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Estimation of Maximum Sustainable Yield of Fish for the Two PFCS: A Case Study

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Abstract— *Fisheries sector creates a significant impact on the economy of the country as a whole. The aim of rural development without fisheries development will forever remain unrealised. The importance of the sustainable growth of fish for countries which seek environmentally sound and sustainable strategies for growth and development cannot be ignored. The estimation of such growth is essential for India, where fishery is considered as one of the most important natural resources. From the perspective of food security, the resource is very important as fish is a major protein source for the country's population constituting about 60% of total animal protein consumed.*

Keywords— Fisheries sector, fisheries development, sustainable growth and development

I. INTRODUCTION

The study mainly focuses on the inland fisheries whose features are completely different from marine fisheries. The activities in inland fisheries are performed in more controlled environment and this open up opportunities for employment generation. This type of fishing activity is most suited in the monsoon belt. West Bengal has an annual average precipitation of 1000mm. It has extensive water resources in the form of hill, rivers, canals, wetlands, ponds, tanks, etc. With the sustained propaganda of the Department on the importance of 'Conservation of Wet Land' and application of Inland Fisheries Act, a sense of awareness in preserving the 'Wet Land' has been observed amongst the general section of the people and 'Panchayat Level Functionaries'.

In the study, two Primary Fishermen Cooperative Societies in Burdwan district have been taken for analysis - Naliapur Dhibar Samabay Samity and Sakhai Dhibar Samabay Samiti. The Burdwan district maintains a significant balance between agriculture and industries. The district is enriched with rivers like Ganges, Ajay, Damodar and many other small rivulets. Burdwan Zilla Parishad through Panchayats has taken up massive program of water area development under JRY scheme. These water bodies are gradually being brought under Pisciculture and in a number of cases by forming new Fishermen's Co-operative Societies. Co-operative can play an important role in economic upliftment of poor fishermen as well as proper utilisation of vast water bodies. However, there are certain difficulties which arise in practice for making actual estimation of growth. It is sometimes said that cooperatives are not aware about the sustainability of fish catch as they seek to maximise yield from fish culture. Hence, for a resource dependent country like India, the estimation of sustainable growth of fish poses a major challenge. In the study, we have estimated the maximum sustainable yield of fish for the two concerned Primary Fishermen Cooperative Society.

II. REVIEW OF THE LITERATURE

The literature on the economics of inland fisheries is not very substantial. Some of them consider only the performance of the cooperative societies engaged in fisheries activities and some on the problems and management of the cooperatives, individually or collectively. Again there exists some literature which is based on the estimation of total production of inland fish and also on the area available for both culture and capture of inland fisheries. In a brief survey, it is not possible to consider all these aspects. Here, we would consider only some major areas of research related to inland fisheries.

A study had been done by the Directorate of the National Sample Survey in Odissa in the year 1958 to evolve suitable technique for estimation of fish production. This survey discussed issues like various resources of inland fisheries and their relative importance, availability of sampling frame, fishing practices and availability of suitable agency for field work. The main objective of the survey was to develop suitable technique for the estimation of (i) number and area of ponds and swamps and (ii) total catch of fish for them. In 1960-61, Indian Statistical Institute made an attempt to develop some suitable sampling techniques for inland fish production in West Bengal. This study dealt with the problems faced by a sampler on this aspect. The study also suggested some broad indications of the character of variability in different stages of sampling. In the year 1978-79, a pilot survey was undertaken jointly by Central Inland Fisheries Research Institute (CIFRI) in 24 Parganas district of West Bengal with a view to evolve a suitable methodology for estimation of inland fisheries resources and total catch of fish for them. The study showed that 94% of the water units were perennial,67% having water depth ranging from (1-3) meter and only 60% of the ponds were subject to multipurpose uses including fish culture, while 33% were exclusively for fish culture, the remaining 3.3% are not used for fish culture. The fish catch was estimated to be 1360kg/ha with 16% standard error. Speaking pond wise the catch was 246 kg/pond with 25.5% standard error. During early 1984, a Central Sector Scheme on Development of Inland Fisheries Statistics was launched in eight statesviz, West Bengal, Uttar Pradesh, Assam, Bihar, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and Maharashtra. The scheme consisted of two phases-the focus of the first phase was on developing suitable

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methodology for estimation of resources under ponds and tanks and the focus of the second phase was on developing sampling methodology for estimation of fish catch from resources. Sample was also taken for the estimation of inland fish production from selected fresh water riverine stretches of the Ganges, the Narmada and the Godavari. Singh and Dhar Choudhury (1986) in their study make an attempt to examine the governance structure, decision making environment, operations, management and performance of a Primary Fishermen's Co-operative, the Captain Bhery Fishermen's Co-operative Society in West Bengal. This study suggests that Co-operatives serve as an ideal model for vast common pool ponds, tanks, and reservoirs in West Bengal. Marothia (1996) emphasises that the method of selecting beneficiaries and privatisation of fishing rights in Community ponds has given rise to social conflict between lease holders and other villagers. It has affected productivity of fish farming and has created inequalities in the management of community ponds.

III. METHODOLOGY

The method which has been developed for measuring the sustainable growth of fish is taken from a particular form of Schaefer (1954) model. In the model, the maximum sustainable yield (MSY, hereafter) is obtained by setting

$$\dot{X} = F(X) - Y = 0 \quad (1)$$

Where Y is the harvest rate (or catch of fish). F(X) is the gross absolute rate of growth of fish used and X is the net rate of growth of fish. From the literature on Economics of Fishery we find that harvest rate or fish catch is expressed as a function of an aggregate input (which we refer to as effort level) and the stock of fish.

That is,

Y(t) = H[E(t),X(t)]

Where, E(t) = effort at time 't'; X(t) = stock of fish at time 't'.

Following Schaefer (1954) we find that the catch effort ratio is proportional to stock of fish, and we can write-

$$Y = qEX \quad (2)$$

Where, q is the constant of proportionality. For simplicity we assume that its value is unity as has been done by several authors.

Therefore equation (2) can be rewritten as Y= EX. This equation can be interpreted as a Cobb - Douglas production function with increasing returns to scale.

Now equation (1) can be rewritten as

$$rX(1-\frac{X}{K}) = EX \quad (3)$$

Where $F(X) = rX(1-\frac{X}{K}) = EX$

The above relation follows from the logistic model. Here 'r' is the intrinsic growth rate of fish and K is the environmental carrying capacity. By solving equation (3), we get $X= K(1-\frac{E}{r})$

Therefore equation (2) can be reorganised as

$Y = EK(1-\frac{E}{r})$

or $\frac{Y}{E} = a-bE$

Where a= K and $b = \frac{K}{r}$

Or $Y = aE-bE^2$

Now, Y is maximised when $\frac{dY}{dE} = 0$ or E=a/2b

Thus, $Y_{max} = a(\frac{a}{2b}) - b(\frac{a}{2b})^2 = \frac{a^2}{4b}$

The value of 'a' and 'b', can be determined from the value of K and r. Pearl and Reed method has been used for estimating 'K' and 'r' as data on the yield rate or catch are not available for the two concerned PFCS of our study. Available data on fish stock for consecutive six years, help us to find the values of 'K' and 'r' following the Pearl and Reed method. Here, data of fish stocks are available in money term. For the study, the stock of fish has been considered in real term by deflating the values of the stock of fish by the average price of fish for the corresponding year.

Calculation of MSY for the two PFCS

The maximum sustainable yield of fish for the two concerned PFCS have been calculated in the following way-

Calculation for MSY for Naliapur Dhibar Samabay Samiti

By Pearl and Reed method, we have divided the entire time period into three equal parts in order to choose three selected points (t,Z_t). These points are denoted by $(i, Z_i);(i+n, Z_{i+n})$ and $(i+2n, Z_{i+2n})$ or through a change of origin of 't' by $(0,Z_0).(n,Z_n),(2n,Z_{2n})$. The data set is shown by table given below

TABLE 1: Stock of fish in real term for Naliapur Dhibar Samabay Samiti

Year	Stock of fish in Rs.	Average price of fish in Rs.	Stock of fish in real term
94-95	3000	32.6	92.02
95-96	1000	37.2	26.88
96-97	2000	41.8	47.85
97-98	3000	46.4	64.65
98-99	3000	51	58.82
99-2000	5000	55.6	89.93

Source: Records of the PFCS

From the above table, we have considered the values of $Z_0,Z_n.Z_{2n}$ as 26.88, 64.65 and 89.93 respectively. Now,

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$$d_1 = \frac{1}{Z_0} - \frac{1}{Z_n} = \frac{1}{26.88} - \frac{1}{64.65} = 0.022$$
$$\ln d_1 = -3.817$$

$$d_2 = \frac{1}{Z_n} - \frac{1}{Z_{2n}} = \frac{1}{64.65} - \frac{1}{89.93} = 0.0039$$
$$\ln d_2 == -5.55$$
$$\therefore r = \frac{1}{n}(\ln d_1 - \ln d_2) = \frac{1}{2}(-3.817 + 5.55) = 0.87 \text{ and}$$
$$\frac{1}{K} = \frac{1}{Z_0} - \frac{d_1^2}{d_1 - d_2} = 0.01$$
$$K = 100$$

Under the assumption q=1, we find a=K=100 and $b = \frac{K}{r} = 114.94$

Hence $Y_{max} = \frac{a^2}{4b}$ = 21.75

Calculation for MSY for Sakhai Dhibar Samabay Samiti

We first consider the table related to the stock of fish

TABLE 2: Stock of fish in real term for Sakhai Dhibar Samabay Samiti

Year	Stock of fish in Rs.	Average price of fish in Rs.	Stock of fish in real term
94-95	1500	27.08	55.39
95-96	1500	30.83	48..65
96-97	2000	34.58	57.83
97-98	3000	38.00	78.95
98-99	4000	41.78	95.74
99-2000	5000	45.5	109.89

Source: Records of the PFCS

From the above table, we have considered the values of Z_0, Z_n and Z_{2n} as 48.65, 78.95 and 109.89 respectively. Now,

$$d_1 = \frac{1}{Z_0} - \frac{1}{Z_n} = \frac{1}{48.65} - \frac{1}{78.95} = 0.00789$$
$$\ln d_1 = -4.842$$

$$d_2 = \frac{1}{Z_n} - \frac{1}{Z_{2n}} = \frac{1}{78.95} - \frac{1}{109.89} = 0.00357$$
$$\ln d_2 == -5.55$$

$$\therefore r = \frac{1}{n}(\ln d_1 - \ln d_2) = 0.396$$

$$and \frac{1}{K} = \frac{1}{Z_0} - \frac{d_1^2}{d_1 - d_2}$$

Putting the respective values, we get the values of K as 162.74

Again, under the assumption q=1, we find a=K=162.74,

$$b = \frac{K}{r} = 410.96$$

Hence $Y_{max} = \frac{a^2}{4b}$ =16.11

Logistic Curve Estimation for the two PFCS

Following Pearl and Reed method, the logistic curve is generally fitted as-

$$Z = \frac{K}{1 + e^{r(\beta - t)}} where \beta = \frac{1}{r}\ln(\frac{K}{Z_0} - 1)$$

$$t = Year - Year('95 - '96)$$

The year '95-'96 is taken as the initial period and hence its value is considered as zero. Z is the estimated stock of fish. 'β' is the value of 't' for which Z is K/2.

Estimated stock of fish for Naliapur Dhibar Samabay Samity using the logistic equation

From the above analysis we obtained the values of r,K, and Z_0. So we can easily estimate β from the equation

$$\beta = \frac{1}{r}\ln(\frac{K}{Z_0} - 1)$$

By putting the values of r= 0.87. K= 100 and Z_0= 26. 88, we get β = 1.15. Hence the estimated logistic equation is

$$Z = \frac{100}{1 + e^{0.87(1.15 - t)}}$$

The values of the estimated stock of fish in different years is shown in the table below-

TABLE 3: Calculation of the estimated stock of fish for Naliapur Dhibar Samabay Samity

Year	$Z = \frac{K}{1 + e^{r(\beta - t)}}$
95-96	26.88
96-97	46.74
97-98	67.69
98-99	83.33
99-2000	92.27

The figures for estimated stock of fish are thus close to the actual stock as shown in Table 1 for Naliapur PFCS.

Estimated stock of fish for Sakhai Dhibar Samabay Samity using the logistic equation

Dr. Chameli Mandal, "Estimation of Maximum Sustainable Yield of Fish for the Two PFCS: A Case Study," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 9, pp. 83-86, 2022.

From the above analysis we obtained the values of r,k, and Z0. So we can easily estimate β from the equation $\beta = \frac{1}{r}\ln(\frac{K}{Z_0} - 1)$

By putting the values of r= 0.396. K= 162.74 and Z_0= 48.65, we get β = 2.225. Hence the estimated logistic equation is $Z = \frac{100}{1+e^{0.396(2.225-t)}}$

The values of the estimated stock of fish in different years is shown in the table below-

TABLE 4: Calculation of the estimated stock of fish for Sakhai Dhibar Samabay Samity

Year	$Z = \frac{K}{1+e^{r(\beta-t)}}$
95-96	48.65
96-97	63.281
97-98	79.34
98-99	95.68
99-2000	111.07

The figures for estimated stock of fish are thus close to the actual stock as shown in Table 2 for Sakhai PFCS.

IV. CONCLUDING REMARKS

From the analysis, it is to be noted that though the MSY figure for Naliapur PFCS is higher than that of Sakhai PFCS. However, the figures for stock of fish for the former are lower than that of the latter. This contradicts results clearly indicates overfishing. The chance of overfishing is also high in case of Sakhai PFCS as the figure for MSY is very low compared to its stock. As most of the fishermen engaged in the two PFCS are poor the chance of overfishing is not unlikely. However, the PFCS should be more conscious about the availability of fish for future generations. The unconsciousness arises because they get spawn from government at a cheaper rate rather than the cost required for breeding purposes. This is one major reason due to which the PFCS are not interested to maintain stock. From the estimated results, we have seen that the figure is not a good reflector of better performance of the cooperatives. Government must pay attention for the upliftment of these cooperatives. It has to be ensured that the training given to the cooperative must not go waste. The members should be skilled technically.

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Dr. Chameli Mandal, "Estimation of Maximum Sustainable Yield of Fish for the Two PFCS: A Case Study," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 9, pp. 83-86, 2022.