

A BIOECONOMIC ANALYSIS OF SUSTAINABILITY OF MARINE FISH PRODUCTION IN KERALA

Aswathy N.¹, T.R.Shanmugam², K.R.Ashok² and R.Sathiadhas¹

¹*Socio-Economic Evaluation and Technology Transfer Division (SEETTD), Central Marine Fisheries Research Institute (ICAR), Post Box No. 1603, Cochin-682 018, Kerala, India
e-mail: aswathysaji@rediffmail.com*

²*Department of Agricultural Economics, Tamil Nadu Agricultural University, Lawley Road P.O., Coimbatore-641 003, Tamil Nadu, India*

ABSTRACT

The study has been undertaken in Kerala State in India with an overall objective of analyzing the bioeconomic conditions of commercially exploited marine fishes for assessing their sustainability in the context of existing management practices. Maximum Sustainable Yield, Maximum Economic Yield and Open Access levels of yield and effort were analyzed using Gompertz-Fox growth model. The study concluded that the fishing effort exceeded the economically optimal levels and there is unnecessary wastage of money, manpower and fuel in the fishing industry. The study stressed the urgent need for capture fisheries management in the State which at present follows an open access fishery where regulations exist only in the form of seasonal closure in the monsoon season.

Key words: Open access, Bioeconomics, MSY, MEY.

INTRODUCTION

Kerala is India's most well-known fishery State. It has a coastal length of 590 kilometers covered by the Arabian sea with an exclusive economic zone of 1.4 lakh square kilometers and continental shelf area of 39,000 square kilometers. The state contributed 22.32 per cent of the country's marine fish landings in 2006 (CMFRI, 2007). The marine fishery in the state is multispecies and multifleet and characterized by regulated open access. The fishing effort of mechanized vessels has been controlled through introduction of fishing ban during the monsoon season from the year 1988. The monsoon season is considered to be the breeding season of important marine fishery resources of the state. More than 60 per cent of the catch is pelagic resources and the demersal resources contribute the rest. The mechanized trawlers target mainly high

valued demersal resources consisting of shrimps, cephalopods and threadfin breams, due to their increased demand in the export market.

Though the marine fish production in the state had registered an impressive growth between 1950 & 1980, it showed a dwindling tendency during 1981-87. The depletion in the stock of several marine fish species, diminishing catch of traditional fishermen and the adverse effect of bottom trawling on the ecosystem called for resource conservation and management measures through legislation. Analysis of the species wise landings for the last four decades showed that many of the marine fish species had depleted with technological change in fish harvesting. The extinction of catfish fishery of the Kerala coast is a best example of indiscriminate fishing by the mechanised sector (Sathiadhas and Narayanakumar, 2001).

Analysis of species wise landings for the last four decades showed that many of the marine fish species had depleted with technological change in fish harvesting. In addition, there is considerable growth of population within the fishing community and biological and economic over fishing due to adoption of newer technologies, lesser per capita production, stressing the need for efficient fisheries management essentially directed towards sustainable development. The physical productivity of worker per unit of capital invested had declined steeply, which is a phenomenon characteristic of the open access resources subject to increased commercialization (Mohan Joseph *et al.*, 2006). The problems of overexploitation were further aggravated by externalities like inflow of pollutants, shallow water mining and lifting of coastal sands and various other environmental threats. Hence the present study is undertaken in Kerala state for assessing the sustainability of marine fish production in the state and to suggest appropriate policy recommendations for improving the capture fisheries scenario in the state.

The specific objectives of the study are:

1. to assess the trends & fluctuations in landings of commercially important marine fish species in Kerala
2. to analyse the bio economic conditions of marine fish production and
3. to assess the sustainability of current level of fishing effort and to suggest policy options for sustainable marine fish production.

MATERIALS AND METHODS

Time series data on species wise catch and gear wise fishing effort for the period from 1985 to 2006 were obtained from publications

of Central Marine Fisheries Research Institute. The period was selected specifically as the gear wise information on catch and effort of resources were available from the year 1985 only. The economics of operations of different fishing units were collected from selected landing centres in Kollam, Ernakulam and Kozhikkode districts of Kerala for obtaining the cost per hour of fishing for different vessel categories.

The growth in major marine fish resources during the period 1985-2006 was analyzed by working out annual compound growth rate. The sustainability of marine fish production was analyzed using surplus production model of the exponential form (Fox model). For the sake of simplicity in analysis and also due to lack of information on fishing effort towards individual species, the overall marine fish production in the state is assumed be resulting from a single stock. Since there was variation in the fishing power of different categories of vessels and among the same category of vessels, standardization of fishing effort was done by taking into account the catch per hour of mechanized single day trawlers in 2006 as the standard unit.

Growth in landings

Annual compound growth rates were estimated to analyse the trends in landings of the demersal, pelagic, crustacean and cephalopod resources as well as important species in each group.

Analysis of sustainability using Fox model

Maximum Sustainable Yield (MSY)

Maximum Sustainable Yield (MSY) is the yield produced by applying the optimal level of effort that could be sustained without

affecting the long-term productivity of the stock. Biologists set the targets for fishing effort at maximum sustainable levels. Beyond this point each additional effort reduces sustainable yield.

Schaefer (1954) developed the logistic form of population growth as follows;

$$Y=qEk(1-qE/r) \quad (1)$$

The model assumes, at equilibrium the removals from the stock due to fishing equals the additions to the stock from growth and recruitment. Hence the functional form used becomes;

$$Y = aE - bE^2$$

Where, Y = catch

E = effort (standardized)

q = catchability coefficient

r = intrinsic growth rate

k = maximum carrying capacity

The logistic model developed by Schaefer was modified by Fox by assuming a Gompertz function, resulting in an

exponential relationship between fishing effort and population size and asymmetrical harvest curves (Fox, 1970).

$$\ln(Y/E)=a+bE \quad (2)$$

Where Y is total annual catch, E annual fishing effort, a and b are constant parameters.

The level of effort that corresponds to Maximum Sustainable Yield (MSY) could be obtained from equation (2) easily. Exponentiating both sides and solving for Y, gives

$$Y=E\exp(a+bE) \quad (3)$$

Differentiating Y with respect to E in the above equation, setting the result equal to zero, and solving for effort(E_{MSY}) that maximizes Y gives,

$$E_{MSY}=-1/b \quad (3a)$$

The corresponding MSY can be obtained by substituting equation (3a) into equation (3)

$$MSY=-1/b(\exp(a-1)) \quad (3b)$$

Table 1

Effort standardization parameter of different fishing units

Category	Effort standardization parameter
Singleday trawler	1
Multiday trawler	1.02
Mechanized seiner	26.01
Mechanized gillnetter	0.42
Motorized units	1.20
Non -motorized units	0.26

Table.2**Annual catch and effort of marine fish landings in Kerala**

Years	Total standardized effort (in fishing hours)	Total landings (in tonnes)
1985-90	41,88,678	4,65,139
1991-96	1,01,48,857	5,76,324
1997	1,39,32,979	5,74,774
1998	1,44,43,599	5,42,696
1999	1,24,61,258	5,80,773
2000	1,04,96,118	6,04,113
2001	1,03,04,845	5,14,139
2002	1,13,38,289	5,89,519
2003	1,09,36,797	6,23,293
2004	1,03,74,774	6,16,839
2005	1,06,04,021	5,36,215
2006	1,28,14,317	5,91,902

Table 3**Fox model results – Sustainability of marine fish landings in Kerala**

Particulars	Parameters
Intercept	5.4283**
Slope	-1.31405E-07**
MSY (tonnes)	6,37,667
EMSY (hours)	76,10,040
MEY (tonnes)	5,78,012
EMEY (hours)	47,15,923
Open access effort (hours)	1,47,14,598
Maximum economic rent at MSY (in rupees crores)	1,192
Maximum economic rent at MEY (in rupees crores)	1,302
R ²	0.97

** - Significant at one per cent level

Maximum Economic Yield (MEY)

Managing fisheries at its biological maximum or Maximum Sustainable Yield (MSY) may not prove to be economically efficient. Integrating economic considerations like fishery input and output prices with the biological and technical aspects become essential in order to maximize fishery net returns. Maximum Economic Yield is the yield, which would generate maximum resource rent from the fishery. The resource rent simply refers to the profit earned from the fishery.

In the simple economic model developed by Gordon (1954), fishery input and output values are expressed in terms of total cost and total revenue and as functions of fishing effort. Assuming a fixed price P for the fish caught, total revenue (TR) can be expressed as;

$$TR = PY$$

If C is the cost for each unit of effort (E), the total cost in the fishery may be defined as,

$$TC = CE$$

From equation (3), $Y = E \exp(a+bE)$

$$TR = PY = PE \exp(a+bE) \quad (4)$$

In order to reach the economic objective, the fishing effort must be cut down to the point where marginal cost (MC) is equal to marginal revenue (MR).

$$MR = P(bE+1) \exp(a+bE) \quad (4a)$$

Using $MR=MC$;

$$P(bE+1) \exp(a+bE) = C \quad (4b)$$

Which gives,

$$E_{MEY} = 1/b [-1 + (C/(P \exp a))^{-1/2}] \quad (4c)$$

$$MEY = E_{MEY} \exp(a+bE_{MEY}) \quad (4d)$$

Open Access Equilibrium (OAE)

In open access fisheries, fishermen will increase their fishing effort as long as that is profitable. The open access equilibrium (i.e. no further entries in the fishery) occurs where total revenue (TR) equals total cost (TC) and hence resource rent becomes zero (Ahmed *et al.*, 2007). This equilibrium is otherwise called the Bioeconomic Equilibrium. Bioeconomic Equilibrium (BE) refers to the simultaneous biological and economic equilibrium in a fishery.

Under an open-access or unregulated fishery, individual fishers attempt to maximise their income by expanding effort as long as their average revenue (AR) is greater than the average cost (AC) of their effort and the fishery settles at an equilibrium level, called the Bionomic Equilibrium, when $AR=MC$ (Sonny and Oscar, 2001).

From equation (4), $TR = PY = PE \exp(a+bE)$

Which gives average revenue,

$$AR = P \exp(a+bE) \quad (5)$$

Effort at Open Access Equilibrium

$$E_{OA} = [\ln(C/P) - a]/b \quad (5a)$$

Standardization of fishing effort

The total standardized effort applied to the resource group was worked out using the following procedure. The catch per hour (CPH) of each fishing unit was worked out by dividing the annual catch in tonnes by the annual fishing effort in hours. An effort standardization parameter was worked out to obtain the standardized fishing effort of a gear.

Effort standardization parameter (S_j) for vessel j is worked out as follows

$$S_j = \frac{CPH_j}{CPH_m} = \frac{C_j/E_j}{C_m/E_m}$$

Where CPH_j is the catch per hour of vessel j and CPH_m is the catch per hour of vessel m and m is the standard vessel (single day trawler). The fishing effort of each vessel category was standardized by multiplying with the effort standardization parameter. The standardized effort for all fishing units in a year was summed up to obtain the total standardized effort for that year.

RESULTS AND DISCUSSION

The different types of craft-gear combinations existing in the State were mechanized purse-seiners, ring seiners, gillnetters, liners and trawlers. In the motorized category, gillnetters, ringseiners and minitrawls were operating. In the non-motorized sector also, gillnetters and ring seiners were the major gears. For the purpose of making the analysis simple, all the craft - gear combinations were categorized into six groups consisting of mechanized singleday trawlers, multiday trawlers, mechanized seiners, gillnetters, motorized units and non-motorized units. Analysis of growth in the catch of different marine fishery resources was necessary in order to have a clear understanding of the species wise status of marine fisheries depletion in the state and associated factors contributed by different fishing units.

Growth in landings

The growth in marine fish landings was assessed for major resource groups as well as for selected species. Comparison of annual growth during the periods 1985-96 and 1997-06 for each of the major resource groups was also done. A comparative analysis of the compound annual growth rate during the periods 1985-96 and 1997-06 showed that most of the marine fish species with the

exception of oil sardines showed positive growth during 1985-96 period, whereas the growth rate was negative for most of the resources during 1997-06 period. Cephalopods showed the highest growth rate of 15.26 per cent during 1985-96 period. Pelagics showed a growth rate of 4.99 per cent followed by demersal finfishes (4.31 per cent) and crustaceans (3.28 per cent) in that order. Among the species groups, Indian mackerel showed the highest growth rate (12.19 per cent) and sharks and rays showed negative growth.

During the period, 1997-2006, pelagics showed a positive growth of 2.76 per cent whereas the demersal, crustacean and cephalopod resources showed negative growth rates of -1.56, -5.59 and -1.40 per cent respectively. Oil sardine showed a positive growth rate of 11.55 per cent, seer fishes 12.45 per cent and tunnies, 5.47 per cent, whereas carangids and scads showed a negative growth trend. Among the demersal fin fishes, sharks and threadfin brems showed a positive growth trend, whereas croakers and flat fishes showed negative growth trend. Among the crustaceans, penaeid shrimps and stomatopods showed very high negative growth rates of -5.94 and -17.74 per cent respectively.

The overall marine fish production showed a growth rate of five per cent during 1985-96 period, whereas the growth rate was only 0.43 per cent during 1997-2006 period. The positive growth rate of major marine fish species during the period 1985-96 was due to the improvement in fishing technology in terms of increased fishing power of gears and engine and increase in the number of motorized and mechanized fishing units. Further expansion in fishing capacity and initiation of multiday fishing trips by most of the mechanized units had resulted in depletion of marine fish resources, which may

be attributed to the negative growth trend during 1997-2006 period.

Standardization of fishing effort

The fishing effort exerted by each vessel category was standardized prior to fitting the regression model. The effort standardization parameter was worked out based on the catch per hour of singleday trawlers at 2006 level (Table 1).

Sustainability of marine fish production in Kerala

The Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY) and open access levels of catch and effort were analysed for the total marine fish production in Kerala using the Fox model. The total effort of all the six categories of fishing units were standardized in terms of singleday trawler hours prior to running the regression. Table 2 shows the annual catch and standardized effort towards overall marine fish production in Kerala.

The results of the Fox model regression (Table 3) showed that the Maximum Sustainable Yield (MSY) at 6,37,667 tonnes of fish and the effort level corresponding to MSY (EMS_Y) at 76,10,040 standard fishing hours. The Maximum Economic Yield levels of catch (MEY) and effort (EMEY) were respectively 5,78,012 tonnes & 47,15,923 standardized fishing hours. The maximum economic rent realized from the fishery at MEY effort level amounted to Rs.1,302 crores, whereas at MSY effort level, the maximum economic rent realized from the fishery stood at Rs.1,192 crores only. The average fish catch during the periods 1989 (6,47,526 tonnes) and 1990 (6,62,890 tonnes) had exceeded the MSY level and the fish catch had exceeded the MEY level in most of the

years after 1988. The total standardized effort showed gradually increasing tendency from 1985 and remained almost static after 1999. The effort towards marine fish production was well above the MSY and MEY levels and nearer to the open access level (1,47,14,598 standardized fishing hours).

CONCLUSION

Even though the catch exceeded the MSY level in the years 1989 and 1990 only, the overall marine fish production exceeded the Maximum Economic Yield level in most of the years after 1988. The fishing ban had initiated in the state of Kerala in 1988 at varying period from 45 to 70 days during the monsoon season in Kerala. Even with this regulatory measure, the current fishing effort is above the biologically and economically sustainable levels and the effort is very near to the open access equilibrium level. Further expansion in the fishing capacity will not produce any economic benefits and there is unnecessary wastage of money, manpower and fuel in the fishing industry in the state. Excessive fishing pressure and unnecessary wastage of fuel adds to the problem of environmental damage. The results indicated the urgent need for capture fisheries management in the state through restrictions on fishing effort and catch rates of fishing vessels. Large scale sea ranching programmes can play vital role in the natural stock enhancement (Mohan Joseph et al., 2006). According to World Wide Fund (WWF), Marine Protected Areas play a significant role in safeguarding marine ecosystems and local economies. Hence resource stock improvement through community based fishery management practices including creation of marine parks and marine protected areas, promotion and expansion of mariculture or aquaculture activities and initiation of sea ranching and open sea farming may also be recommended

as immediate measures for ensuring sustainability of marine fish production in the State.

ACKNOWLEDGEMENT

We express our deep sense of gratitude to the chairman and members of the advisory committee, Tamil Nadu Agricultural University, Coimbatore for their guidance and encouragement. Thanks are also due to the Director, CMFRI for granting study leave for doing the Ph.D. Course.

REFERENCES

- Ahmed, M., Pongpat Boonchuwongse, Waraporn Dechboon and Dale Squires**, 2007. Overfishing in the Gulf of Thailand: Policy Challenges and Bioeconomic Analysis. Environment and Development Economics, Cambridge University Press, 12, 145-172.
- CMFRI**, 2007. Annual Report-2006-07. Central Marine Fisheries Research Institute, Kochi, pp.20-26.
- Fox, W. W. Jr.**, 1970. An Exponential Surplus-Yield Model for Optimizing Exploited Fish Populations. Transactions of the American Fisheries Society, 99, 80-88.
- Gordon, H. Scott**, 1954. The Economic Theory of a Common Property Resource. Journal of Political Economy, 62, 24-142.
- Mohan Joseph Modayil, R.Sathaidhas and G.Gopakumar**, 2006. Marine Farming-Country Analysis: India. Central Marine Fisheries Research Institute, Ministry of Agriculture, Government of India.
- Sathiadhas, R and R. Narayanakumar**, 2001. Environmental Economic Analysis of Inshore Fishery Resource Utilisation of Coastal Kerala. Final Report, EERC Working Paper Series: MES-3, CMFRI, Kochi.
- Schaefer, M.**, 1954. Some Aspects of the Dynamics of Populations Important to the Management of Commercial Marine Fisheries. *Inter-American Tropical Tuna Commission Bulletin*, 1(2), 27-56.
- Sonny Koeshendrajana and Oscar Cacho**, 2001. Management Options for the Inland Fisheries Resource in South Sumatra, Indonesia: A Bioeconomic Model. Working Paper Series in Agricultural and Resource Economics.