Measuring the economic benefits from the inland fishery management in South Sumatra, Indonesia : A bioeconomic approach[1]

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Abstract

The issue of deriving benefits from the fishery resource on a sustainable basis exists in most developing countries. This tends to create a major problem confronting both biologists and economists in managing the fishery. In response to this issue, this paper explains one possible method to measure the economic benefits from the inland fishery management. To model the fishery, a bioeconomic approach is applied, and the potential applicability of the model in measuring economic benefits is discussed.

Surplus production models developed by Schaefer (1954) and Fox (1970) are used. The biological model for the inland fishery starts with the assumption of zero rate of change in biomass all year and of an exact index of relative abundance. Economic models are developed by describing costs-returns of the fishery. Based on the incorporated biological and economic models, the current fishery management policy is evaluated and possible economic benefits are assessed.

Keywords : resource economics, bioeconomic and fishery management

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Introduction

The performance of the fishery sector in South Sumatra in 1992 was relatively small (1.5 % of GDP) as compared to that of the agricultural sector (17.7 % of GDP). However, the fishery is considered an important sector for the region because of its significant contribution as a source of income, employment and animal protein in the diet of many households, both in rural areas and urban centres. The contribution of fisheries to GDP remained relatively constant during the period 1988-1992. This may indicate that the continuing growing number of fishermen and fishing units entering the fisheries was not accompanied by increases in fishery resource productivity.

According to present practices, inland fishery resources in South Sumatra may have assigned property rights. Some resources are managed by the community based on the traditional fishing rights. However, problems similar to those of an open-access fishery commonly occur. Under such management, each individual can maximise his or her individual benefits from the resource. The tendency is for the fishing community to deplete the resource. Consequently, the fishing community faces lower and unevenly distributed income.

The open-access fishery will lead to over-fishing from both biological and economic points of view. Biological over-fishing occurs when the growth of the stock is lower than the rate of harvest. Economic over-fishing occurs because fishermen are attracted by expected high rates of return from harvesting the fish stock. This tends to attract more investment long after the rate of return from the fishery becomes negative. This phenomenon was clearly explained by Gordon (1954).

In response to the above issue, this paper explains one possible method of measuring economic benefits from management of the inland fishery. In order to understand the complexity of the inland fishery in South Sumatra, a theoretical framework for analysis in the study was developed to solve current conflicts of interest in defining objectives of fishery management between biologists and economists.

Inland Fishery of South Sumatra, Indonesia

The inland fishery of South Sumatra, which could well represent inland fisheries of Indonesia in general, may be exemplified by the extensive floodplains of the Musi river and its major tributaries. The catchment area of the river basin comprises about 60,000 km^2 and has a cumulative length of over 2,000 km. The fishery resource consists of the main river itself, swamp areas (*rawang*), and small lakes (*lebung*). The river and small lakes contain water throughout the year, while the swamp areas tend to lose their water during the dry season (July to September). Fishing is traditionally considered an important occupation for many rural people living in the area. Fishing patterns in the area are significantly affected by fluctuations of water levels. The fishing seasons can be distinguished as high water (December to February), receding water (March to May), low water (June to August) and rising water (September to November). The types of fishing gear operated will depend on both area and season.

There are three classifications of fishermen in the fishing community, namely : occasional, part-time and full-time. The occasional fishermen harvest fish for their own consumptions. The time they spend fishing is relatively short and they use a comparatively unproductive fishing unit. Part-time and full-time fishermen use more productive fishing units. However, they differ in the sense that part-time fishermen tend to use various fishing gear rather than concentrating on a single item of gear. Full-time fishermen operate their fishing as a main occupation, whereas part-time fishermen usually operate their fishing as a consequence of lack of work in their main occupation. This is very typical for fishing communities in South Sumatra.

There are three types of inland fishery resources (rivers, swamps and lakes) and many different types of fishing units are used by fishermen; the South Sumatra Fishery Service divides those units into 10 categories. Over one hundred species of fish are currently being harvested from the fishery. However, official records of the Fishery Service indicate that all harvested fish are combined into only 17 species. This may create difficulty in modelling the biology of the fishery according to specific species.

During the period 1985-1993, fishery production in a major fishing has shown a tendency to decrease. On the other hand, demand for fish from that fishery has significantly increased. The fishery is likely to face a problem of over-fishing, and the local authority seems to be unable to maintain productivity and sustainability of the resource. This implies that the important task of maintaining the flow of benefits derived from the fishery may not be fulfilled.

A Theoretical Framework

The inland capture fishery system in South Sumatra, Indonesia, may be represented as in Figure 1. The underlying structure of the simplified system model comprises four submodels, i.e., biological submodel, (social) economic submodel, bioeconomic submodel and management submodel. The biological submodel describes the population dynamics of the fisheries. The economic submodel describes the prices, revenues and costs from harvesting the fish stock using a composite production factor called fishing effort. The bioeconomic submodel describes the combination of biological and economic models applied to the fishery. The management submodel describes the policies and regulations which might be imposed by the authority.

Biological submodel

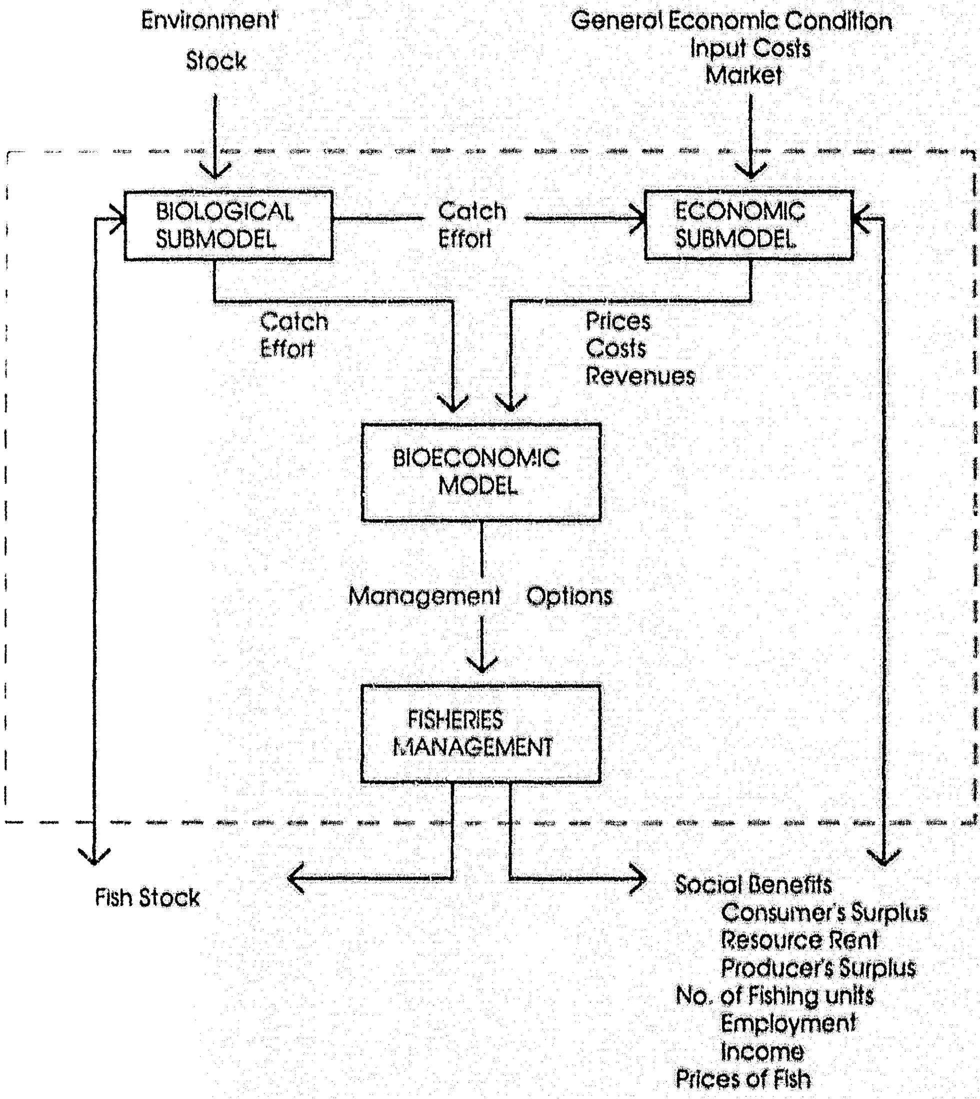
Biological dynamics of the fishery can be simplified by developing a model which may be approached holistically or analytically (Sparre and Venema, 1992). In practice, however, an ideal model representing the dynamic nature of the fishery seems not to exist. Caddy and Gulland (1983) reviewed various fishery models and confirmed this statement. Any selected biological model usually holds certain parameters fixed in describing the behaviour of the stock. It seems impossible to develop a single model which copes with all varieties of internal and external behavioural characteristics of the stock. This is because real biological systems will always change over time and vary according to available resources and the size of the fish stock (Hilborn and Walters, 1992). Therefore, in most cases, the decision on the type of model to be used is limited by the quality and quantity of available data.

Modelling of the biological aspects of a fishery can be approached as in Figure 2. This approach assumes that the fishery dynamics depend on the biomass of the stock. These models, called biomass dynamics models, can be extended in four major directions on the basis of incorporating parameters on : (1) age structure of the fish; (2) fishing dynamics in terms of fleets, processing and marketing; (3) multiple species and their ecosystem interaction; and (4) spatial representation of stock structure. Amongst all of the possible extended models, the explicit age structure of the fish is the parameter most commonly added to the basic models (Beverton and Holt 1956, 1957; Ricker 1954, 1975; Walters 1969). In contrast, fishing dynamics in terms of fleets, processing and marketing have not been widely applied. A different perspective for classifying the basic biological model for fishery dynamics was given by Cushing (1983). This author outlined three types of biological models, namely: biomass dynamics models (Russell, 1931; Graham, 1935; and Schaefer, 1954, 1957), discrete time stock growth models (Ricker, 1954) and age structure models (Beverton and Holt, 1956, 1957). Most possible extended models are developed on the basis of these basic models, which are widely applied in the analysis of the bioeconomics of the fishery (Hannesson, 1993).

In the context of an inland tropical fishery biological data such as fish growth, mortality, age class and stock recruitment, required to set up a detailed model, are not available. In this situation, simple biological models, such as surplus production models, may be more useful to analyse the fishery dynamics (Sparre and Venema, 1992; Tai, 1992)

Catch in the inland tropical fishery encompasses many species and their age structures. It is very difficult, if not impossible, to obtain data by species and corresponding age structures. Several important parameters, such as intrinsic growth rate and natural mortality of the specific species, are generally not known. From the perspective of the fishery management authority, regulations imposed on the tropical fishery are not addressed for specific species of the fish. The entire catch data often treat biomass as a dynamic pool rather than by single specific species. Hilborn (1979) and Ludwig and Walters (1989) pointed out that, in the case of the absence of important growth parameters, and if there is little contrast between fishing effort and stock abundance, it may be appropriate to employ surplus production models. Thus, in this study biomass dynamic models, also called 'Surplus Production Models', or 'Schaefer Models' (Hilborn and Walters, 1992) are used. As an alternative, an exponential Surplus-Yield model developed by Fox (1970) is also applied. Those models require a relatively simple set of data (catch and fishing effort).

Figure 1 Simplification of System of Inland Capture Fishery Management



Note : Adapted, in part, from Figure 4.1 of Tai (1992)

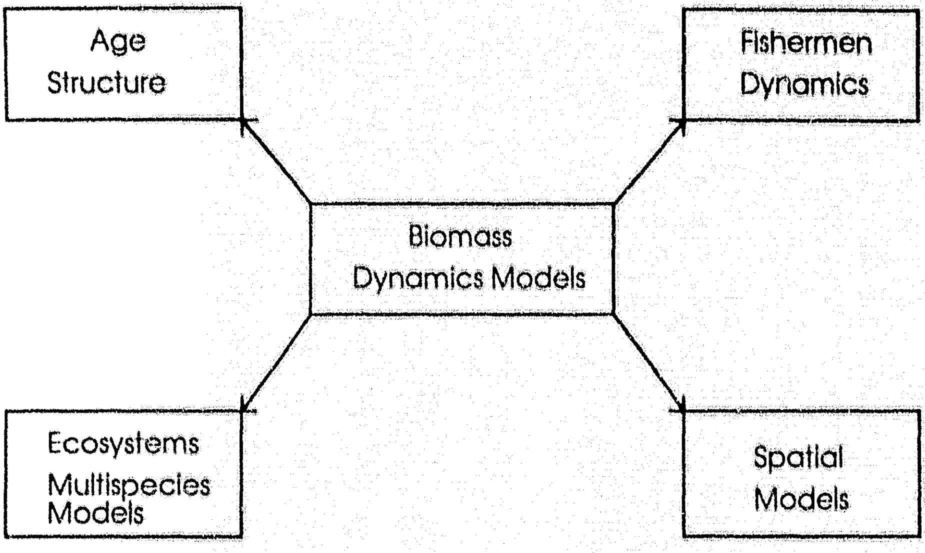


Figure 2 Basic biological model of fisheries dynamics and four directions of possible elaboration (from Hilborn and Walters, 1992, p. 70)

Economic submodel

The economic submodel describes the revenues and costs of fishing operations. A simple economic submodel of the fishery was introduced by Gordon (1954), where the total revenue and total cost of the fishery are expressed in terms of fishing effort. The amount of fishing effort is assumed to have no effect on factor prices[2]. With this assumption, cost per unit of fishing effort (c) is constant. Hence, the relationship between total cost and fishing effort is linear. This means that the average and marginal costs of fishing effort are the same.

Price of fish can be considered either as fixed or variable in response to the conditions of supply of and demand for the product in the market. Most likely, the former is commonly applied to formulate an economic model of the fishery.

Bioeconomic submodel

The bioeconomic submodel describes the combination of the biological and economic models as discussed in the previous section. The basic traditional bioeconomic model of Gordon and Schaefer covers only biological and economic factors in the fishery. With this model, it is implicitly assumed that the market prices of the fishing effort reflect the true cost to society. This means that fishermen use all their available resources in fishing rather than in other possible occupations. Whenever the social aspect is taken into consideration, e.g., unemployment , the fishing wages do not reflect the true opportunity cost of labour anymore. Under such an unemployment condition, fishermen have no alternative to fishing. Society makes little sacrifice by keeping them in the fishery. As a result, their opportunity cost is close to zero. Inclusion of this kind of aspect in the traditional bioeconomic model of Gordon and Schaefer will provide an extension of the basic model. This has been formulated by Panayotou (1982). With this assumption, the cost of labour will not be included in the variable cost of fishing effort.

Management submodel

The management submodel describes the policies and regulations which might be imposed by the authority in managing the fishery. The management submodel in this case may be viewed as a means of achieving certain social goals or objectives through the use of appropriate regulatory instruments to avoid over-fishing. Such instruments would provide an institutional and regulatory framework within which the desired level of fishing effort can be

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[2] Detailed explanation for this assumption can be found in Gordon (1953).

obtained. In this case, a biological reference point is first selected in fishery management as a measurement of the optimum level. This measurement aims at stabilising the stock at that biomass which provides the maximum sustainable yield (MSY) which is available under average environmental conditions. From this viewpoint, effort levels exceeding MSY will cause reduction in the stock population and thereby constitute biological over-fishing. On the other hand, effort levels below MSY will cause biological under-fishing. The economic objective of fishery management takes into account price of the output and cost per unit fishing effort. Optimal resource use in terms of economic criteria is more conservative than the biological optimal. Therefore, the possible management options will be assessed from the viewpoint of economic efficiency, that is, the capability of the selected regulations to ensure the greatest net contribution to the economy. There are several alternatives for managing a fishery, which can be classified into two categories, fishing effort and catch limitations. Other classifications or combinations of these two categories can also be introduced.

The Models

As is discussed in the previous sections, surplus production models of Schaefer (1954) and Fox (1970) are used in this study. The Schaefer and Fox models may be simply written respectively as:

(1) $$\frac{dX}{dt} = rX - \frac{r}{K}X^2 - qXE$$

(2) $$\frac{dX}{dt} = rX\ln\left(\frac{K}{X}\right) - qXE$$

where K is carrying capacity, a parameter corresponding to the unfished equilibrium stock size, r is intrinsic growth rate of the fish, X is fish stock, E is fishing effort and q is catchability coefficient. The continuous form of the Schaefer model in equation (1) assumes that the growth rate to fish stock relationship is logistic. The Fox model on the other hand, assumes a 'Gompertz growth' fish stock relationship (Yoshimoto and Clarke, 1993). This model exhibits an asymmetrical stock production curve. The model, in turn, describes an exponential relationship between fishing effort and stock size. Those are similar in the sense that they show a decline in catch per unit of effort (CPUE) with increasing fishing effort. Both stock production curves imply that at a lower level of effort each additional unit of fishing effort will add a positive increment to the sustainable catch. However, additional catch declines as fishing effort increases further. Beyond the maximum point of the sustainable yield curve, an additional unit of fishing effort will decrease the sustainable catch. The two models differ in terms of their definition of the relationship between catch per unit effort and fishing effort. The former model assumes a declining linear relationship whereas the latter assumes a declining logarithmic relationship as shown respectively in the following equations:

(3) $$\frac{Y}{E} = a - bE$$

(4) $$\mathrm{Ln}\left(\frac{Y}{E}\right) = a - bE$$

Following the Gordon (1954) formulation, total cost and total revenue of the fishery are expressed in terms of fishing effort. If fishing effort has no effect on factor price, cost per unit of fishing effort is constant. Hence, the relationship between total cost and fishing effort would be a linear form. This means that the average and marginal costs of fishing effort are the same. The total cost of fishing (TC), marginal cost (MC) and average cost (AC) can be written as :

(5) $TC = c\,E$

(6) $AC = MC = c$

Then, total revenue (TR), marginal revenue (MR) and average revenue (AR) functions are:

(7) $$TR = pY = p\left(aE - bE^2\right)$$

(8) $MR = p\,(a - 2b\,E)$

(9) $AR = p\,(a - b\,E)$

This model can be used to find the level of effort which results in MSY and maximum economic yield (MEY) in the long run.

Concerning the objectives of fishery management, biologists often aim at achieving MSY, while economists aim for MEY. Instead of either MSY or MEY, optimal resource use can also be viewed in terms of maximising social benefits. The analytical framework to measure this criterion is described below.

Following the fixed price model, the long-run relationship between total revenue and effort, and total cost and effort, is illustrated in Figure 3. The maximum sustainable yield, E2, is the point about which most biologists are concerned in determining the level of effort to be allowed. Fishery economists prefer operate at the point of MEY (E1) rather than the MSY (E2). The maximum economic yield generates the highest profits on the sustainable yield curve without threatening the fishery. This means that the net benefit to society from the fishery is maximised when marginal revenue equals marginal cost. Resource rents are maximised at MEY. Expanding the level of fishing effort up to E1 adds to profit. Beyond this point profits decrease as fishing costs exceed revenues.

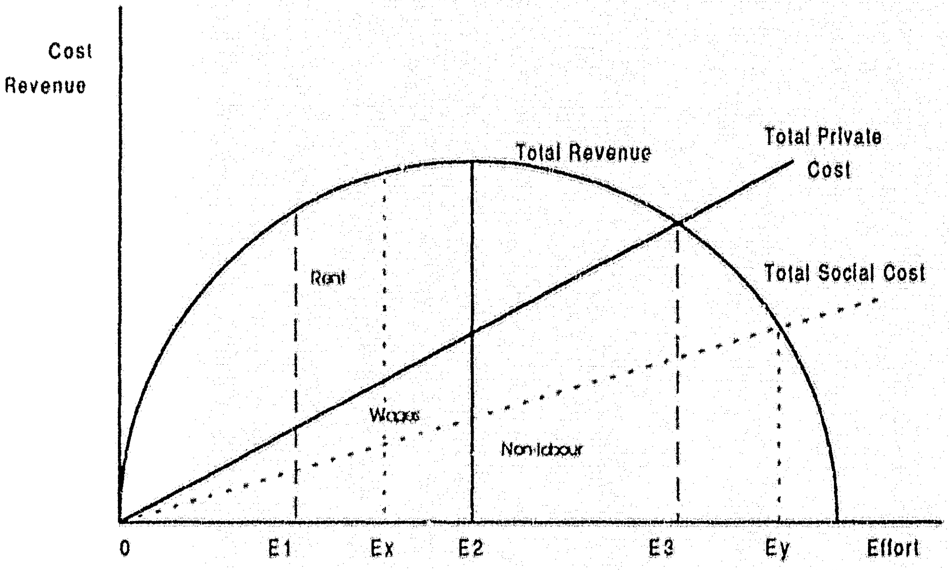

Figure 3. Fixed Price Model of a Fishery Indicating Five Possible Equilibria, i.e., MEY (E1), MScY (Ex), MSY (E2), ZRR (E3) and ZScY (Ey)

Under an open-access or unregulated fishery, individual fishermen 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. At the level of effort which generates zero resource rent (ZRR), the equilibrium is called a bionomic equilibrium (E3). At this point, there is no economic rent from the fishery resource. The reduction of effort from E3 to E1 would generate substantial profits to some of the fishermen. At the same time, the size of the fish stock would increase.

Both the objectives of MSY and MEY are essentially considered single-objective options. The MSY provides maximum quantity of the fish which could be theoretically exploited from a given stock. The MEY determines the quantity of the fish which would privately produce the highest profit in the long term. Optimum sustainable yield (which would consider multiple objectives of the fishery) may be defined as maximum social yield (MScY).

The MScY may balance multiple-objective fishery management (Charles, 1988). This optimum level ensures the quantity of fish which would maximise the social value of factors such as income distribution and employment. Maximum social yield can be defined by taking the social aspect into consideration in determining fishery management. Crutchfield (1979) and Sinclair (1983) pointed out some previous studies on the socioeconomic factors in fishery management. The results indicated that most studies have focused on the choice of fishery policy in accordance with the case where fishermen had low opportunity costs. In the small-scale fishery, for example, if other job opportunities are not available for poor fishermen, at least they can earn a low but subsistence income. Referring to the problems of the small-scale fishery, Panayotou (1982) noted that a variety of socioeconomic factors could be incorporated into the basic static bioeconomic model.

MScY includes the severe scarcity of alternative employment opportunities. This optimum level can be determined by dividing the cost of fishing into two components, private labour costs (wages) and other capital and operating costs. Given high levels of unemployment in the economy, the opportunity cost of labour in the fishery is close to zero. This means that net social benefits will comprise the sum of surplus profits generated by the fishery and wages as payments to fishermen.

The bioeconomic model implicitly assumes that the market price of fishing inputs reflects the true sacrifices which society makes in using these inputs for fishing rather than in other occupations. Under this assumption, attaining the level of MEY from the fishery may require a large reduction in effort. This implies that a large number of fishermen may be forced out of fishing.

However, because of unemployment problems, fishermen may have no other alternative. Their opportunity cost is already close to zero. Society is making little or no sacrifice in keeping them in the fishery. Under these conditions, the cost of labour as well as labour paid in calculating the cost per unit effort is zero. Therefore, the new total cost (TC) will be lower than the previous one. This makes the level of effort in MScY (Ex) higher than MEY (E1) as shown in Figure 3

With respect to various fishery objectives, Figure 3 shows the existence of five possible equilibria. The first three equilibria, MEY (E1), MSY (E2) and open access equilibrium (E3) have been discussed earlier. Another equilibrium in this figure is MScY (Ex) which incorporates the opportunity cost of fishermen into the bioeconomic model. The other equilibrium is optimum in terms of the employment (Ey), that is the point where social yield is zero

Empirical model

The Schaefer and Fox productions model as shown in equation (1) and (2) indicate that total catch at time t is a parabolic function of fishing effort at time t. Consequently, the estimation of those function requre a non-linear technique However, this problem can be solved by assuming constant catch per unit of effort in each respective year. Thus, the Schaefer and Fox models become linear as shown in equations (3) and (4), respectively, and rewrite as:

(10) $CPUE = a + bE$

(11) $Ln(CPUE) = a + bE$

These models can be estimated using ordinary leeast square technique.

The Data

In order to derive a production function for the fishery, time series data (1979 - 1994) of the inland capture fishery in South Sumatra, Indonesia, were used The data consist of three different types of inland fishery resources, namely : swamps, rivers and lakes. The average historical data on the total of unit, trip and production associated with fishing gears is presented in Appendix 1 They show that the most important fishing gear is portable traps, followed by gillnets, hooks and The riverine and swamp fisheries contributed significantly to the total inland capture fishery in South Sumatra. Lake fishery contributed a relatively small proportion.

The various species were aggregated and treated as a 'single species'. Fishing effort was measured in terms of number of fishing trips Standard fishing effort was calculated by using the procedure outlined in Appendix 2. The bamboo fishing trap (*bubu*) was selected as the standard fishing unit because this type of fishing unit is widely used by fishermen The calculated catch, standard fishing effort and catch per unit effort are presented in Table 1.

The average costs of fishing effort of the *bubu* fishing traps in riverine and swamp fisheries in South Sumatra are Rp. 2,973.57 and Rp 2,631.48 (Table 2). The average price of freshwater fish in the market is Rp.1,335. Average prices at the producers level are Rp. 1,215.00 (riverine fishery) and Rp. 1,125.00 (swamp fishery).

Results and Discussion

The production function models for the inland fishery in South Sumatra with respect to different types of resources were estimated by linear regression (Table 3) These results consist of four possible models, i.e., Schaefer and Fox models with (1) or without (2) a time trend. All the proposed models are based on the assumption that there are two different types of inland fishery resources in South Sumatra, namely, riverine and swamp fisheries.

Table 1 Average calculated catch, standard fishing effort and catch per unit effort of inland fishery in South Sumatra, Indonesia, 1979-1994

Year	Riverine			Swamp[2]		
	Catch (ton)	Effort[1] (trip)	CPUE (kg/trip)	Catch (ton)	Effort[1] (trip)	CPUE (kg/trip)
1979	19,226.90	7,968,722	2.41	8,886.80	4,640,975	1.91
1980	20,245.20	9,767,450	2.07	11,793.50	4,787,623	2.46
1981	24,934.50	12,848,280	1.94	12,380.80	7,573,612	1.63
1982	22,800.90	10,658,653	2.14	13,185.70	6,597,145	2.00
1983	22,753.10	9,180,946	2.48	13,581.90	6,842,005	1.99
1984	22,691.50	8,364,851	2.71	13,515.30	6,731,566	2.01
1985	23,344.60	7,057,137	3.31	15,074.50	4,557,570	3.31
1986	23,922.20	5,933,176	4.03	15,983.60	4,802,313	3.33
1987	24,180.40	4,878,222	4.96	16,429.60	5,858,133	2.80
1988	24,489.90	4,988,222	4.91	15,606.20	6,830,128	2.28
1989	23,896.20	5,233,669	4.57	14,764.90	4,786,324	3.09
1990	22,832.80	8,753,780	2.61	15,127.40	5,735,803	2.64
1991	23,186.70	5,804,116	3.99	16,489.10	4,926,004	3.35
1992	21,569.00	4,082,591	5.28	18,094.10	2,993,435	6.04
1993	22,072.00	2,618,949	8.43	19,409.70	2,153,145	9.01
1994	22,248.80	4,017,995	5.54	19,730.40	3,348,192	5.89
Average	22,774.67	7,009,797	3.84	15,003.34	5,197,686	3.36

Source : Based on data from Fisheries Service of South Sumatra (various years)

Note 1) Effort is a standard fishing effort in terms of *bubu* fishing trap

2) Swamp data consists of swamp and lake fishery data

Table 2. Calculated costs of fishing effort by bamboo fishing traps (*bubu*) in different types of resources in South Sumatra

Type of costs	Type of resource	
	Riverine (rupiah)	Swamp (rupiah)
Fixed Costs		
Depreciation of canoe/boat	26.20 (0.88)	103.71 (3.94)
Depreciation of gear	1,184.21 (39.82)	936.00 (35.57)
Lease of resource	131.58 (4.42)	266.67 (10.13)
Variable Costs		
Operating costs (bait and food)	631.58 (21.24)	325.00 (12.35)
Labour	1,000.00 (33.64)	1,000.00 (38.01)
Total costs	2,973.57 (100.00)	2,631.48 (100.00)

Source Cross-sectional survey 1994

Note : Values in parentheses are percentages

Table 3. Regression results of selected model in each type of fishery resource in South Sumatra

Description	Models			
	Schaefer-1	Schaefer-2	Fox-1	Fox-2
R-square (adjusted)	0.7991	0.7520	0.9184	0.8516
Effort[1]	-0.45870E-06 (-5.207)	-0.62926E-06 (-8.923)	-0.11261E-06 (-8.193)	-0.15999E-06 (-11.98)
DESWLK[2]	-0.27758E-06 (-4.825)	-0.33711E-06 (-5.679)	-0.75715E-07 (-8.436)	-0.92251E-07 (-8.208)
TM	0.12500 (2.796)		0.34722E-01 (4.971)	
Constant	6.0567 (6.510)	8.3149 (16.27)	1.7622 (12.14)	2.3895 (24.70)

Note

Values in parentheses are t-values

1) Standard fishing effort in terms of bamboo fishing trap (*bubu*)

2) Dummy variable for slope of fishing effort representing swamp fishery

The surplus production model implicitly assumes that there is no change in the environment and that the food supply is limited so that the unexploited fish stock increases toward the maximum carrying capacity of the environment. In the inland capture fishery system, environmental change affects the food supply and hence the maximum fish stock changes. Fishing mortality is proportional to effort, which measures the number of trips per year over the period 1979 to 1994. This means that the catchability coefficient (q) is a function of time. In the surplus production model, the catchability coefficient is assumed to be constant. Therefore, Sparre and Vanema (1992) suggested the use of short-series data instead of longer data. In contrast, for better estimation results, longer series of data are desirable to preserve as many degrees of freedom as possible. An alternative value for 'q' is taken into account by introducing a time trend as shown by the variable TM.

All the estimated coefficients of the proposed models are highly significant, and conform to their expected signs. The judgement of 'best fit' for each proposed model, based on the value of adjusted R-square indicate that Fox models provide better performance than Schaefer models.

In both models, inclusion of a time trend improved statistical performance. However, further analysis will consider only the first models of Schaefer and Fox. This is because the surplus production models implies that technological change does not occur.

Even though the estimated results indicated good performance by the models, it has to be noted that the assumption of zero rate of change in biomass all year and of exact index of relative abundance in that a surplus production model may not be biologically correct (Hilborn and Walters, 1992). To overcome such a problem, various approaches to estimating model parameters have been suggested by Polacheck *et al.* (1993) and Laloe (1995), such as effort-averaging methods, process-error estimators and observation-error estimators. With regard to the nature of the biological model of the fishery, Berck and John (1991) suggested an estimation procedure which combined the methods of maximum likelihood and the Kalman filter. However, this study will not discuss all the suggested methods.

Equilibrium points for the Fox and Schaefer models and actual capture averages are presented in Tables 4 and 5, respectively. Both models indicate that the inland capture fishery in South Sumatra during the period of study faced a problem of over-fishing from both the biological and economic perspectives. This is demonstrated by the fact that actual average effort is beyond both MEY and MSY levels.

With respect to the Fox model (Table 4) the MEY and MSY levels of effort of the riverine fishery are respectively 53 and 89 per cent of actual average effort during the period of study. Those figures imply that average level of effort must be reduced by 47 per cent in order to reach MEY and by 11 per cent to reach MSY. However, the average level of effort is 25 per cent below the level of open access (BE).

Table 4 Calculated effort, catch, total cost, revenue and profits based on Fox model in different fishery resources

Description	Effort (trip)	Catch (kg)	Total costs (million rp.)	Revenue (million rp.)	Profits (million rp.)
Riverine					
MSY	6,250,391	25,081,837	18,585.97	30,474.43	11,888.46
MEY	3,711,069	22,355,805	11,035.12	27,162.30	16,127.18
MScY	4,375,890	23,700,858	13,012.01	28,796.54	15,784.53
BE	9,341,089	22,861,219	27,776.38	27,776.38	0.00
BES	11,903,245	19,334,884	23,491.89	23,491.88	0.00
Actual average	7,009,797	22,744,670	20,844.12	27,634.77	6,790.65
Swamp					
MSY	3,964,463	15,908,766	10,432.40	17,897.36	7,464.96
MEY	2,405,076	14,302,334	6,328.91	16,090.13	9,761.22
MScY	2,875,783	15,186,922	7,567.57	17,085.29	9,517.72
BE	6,104,228	14,278,360	16,063.15	16,063.15	0.00
BES	7,999,475	11,600,874	13,050.98	13,050.98	0.00
Actual average	5,197,686	15,003,340	13,677.61	16,878.76	3,201.15

Source Calculated from Table 3

Table 5 Calculated effort, catch, total cost, revenue and profit based on Schaefer model in different fishery resources.

Description	Effort (trip)	Catch (kg)	Total costs (million rp.)	Revenue (million rp.)	Profits (million rp.)
Riverine					
MSY	6,606,887	27,467,804	19,646.04	33,373.38	13,727.34
MEY	4,662,236	25,088,151	13,863.49	30,482.10	16,618.62
MScY	5,316,215	26,419,560	15,808.14	32,099.77	16,291.63
BF	9,324,472	22,820,552	27,726.97	27,726.97	0.00
BES	10,632,429	17,270,653	20,983.84	20,983.84	0.00
Average	7,009,797	22,744,670	20,844.12	27,634.77	6,790.65
Swamp					
MSY	4,302,131	17,885,893	11,320.97	20,121.63	8,800.66
MEY	3,035,854	16,336,362	7,988.79	18,378.41	10,389.62
MScY	3,461,698	17,203,320	9,109.39	19,353.74	10,244.35
BE	6,183,767	14,464,408	16,272.46	16,272.46	0.00
BES	7,103,589	10,301,657	11,589.36	11,589.36	0.00
Average	5,197,686	15,003,340	13,677.61	16,878.76	3,201.15

Source : Calculated from Table 3

In terms of catch, the average historical values and the optimal solution values are not significantly different. The actual average figure is 9 per cent below MSY, but it is 2 per cent above MEY. An expansion of effort to the level of open access will add only 0.5 per cent to the catch.

Financially, the possible profits which can be reached with the optimal solution at MEY and MSY are Rp. 16,127.18 and Rp. 11,888.46 millions, respectively. However, reduction in effort implies that fishermen have to be forced out of fishing. This kind of decision is not popular or commonly applied to small-scale fishery. Appropriate policy actions in small-scale fisheries may be to set the objective of MScY in which a potential reduction in effort is less than MEY.

The case of the swamp fishery is similar to that of the riverine fishery. The average historical effort must be reduced by 54 per cent in order to reach MEY and by 24 per cent to reach MSY. The reduction in effort to reach MSY will increase the expected sustainable catch by 10 per cent but further reduction in effort to reach MEY will decrease the sustainable catch by 2 per cent. Financially, applying the optimal solution significantly increases possible profits derived from the fishery.

The optimal solutions from the Schaefer and Fox models are similar. However, the Schaefer model allows a relatively higher level of effort than does the Fox model. In the riverine fishery the Schaefer model permits respectively 1 per cent, 25 per cent and 20 per cent higher level of effort at MSY, MEY and MScY than with the Fox model. This implies that the reduction in effort necessary to reach the optimal solution is higher with the Fox model than with the Schaefer model. However, the Fox model produces an open access level of effort higher than the Schaefer model does. The Schaefer model produces higher profit estimates from the riverine fishery than the Fox model.

Total accumulated profits derived from the riverine fishery by applying the Schaefer model are 13,727.34, 16,618.62 and 16,291.63 million rupiah MSY, MEY and MScY, respectively. In the swamp fishery, the possible profits are Rp. 8,800.66 (MSY), Rp. 10,389.62 (MEY) and Rp. 10,244.35 (MScY) millions rupiah.

These results suggest that management options should be introduced in the inland capture fishery in both types of resources in South Sumatra, to avoid degradation of the resources and potential losses of resource rent.

Conclusions

Economic benefits from the management of the inland capture fishery can be measured by applying the surplus production model. Analysis of recent data on inland capture fishery in South Sumatra indicate that the fishery has been biologically and economically over-fished. This conclusion is supported by the fact that average fishing effort is above the sustainable potential of the resource and the potential profits.

The evidence of over-fishing suggests the need for further study to extend the analysis and determine the type and level of management options which may be appropriately applied in the South Sumatra inland fishery.

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Appendix 1. Average annual data of unit, trip and production by fishing gear operated in inland fishery in South Sumatra, Indonesia, 1979 - 1994.

Fishing Gear	Riverine			Swamp			Lake			Total		
	Unit	Trip	Production (ton)	Unit	Trip	Production (ton)	Unit	Trip	Production (ton)	Unit	Trip	Produc (ton
Drift gillnet	1,936 (100.00)	308,472 (100.00)	3,004.59 (100.00)							1,936 (100.00)	308,472 (100.00)	3,00 (10
Fixed gillnet	1,342 (32.27)	171,431 (26.44)	1,271.73 (29.41)	2,515 (60 47)	429,311 (66.22)	2,748.98 (63.57)	302 (7.26)	47,550 (7.33)	303.78 (7.02)	4,159 (100.00)	648,292 (100.00)	4,32 (10
Anco	680 (64.52)	69,674 (59.12)	324.06 (59.73)	252 (23.91)	35,671 (30 27)	176.18 (32.48)	122 (11.57)	12,510 (10.61)	42.26 (7.79)	1,054 (100.00)	117,855 (100.00)	54 (10
Serok	489 (49.75)	83,737 (68.98)	379.19 (68.40)	494 (50.25)	37,663 (31.02)	175.21 (31.60)				983 (100.00)	121,400 (100.00)	55 (10
Rawai	655 (66.91)	69,431 (67.30)	217.06 (56.51)	324 (33.09)	33,739 (32.70)	167.06 (43.49)				979 (100.00)	103,170 (100.00)	38 (10
Pancing	2,961 (53.97)	438,991 (50.44)	2,364.20 (51.21)	2,210 (40.28)	395,121 (45.39)	2,088.67 (45.24)	315 (5.74)	36,296 (4.17)	163.68 (3.55)	5,486 (100.00)	870,408 (100.00)	4,61 (10
Sero trap	1,435 (53.89)	237,816 (61.80)	5,162.66 (64.52)	1,151 (43.22)	136,030 (35.35)	2,599.67 (32.49)	77 (2.89)	10,997 (2.86)	239.53 (2.99)	2,663 (100.00)	384,843 (100.00)	8,00 (10
Jermal	776 (100.00)	149,278 (100.00)	2,549.27 (100.00)							776 (100.00)	149,278 (100.00)	2,54 (10
Babu trap	2,931 (46.67)	446,464 (47.75)	2,598.03 (49.36)	3,112 (49.55)	45 349 (4 59)	2,395.33 (45.51)	237 (3.77)	34,249 (3.66)	270.18 (5.13)	6,280 (100.00)	935,062 (100.00)	5,26 (10
Others	5,820 (57 76)	774,417 (59.27)	5,381.86 (59.70)	3,760 (37.32)	467,786 (35.80)	3,205.9 (35.56)	496 (4.92)	64,347 (4.92)	426.84 (4.73)	10,076 (100.00)	1,306,550 (100.00)	9,01 (10

Note : Values in parentheses denote per cent of total inland fishery

Source Annual Fisheries Statistics of South Sumatra (various years)

Appendix 2. Procedure for standardising fishing effort

Suppose we have different types of 1, 2, 3... N fishing units The total catches of each fishing unit are catch-1, catch-2, catch-3 ... catch-N. The corresponding efforts are effort-1, effort-2, effort-3... effort-N. The CPUE-i represents the catch per unit of effort of fishing gear-i.

Let fishing unit-1 be chosen as the standard fishing unit in the inland fishery, then the total effort can be calculated by the following procedure.

$$\text{Effort-t1} = \frac{\text{CPUE}_t}{\text{CPUE}_1} \text{ (Effort-1)}, \qquad t = 2, 3, \ldots N.$$

$$\text{Total Effort} = \text{Effort-1} + \sum \text{Effort-t1}$$

The total catch is calculated by summing up total fish caught by the standard fishing unit and other fishing units.

$$\text{Total Catch} = \text{Catch (standard)} + \sum \text{catch-t1}$$

The catch per unit effort of standard fishing is calculated as follows,

$$\text{CPUE} = \frac{\text{Total Catch}}{\text{Total Effort}}$$