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Bioeconomic Analysis of Marine Fish Production in West Bengal

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Abstract
This paper presents the research findings of the study on the costal fisheries of Midnapore East, one of the costal districts of West Bengal by applying Surplus Production Model developed by Schaefer. We have estimated maximum sustainable yield (MSY), maximum economic yield (MEY) and open access yield (OAY). The Bioeconomic Model suggests the output corresponding to maximum sustainable yield is less than that of maximum economic yield, suggesting that allowing the fishermen at the point corresponding to optimum economic profit will violate the sustainability criteria. Open access yield (free access fishing) has been wasteful because it requires more effort and results in smaller catch than it would have been at MEY. So some regulatory mechanism in fishing effort is needed urgently to prevent over harvesting of stock.
Keywords*:* Bio economics, Fishery, Sustainability

1. Introduction:

India is the seventh largest producer of fish in the world and perhaps, second in inland fish production. Fisheries play an important role in the Indian Economy. Importance of the fisheries sectors to the Indian Economy is widely acknowledged. Its significance lies in three major areas: First of all, it is a source of animal protein for human consumption. It is expected that that by the years 2020 the fish eating population would be around 650 million even if the rate of increase were only 50% of the last decade. Secondly, it is a source of Employment. About 1.8 million fishermen draw their livelihood from fisheries, though they generally live on the verge of extreme poverty. Thirdly, it is a source of foreign exchange.

Despite the vast fishery resources, the production of fish in India is far from adequate. India produces 9% of total supply of fish in Asia. The importance of developing fishery resources lies in the fact that they can act as substitute to our land resources. However, we have not exploited our marine fisheries fully. The Indian Ocean Expedition has estimated that only 1% -8% of fish available along the Eastern and Western coast is being caught at present. If modern methods of catching are employed, it is possible to increase the fish catch by 10 times. This indeed would make a tremendous impact on raising the nutritional standard of people and on raising the standard of living of our poverty stricken fisherman, as also on our foreign exchange earnings.

From the very beginning of the plan period, planners are interested in the development of fisheries sector and the welfare of fishing community. However, for proper development and policy formulation some micro level study is needed. The studies on socio-economic condition of the fisherman are not large in number both in the Indian context as well as for West Bengal. These are Mathur (1978), Central Marine Fisheries Research Institute (CMFRI,1981), Jhinrgran (1983), George and Rao(1986), Shukla(1986), Nair(1986), Paniokkar and Rao (1986), Samal and Meher(2003), Patel (2003) in Indian Context and by Pantalu(1967), Saha(1970), Central Marine Fisheries Research Institute (1985), Neogi, Das and Chakraborty (1995) and Dhar(2004, 2005) in context of West Bengal.

For formalization of appropriate policies of fishery estimation of maximum economic yield (MEY) and open access yield (OAY) along with the estimation of maximum sustainable yield (MSY) are a prerequisite and also it is necessary to have a comparison between these three definitions of yield. Studies available regarding estimation of MEY, MSY, OAY are Waters J.R(1991),Eggert,Haken et.al(1999),Christensen,Steen et.al.(1993),Clarke et.al(1992).

In the Indian context Das, Neogi, Guha (2000)'s paper is related to Indian economy where they have computed maximum sustainable yield (MSY) for Digha, Sankarpur coastal region of West Bengal based on a bioeconomic model. They have not estimated maximum economic yield or open access yield. Apart from this fact the problem with their approach is that they have based their study on cross section primary data for the year 1992-'93. Since MSY can be better judged by looking at the historical time series data, Proper calculation of MSY need to be taken into account these figures. Also their study is not of recent one.

The present paper attempts to add the literature in this context. The purpose of this paper is to

- Estimate maximum sustainable yield (MSY), maximum economic yield (MEY) and open access yield (OAY) for coastal fisheries in West Bengal. To find out MSY apart from the data collected through primary survey for this region, the historical secondary data published by the Office of Assistant Director of Fisheries, Govt. of West Bengal is also incorporated.

- Since computation of MEY and OEY in turn requires cost and returns of fishing effort, the cost, returns, and efforts are calculated using the micro data based on primary survey for this region. On basis of the results of estimates some policy suggestions for development and welfare of fishery community are being suggested.

The plan of the present paper is as follows:

In section 2 we describe the methodology of the research. Section 3 is concerned with the description of calculation of data required for the analysis. Section 4 deals with results and discussions. Some concluding observations are made in section 5.

2. The relevant concepts and Methodology

As a first step, we represent the functional specification of the concepts of MSY, MEY in estimable form, which can be used for empirical analysis of the model.

- **Maximum sustainable yield (MSY):** We indicate the level of yield that can be harvested without affecting the stock of biomass. **The MSY** concept refers to a steady state because 'sustained' means "sustained forever" under biological conditions change. Harvesting offsets natural growth so that if harvesting equals natural growth then the biomass is stationary. This idea can be represented in terms of a formal model.

Biomass growth ($\frac{db}{dt} = \dot{b}$) is the algebraic difference between natural growth

(G (b) and the harvest (x): $\dot{b} = G(b) - x$

The steady state is defined as

$\dot{b} = G(b) - x = 0$

i.e. $x = G(b)$

The steady state requires that the natural growth (G (b)) should be harvested (x), nor more nor less so that b is neither declining ($\dot{b} < 0$) nor growing ($\dot{b} > 0$).

The maximum sustainable Yield is found as the solution to the problem

Max. x

(b)

S.T. $x = G(b)$

The choice is to be made from feasible stock levels of b. The solution is found by substituting the steady state constraints ($x = G(b)$) into the objective function.

For empirical purpose, Maximum Sustainable Yield (MSY) can be estimated by using Schaefer's surplus production model (1954).

The function can be written in terms of catch and effort and is as follows:

$$Y = \alpha E + \beta E^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Where Y = total yield, E = effort.

The maximum sustainable yield can be obtained from equation (i) by taking partial derivative of Y with respect to E and setting it equal to zero as shown below.

$$E_{MSY} = -\left(\frac{\alpha}{2\beta}\right) \quad \ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

The output at MSY can be obtained by substituting effort at MSY into equation (i) .

$$Y_{MSY} = -\left(\frac{\alpha^2}{4\beta}\right) \quad \ldots \text{(iii)}$$

- **Maximum economic yield (MEY)**: The **maximum economic yield** represents the level of output where marginal revenue of fishing becomes equal to marginal cost of fishing. Revenues (TR) are derived from the sale of harvested fish (x) at a fixed price ($\overline{P}$). Costs are incurred by employing fishing effort (a) at a fixed wage ($\overline{W}$). In short, the problem is to

$$\text{Max. } \Pi = TR - TC$$
$$= \overline{P}x - \overline{W}a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Let B be a stock specific parameter.

The greater the B, the greater the G (b) for any $b < \bar{b}$

$$G(b) = Bb(\bar{b} - b) \text{ .... (v)}$$

Where, $\bar{b}$ = Maximum sustainable stock / Minimum sustainable Stock is absence of fishing.

The relation (v) specifies a quadratic relation between the biomass and its growth.

$$G(b) = B(-b^2 + b\bar{b})$$

In a steady state, x=G (b), implying

$$x = B(-b^2 + b\bar{b}) \text{ .... (vi)}$$

The technology of harvesting is generally discussed with the harvested product (x) depending in a positive way on both the stock (b) and the flow of effort expended in making the harvest (a).

$$x = F(a, b) \text{ .... (vii)}$$

Particular functional form representing fishing technology is taken to be,

$$x = Aab. \text{ .... (viii)}$$

Output depends on multiplicative interaction of inputs. Technological efficiency is denoted by A. Bringing together the biology and the technology, the steady state is described by,

$$Aab = Bb(\bar{b} - b)$$

$$\text{Or,} \quad a = B/A(\bar{b} - b) \text{ .... (ix)}$$

Since a and b are uniquely related to each other by equation (vi) in steady states, it is a choice of convenience to Max. Π With respect to either 'a' or 'b'.

$$\text{Max. } \Pi = TR - TC$$

$$= \bar{P}x - \bar{W}a$$

$$\text{S.T.} \quad x = Bb(\bar{b} - b)$$

$$a = B/A(\bar{b} - b)$$

Profits are to be maximized subject to output and effort, which depend upon the biomass alone in the steady state. After making substitutions, the problem is to

$$\text{Max. } \Pi = (TR - TC)$$

$$= \bar{P}Bb(\bar{b} - b) - \bar{W}\frac{B}{A}(\bar{b} - b) \quad \text{(x)}$$

This is an unconstrained maximization problem that can be solved graphically as shown in **Fig.1.**

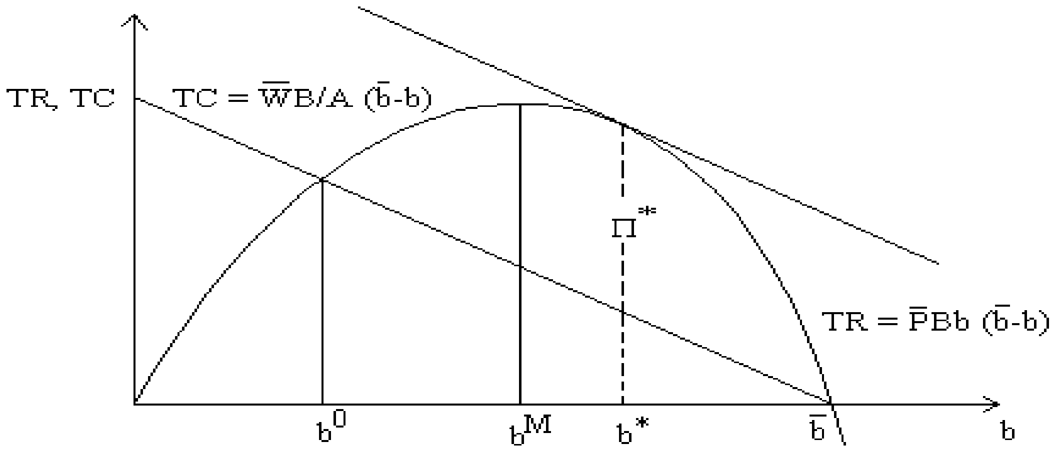

Figure1: The profit from fishing is maximum at b* where the harvest is less than MSY. It is economical to thicken the stock beyond MSY to reduce the cost of searching and catching.

Visual inspection reveals that Π -maximizing b is found where the slope of TR line equals to the slope of TC line. It is labeled b*. b* represents the maximum economic yield is the point where MR = MC. To find out the actual value of b*, let us rewrite the equation (x), which can be presented as

Max. Π = $\bar{P}B(-b^2 + b\bar{b}) - \bar{W}\frac{B}{A}(\bar{b} - b)$

The producer is to find the first derivative of profits (Π) with respect to fish stock (b). The slope Π(b) is zero at b^*. Proceeding,

$$\Pi' = \bar{p}B(-2b + \bar{b}) - \bar{W}\frac{B}{A}(0 - 1)$$

This can be set to zero and solving for $b = b^*$.

$$b^* = \frac{\bar{b}}{2} + \frac{1}{2}\frac{\bar{W}}{P}\frac{1}{A}$$

The maximum economic yield exceeds MSY owing to catching cost ($\bar{W}$ >0).

The amount of effort required to achieve Maximum Economic Yield can be obtained by setting the first order condition of profit maximization, MR=MC .This gives us the effort level required to achieve maximum economic yield.

$$E_{MEY} = \frac{[(\frac{\cos t}{price} - \alpha)]}{2\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(xi)}$$

For empirical purpose, Maximum economic yield is given by

$$Y_{MEY} = (\alpha E_{MEY} + \beta E^2_{MEY}) * \text{price} \ldots\ldots\ldots\ldots\ldots \text{(xii)}$$

- **Open access yield: The Open access yield** represents the level of output for which profit becomes zero (i.e. a situation where TR = TC). Open access yield is depicted by the point b^0 where the potential surplus has been dissipated. The open access yield b_0 is less than maximum economic yield b^*.

  Let us come to the specification of **open access yield** for empirical estimation. At the **open access point**, fishing cost equals fishing revenue so that

  $$E * \text{Cost} = (\alpha E + \beta E^2) * \text{Price} \quad \ldots\ldots\ldots\ldots\ldots \text{(xiii)}$$

  This equation simplifies to calculate the effort to attain Open access Yield

$$E_{OAY} = \frac{[(\frac{\cos t}{price} - \alpha)]}{\beta} \quad \ldots\ldots\ldots\ldots\ldots \text{(xiv)}$$

The output at Open access yield (Y_{OAY}) will be obtained by substituting equation (xiv) in equation (i).

3. The Data Source and Methodology

3.1 The Data source

The paper uses both primary and secondary data. The primary data are collected through a survey from different fish landing centers of Midnapore district of West Bengal in the year 2003-'04. The secondary data are collected on quantity, value of output, number of mechanized and non-mechanized boats compiled by the Dept. of Statistical Wing, Office of Assistant Director of Fisheries, Midnapore East, West Bengal. Both mechanized and non-mechanized boats are added to get the total figure of total number of boats. **Table 3.1** highlights the structure of cost, return and effort of various types of boats used in fishing activities.

Table 3.1Cost, Returns and Efforts for Trawler, Motor Boat and Country Boat

(I) Capital Cost	Trawler (in Rs.)	Motor Boat (MB)(in Rs.)	Country Boat (CB) (in Rs.)	Average for 3 types of boats
1. Cost of Boat	12,000,00	2,000,00	50,000	48,3333.33
2. Cost of engine	450,000	4,000,00	_	28,3333.33
3. Cost of net	50,000	1,000,00	70,000	73333.33
Total Cost	**17,000,00**	**7,000,00**	**120,000**	**84,0000**
(II) Fixed cost per year				
4. Depreciation @ 10% of boat	120,000	20,000	5,000	483333.33
5. Depreciation @ 10% of engine	45,000	40,000	_	28333.33
6. Depreciation @ 30% of net	5,000	10,000	7,000	7333.33
7. Interest @ 12% of capital cost	204,000	84,000	144,00	100800
8. Repairs& maintenance	5,000,00	57,000	42,000	199666.66
Total fixed cost	874,000	211,000	68400	384466.66
(III) **Operating cost per trip**				
9. Ice @ Rs.50 / Block	700	150	_	283.33
10. Disel @ Rs.4800/ Barrel (7 barrel/ trip for trawler, 24ltr. for MB, 1ltr. for CB)	34,000	430	23	11484.33
11. Other fuel (Wood/ gas)	554	18	7	193
12. Commission	2,000	_	_	_
13. Labour	10500	315	190	3668.33
14. Cost in rituals	16.67	1.45	1.60	6.57
(IV) Total operating cost/ trip	47770.67	914.45	221.60	16236.57
(V) Amount of fish harvested/ Trip	1188 Kg.	125 Kg.	61 Kg.	458 Kg.
(VI) Actual fishing effort	600	875	700	763
(VII) Total operating cost/ Kg./ Trip = $\dfrac{\text{Price/Kg}}{\text{Total Actual fishing effort}} = \dfrac{3.93+2.616+16.25}{7.5} = 3.0385$				3.0385
(VIII) Total operating cost/ Kg./ per unit effort = $\dfrac{\text{Total operating cost/ Trip/ Boat}}{\text{Total Actual Fishing Effort}} = \dfrac{2.9+1.5+16.1}{2.5*3} = 2.733$				2.733
(IX) Total revenue/ Trip	772000	42950	8300	274416.66

Source: Author's Own Calculation

3.2 Methodology:

In order to estimate MSY, MEY and OAY figures we need to calculate total effort, total operating cost per kg. per effort, aggregate price per kg. per effort and value of coefficients of α, β as depicted in the relation (i).

- **Calculation of total fishing effort:**

  The total fishing effort was estimated by assuming constant 2.5 hours of actual fishing based on preliminary survey of fishermen and expert opinion. As revealed through the survey that there exist broadly three types of technology for catching fishes, namely, country boat, motorboat and trawler. Data from the representatives of three alternative types of technologies is collected through a well designed questionnaire. The actual fishing effort is calculated by applying the formulae:

The actual fishing effort =

(Actual fishing hour/ day) * (number of trips/ day) * (days allotted for fishing in a month) * (number of months for fishing in a year) …………… (xv)

The actual fishing hours for three different types of boats are as follows:

For trawler, the results becomes

2.5 hour/ day * 3 trips * 10 days * 8 months = 600 hours

For non-mechanized boats

2.5 hour/ day * 2 trips * 20 days * 7 months = 700 hours

For mechanized boats

2.5 hour/ day * 2 trips * 25 days * 7 months = 875 hours

Average actual fishing effort (in hours) weighted by number of different types of boats

$$= \frac{(600*16) + (700*21) + (875*35)}{(16+21+35)}$$

$$= 763$$

In order to get total effort, number of boats available in a year as supplied by historical data is multiplied by the average fishing effort.

- **Calculation of operating cost per kg., per effort and Aggregate price per kg. per effort:**

Cost per kg. is calculated as the ratio of total operating cost per trip per boat to quantity harvested per trip per boat. In this way, the cost per kg. becomes Rs. 2.9, Rs. 1.5 & Rs. 16.1 for motor boat, country boat, and trawler respectively. In order to obtain cost per kg. / effort the cost calculated separately for three alternatives have been divided by the actual fishing effort spent by three alternatives that is kept constant throughout our analysis. Finally the aggregate cost is being calculated. In a similar fashion, price per trip is calculated as the ratio of revenue earned per trip to quantity harvested per trip for three kinds of alternatives.

The cost aspects of fishing activity are measured by cost of fishing per kg. Per unit effort. For this purpose, only variable components are considered. This is consistent with the assumptions made in Hannesson (1993) who has mentioned that it will be appropriate to consider the short term cost only. The components of variable cost are ice, disel, fuel used, commission, labour payments, and costing rituals. These data are collected through the questionnaire. It is revealed from the survey that cost component is different for three different types of boats. The operating cost for three alternatives is Rs. 47770.67 for trawler Rs. 914.45 for motor boat, and Rs. 221.60 for country boat. The quantity harvested per trip is 125 kg. , 61 kg., 118 kg. for motor boat, country boat and trawler respectively.

Aggregate price per kg. Per effort is calculated in the same way as same for aggregate cost. Finally ratio of cost to price has been made. Lastly, actual fishing efforts have been calculated taking average of three efforts for three boats. In order to get total effort, number of boats available in a year as supplied by historical data is multiplied by the average fishing effort.

- **Estimation of α, β using the relation (i):**

The catch effort relationship is estimated by fitting a regression equation with total yield as dependent variable and effort as independent variable. The results of estimation of the coefficients are presented in **Table 3.2.** The model is well fitted and the coefficients are statistically significant.

Table 3.2 Estimated values of E_{MSY}, E_{MEY}, E_{OAY} and Y_{MSY}, Y_{MEY}, Y_{OAY}

Estimated Parameters	Calculated Value
1. a	1.466523606
2. b	- $0.80930*10^{-7}$
3. E_{MSY}	9060444.86
4. E_{MEY}	3502822.2
5. E_{OAY}	7005644.4
6. Y_{MSY} (in M.T.)	6637681.90
7. Y_{MEY} (in M.T.)	94719002.86
8. Y_{OAY} (in M.T.)	6326096.92

Source: Author's Own Calculation

4. Results of Estimation:

The results of estimation indicates $Y_{MEY}>Y_{MSY}>Y_{OAY}$ and $E_{MSY}>E_{OAY}>E_{MEY}$. These are consistent with theoretical concepts. Maximum economic yield is also not desirable from the point of view of sustainability because maximum economic yield is greater than maximum sustainable yield and hence if the fishermen are allowed to go by profit motive it will violate the condition of sustainability. Definitely this requires some regulatory mechanism or reduction in fishing effort. Again, the open access fishing is wasteful because although effort required for open access yield is greater than the effort corresponding to maximum economic yield, still the output corresponding to open access fishing is less than the output corresponding to maximum economic effort.

However, reduction in effort through regulatory mechanism means unemployment of fishermen specially when there is no alternative employment outside the fishing sectors. In view of social and equity considerations people need to be accommodated within the fishing sector although their employment within that sector may cause harm to sustainability. This in turn requires creation of alternative employment opportunities to compensate the unemployed fishing people. Further, diversification of skills could be done to make them more suitable for outside non-fishing sector's employment.

5. Conclusions and policy implication:

A biological reference point should be selected in fishery management as a measurement of optimal level. This measurement aims at stabilizing the stock at the biomass, which provides the MSY, which can be harvested under average environmental conditions. From this viewpoint, efforts level beyond MSY will cause a reduction in stock population and thereby constitute biological over fishing. An economic reference point can be selected as an objective of fishery management in order to take into account economic factors such as value of output and cost of production. The results of study indicate that the optimum economic yield though best target, cannot be maintained unless there are some regularly measures. This requires creation of alternative employment opportunity outside the fishery sector. This in turn places greater emphasis on poverty alleviation programmes

and decentralized planning to take into account the remedial measure for the welfare of fishermen and the fishery sector. Alternative methods of compensating the people to relive them from the impact of regulation would mean very high administrative and transaction cost which the developing countries generally can't support.
Developed countries have been trying with several alternatives for managing the fishing resources. In general these alternatives are classified into two categories: (a) Limitations on fishing effort and (b) catch limitations. Important measures are licensing, limited entry, taxes, quotas etc.

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