) For estimation of K, an index of relative biomass, a_t, which reflects the fluctuations of relative biomass year after year, having the expression $a_t = 1 + \frac{1}{r}\ln(\frac{U'_t}{U'_{t+1}}) - \frac{q}{r}X_t$ is calculated for different years.

Coefficient of Variation (CV) of these quantities from initial year onwards is worked out for different periods and the period with minimum CV is used to calculate the average of these quantities as 'a'.

e) The initial biomass is calculated using the initial year's yield Y and corresponding fishing mortality $F = qX$, where X is the effort, as $B = Y/\exp(-F)$ and K is estimated as $K = B/a$.

f) The net production rate defined as $m_t = r(1-a_t)$ is calculated to study the current status of fish stocks under exploitation. The fishing mortality is calculated as $F_t = qX_t$.

g) Under fishing, successive periods biomass has the relation

$$B_{t+1} = B_t\, e^{m_t - F_t} \text{ or } \quad e^{m_t - F_t} = \frac{B_t}{B_{t+1}} \qquad (4)$$

Equation (4) is the ratio of successive years biomass and the aim should be to keep this ratio close to unity so that there is not much change in the biomass over time. This happens when $m_t - F_t$ is close to zero. Thus, the difference between m_t and F_t provides the current status of the fish stocks under exploitation and the goal of fishery management is to make this difference as small as possible.

A final estimate of the four parameters was arrived at through iteration by minimizing the quantity $\sum[\log(Y_t) - \log(\hat{Y}_t)]^2$. Estimates of maximum sustainable yield (MSY), biomass at MSY level, fishing mortality rate at MSY level and effort at MSY level were calculated as given below (Prager, 1994).

$$\hat{MSY} = \frac{\hat{K}\hat{r}}{4};\ \hat{B}_{MSY} = \frac{\hat{K}}{2};\ \hat{F}_{MSY} = \frac{\hat{r}}{2};\ \hat{f}_{MSY} = \frac{\hat{r}}{2\hat{q}} \qquad (5)$$

The linear version of the model attempted is

$$y = a\,f - b\,f^2 \qquad (6)$$

where f is the effort and y is the yield. The parameters a and b of this model was estimated through regression and the MSY and corresponding effort, f_{MSY} based on this model were calculated using the following formula.

$$MSY = \frac{\hat{a}^2}{4\hat{b}};\quad f_{MSY} = \frac{\hat{a}}{2\hat{b}} \qquad (7)$$

Results and discussion

The time series on catch (in tonnes) and effort (in hours of operation) by ring seine in Kerala during the period 1986-2004 plotted are shown in Fig.1. The final estimates of parameters of the models attempted and estimates of maximum sustainable yield (MSY), biomass at MSY level and optimum effort are given in Table 1. The fluctuations in the index of relative biomass a_t are shown in Fig.2. Values of this index ranged between 0.62 in 1993 and 0.95 in 1987. In the early years, from 1986 to 1993, this index showed a decreasing trend indicating early development of the ring seine fishery. From 1994 onwards, a_t ranged between 0.66 and 0.77 having 0.71 as the average. From Fig.3, it can be seen that both m_t and F_t behave in almost similar manner revealing their dependence which generally is a character of fully developed fishery. In the last five years the quantity $e^{m_t - F_t}$, which is the ratio of biomass in consecutive years varied between 0.927 and 1.064 with 1.013 as the average, very close to unity. This indicates that the biomass of the resources harvested by ring seine does not change much over years. Thus the ring seine fishery in Kerala is very close to the state of equilibrium and hence the stocks of the two resources, oil sardine and mackerel, mainly harvested by ring seine are not under stress.

The net production rate m_t ranged

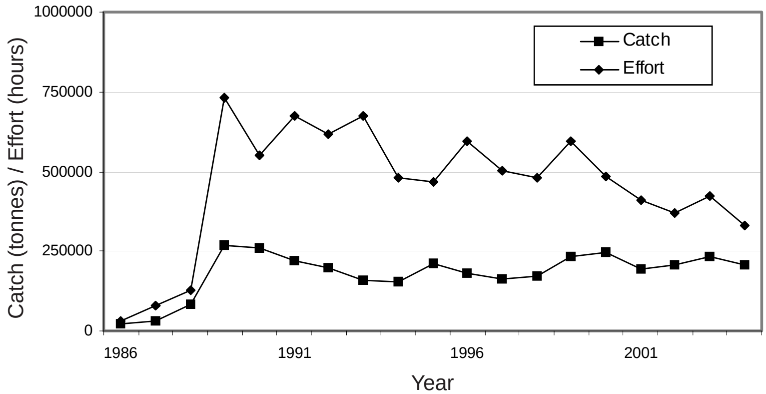

Fig. 1. Catch (in tonnes) and effort (hours of operation) for ring seine fishery in Kerala during 1986-2004

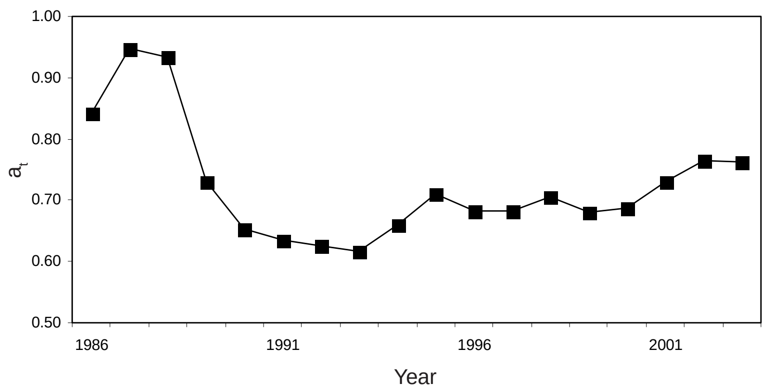

Fig. 2. The index of relative biomass a_t for ring seine operations in Kerala

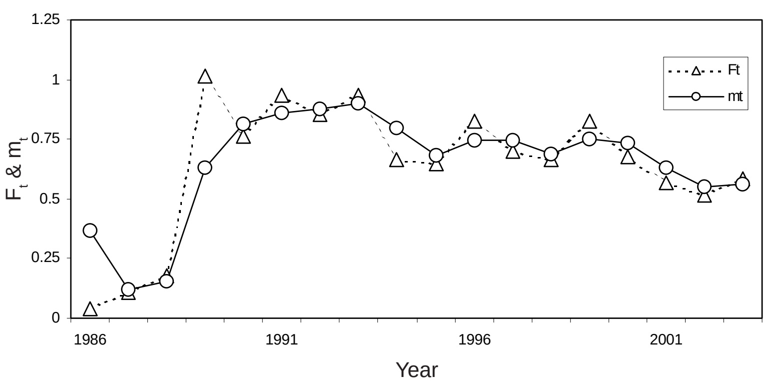

Fig. 3. Net production rate m_t and fishing mortality rate F_t for ring seine operations in Kerala

between 0.123 in 1987 and 0.899 in 1993 and the average was 0.645. The biomass corres-ponding to the highest net production rate is 2,43,500 t. and the corresponding fishing mortality was 0.937. Since the biomass having maximum net

TABLE 1: *Estimates of parameters of (a) nonequilibrium surplus production model and (b) linear version of Schaefer's model, fitted using the ring seine catch and effort data of Kerala*

Parameter	Estimate
(a) Nonequilibrium surplus production model	
Initial Biomass, B_0	261540
Carrying Capacity, K	385534
Catchability coefficient, q	1.386649E-06
Intrinsic rate of increase, r	2.348739
Maximum Sustainable Yield, MSY	226379 t
Biomass at MSY level, B_{MSY}	192767 t
Fishing mortality at MSY level, F_{MSY}	1.1743695
Effort at MSY level, f_{MSY}	846912 h of operation per annum
(b) Linear version of Schaefer's model $y = a\,f - b\,f^2$	
Regression R^2	0.807
Estimate of intercept, $\hat{a}$	0.7482063
Estimate of slope, $\hat{b}$	6.464615E-07
Maximum Sustainable Yield, *MSY*	216491 t
Effort at MSY level, f_{MSY}	578694 h of operation per annum

production is considered as the best density of the stock (Wang, 2002), the status of the stocks exploited by ring seines (mainly oil sardine and mackerel) are considered as the best in 1993. Fishing mortality and the net production rate are nearly equal in this year. The aim of fishery management is to bring these indices very close, to keep the ratio of biomass in consecutive years to unity. It can be seen that from 1997 onwards the difference of m_t-F_t is positive (except in 1999 and 2003) and close to zero which is an indication that the status of ring seine fishery in Kerala is close to the optimal level at present. If this difference continues to go below zero in the coming years, then there is need for concern to bring it above and close to zero by reducing the effort.

The maximum sustainable yield was estimated as 2,26,379 t with 1.174 as the corresponding fishing mortality and 846912 h. as the optimum annual effort. Biomass corresponding to this level of yield is 1,92,767 t. The estimate of MSY and f_{MSY} obtained using equation (7) for the model (6) was 2,16,491 t. and 578694 h. respectively. This model cannot yield estimates of biomass and fishing effort.

During the last five years, the average catch by ring seines is 2,16,614t. and its average effort is 404732 h. per annum. This is below the MSY level obtained using the nonequilibrium surplus production model and to reach up to the MSY level, the level of effort have to be doubled (Table1 a). Doubling of the present effort will at the most result in increase of catch by only around 10,000 t. and hence it is not economically viable and feasible. A better management option is to allow the present level of exploitation by ring seines and monitor the m_t-F_t difference and suggest reduction in ring seine effort if this difference continues to fall below zero consecutively in the coming years, to bring it above but close to zero.

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