Borneo Review 12 (1), June 2001

SUSTAINABLE INCOME CONTRIBUTIONS OF FISHERY RESOURCES IN SABAH: A NATURAL RESOURCE ACCOUNTING APPROACH*

Tai Shzee Yew and *Kusairi Mohd. Noh*

This paper attempts to value the contributions of fishery resources to the income of the state of Sabah using the natural resource accounting approach. Changes in values of fishery resources can occur between successive years as well as between current and optimal levels of catch. A negative change in value indicates depreciation of the fishery resources while a positive change constitutes appreciation in the value of the fishery resources. These changes need to be accounted for in the computation of the indicators of income to reflect the sustainability of the income for Sabah. The results show that on the whole the fishery resources in Sabah depreciate in eight years between 1980 and 1993. For individual species group, depreciations occur in nine years for the pelagics and molluscs, eight years for the demersals and seven years for the crustaceans. In terms of bioeconomic optimal analyses, optimal depreciations occur for all the species groups in Sabah for almost all years from 1980 to 1993. The results also show that the correlations between the levels of fishing effort and depreciations are negative for each species group. Similarly, an inverse relationship exists between changes in the levels of fishing effort and optimal depreciations for each species group. These results imply that current levels of fishing effort in Sabah are too high. Thus policies aimed at curtailing fishing effort should be pursued. These policies can provide improvement in potentially higher capital values of the fishery resources and the earning potentials of the fishing enterprise in Sabah.

---

* The financial support provided by the Malaysian Government through the Intensification of Research in Priority Areas (IRPA) Programme is gratefully acknowledged.

I. INTRODUCTION

The state of Sabah, located at the north-eastern coast of the island of Borneo, is endowed with rich natural resources such as forestry, fisheries, petroleum, natural gas, and agriculture. These resources played crucial roles in the economic growth of the state. From 1978 to 1997, the percentage contribution of natural resources to the state's overall income growth ranged from about 46 to 66 percent (Department of Statistics Sabah, various years). Natural resources have been, and will continue to be, important to the growth of the Sabah economy. However, their relative contributions to the economic growth of the state have been declining. This phenomenon is almost similar to the experiences in other resource-rich economies where the "resource booms" economic growth is transient in nature. These economies expand rapidly when resources are available for exploitation, but they contract once these resources are exhausted (Ward, 1982; Stauffer, 1986; Repetto, *et al.* 1989; Vincent, 1997).

The non-sustainability of economic growth for resource-dependent economies such as that of Sabah may be due to the deficiencies inherent in the conventional measures of economic growth and welfare such as the Gross Domestic Product (GDP), or Gross National Product (GNP). The asymmetric treatment of natural resources (viewed as natural capital) and man-made capital in the computation of national product by the conventional system of national accounts has prompted the development of the so-called "green accounting". The main objective of natural resource accounting is to account for the depreciation of natural capital just as depreciation of man-made capital is deducted from the value of gross national product to obtain the net national product.

In addition, the natural resource accounts should also provide information required for optimal management of natural resources of an economy. The omission of the natural capitals from the conventional system of national accounts provides inaccurate signals to policy makers to overexploit and even deplete the natural resource base to achieve rapid economic growth rate. This may result in illusory gains in income in the short run but permanent losses to national wealth in the long run. As a consequence, natural resource accounting was developed in the late 80s with the interest in sustainable economic development (Atkinson *et al.* 1997).

The marine fishery resource can be considered a renewable natural asset capable of growth over time. However, with overexploitation of most fishery stocks throughout the world, over time this natural asset will likely to depreciate in values, leading to a reduction in the national or regional wealth. Hence this paper attempts to estimate the contributions of the marine fishery resources to the economic growth of the state of Sabah.

The Sabah marine fishery sector is dominated by the inshore traditional subsector. Driftnet and other traditional gears were the major gear groups operated by about 40 and 38 percent of the fishing vessels respectively in Sabah from 1979 to 1994 (Department of Fisheries Sabah, various years). On the other hand, commercial gears such as trawls and purse seines contributed only about 21 percent to the total number of vessels in Sabah during the same period. In terms of total marine landings of more than 160 thousand metric tons in Sabah in 1994, the traditional gears contribute the most in percentage term (40 percent), followed by trawls (27 percent), drift net (19 percent) and purse seine (13 percent). In terms of species group, the crustaceans, demersals and pelagics are of equal importance (30 percent each) in the Sabah fishery. Molluscs make up about 9 percent of total landings.

This paper is organized as follows. The methodology to value the changes in the fishery stock of Sabah will be presented in the next section. This approach is similar to the one used in the studies by Tai, *et al.* (1996) and Tai, Kusairi and Nik Mustapha (2000). The estimation results will be presented in the third section and in the final section, some conclusions are drawn.

II. METHODOLOGY

Two main methods have been developed for valuing the depreciation of natural resource stocks: (1) the present value of future rents (or net revenues) associated with the resource; and (2) the net price or rent per unit of the resource multiplied by the changes in the resource stocks (Crowards, 1996; El-Serafy, 1989; Repetto, *et al.* 1989; Landefeld and Hines, 1985). The latter approach is unsuitable for use in the fishery because it is a unique resource in that the physical quantity of the stock is not as easily determined as for other resources such as forest timber. Fish is found either deep in the ocean or it is freely moving over a wide area without regard to national boundaries. These characteristics often limit the possibility of physically counting the fish stock. In addition, market values for transactions in resource stock are not available. Furthermore the net price approach assumes that actual use is optimum which may not be true for the exploitation of fishery resources in Sabah. Hence, the present value approach is followed here.

Actual Depreciation

The value of any asset is the present value of the expected stream of benefits to be derived from the asset. The central focus of this approach in valuing the fishery resources is the concept of fishery rent. Fishery rent can be defined as the return that can be earned from the fish stock. This fishery rent can be represented by the equation below:

$$\pi_t = p_t H_t - c_t E_t \qquad (1)$$

where π_t denotes the rent, p_t the price of fish, H_t the sustainable catch attributed to a given level of fishing effort E_t, c_t the unit cost of fishing effort and subscript t represents the time period. If a constant level of fishing effort Et is exerted onto the fish stock, and if we assume constant price of fish and unit cost of effort, the present value of the sustainable fishery rent, V_t, can be written as;

$$V_t = \pi_t / \delta \tag{2}$$

where δ is the constant social discount rate.

In practice, fishing effort is not likely to remain constant from one period to the next. The change in V_t will then represent the value of a net change in the resource stock;

$$(V_t - V_{t-1}) = (\pi_t - \pi_{t-1}) / \delta \tag{3}$$

where $V_t = V(H_t, p_t, E_t, c_t, \delta)$ and $V_{t-1} = V(H_{t-1}, p_{t-1}, E_{t-1}, c_{t-1}, \delta)$.

Notice that the change in V_t can also be influenced by changes in prices of fish and fishing inputs. In order to remove these price effects it has been suggested (Solorzano *et al.*, 1991) that the current year's resource value should first be recomputed using previous year's prices. The price effects can be represented as:

$$\text{Price effect} = V(H_t, p_{t-1}, E_t, c_{t-1}, \delta) - V(H_t, p_t, E_t, c_t, \delta) \tag{4}$$

where H_t, p_t, E_t and c_t are as previously defined. Notice the subscript (t – 1) for the price variables (P and c) in the first term on the right-hand-side of the equation.

The actual depreciation is then the difference between current year's resource value recomputed using previous year's output and input prices and actual previous year's resource value. Since the same set of prices has been used in both periods, the difference reflects the actual change in resource value attributed to the change in stock, uninfluenced by price changes. This is equal to the difference between the values computed by equations (3) and (4).

Optimal Depreciation

The depreciation value of the fishery resource outlined above depends on the actual catch, effort and revenue. However, many fisheries throughout the world are not exploited at the optimal level. Since overexploitation decreases the productive capacity of the fishery resource, the difference between the current (actual) and the optimal rates of exploitation of the fishery resource constitutes revenue loss or income foregone from non-optimal exploitation (Devarajan and Weiner, 1990). From the policy perspective, the difference in the resource values between the two rates of harvest will provide a signal to policy makers to make the necessary policy adjustments (Hartwick, 1990). Following Clark and Munro (1975), the equation for intertemporal optimal exploitation of a fishery resource using Pontryagin's Maximum Principle is as follows:

$$\delta = F'(X_t) - \{[c'(X_t)\, F(X_t)] \,/\, [p - c(X_t)]\} \qquad (5)$$

where $F(X_t)$ is the net natural growth of fish stock; $c(X_t)$ is the fishing cost function in terms of stock; $F'(X_t)$ and $c'(X_t)$ are, respectively, the first deritive of $F(X_t)$ and $c(X_t)$ functions; and p, c and δ are as previously defined. The solution (X^*) to the above equation can then be used to compute the optimal rate of catch and effort. The optimal fishery rent is then the product of the price of fish and the optimal catch less the costs of the optimal level of effort.

Sustainable Catch

As mentioned earlier, it is impossible to physically count the fish stock in the ocean. Hence the stock and the sustainable catch from it have to be estimated in fishery resource accounting studies. Fishing is basically the application of fishing effort to a naturally occurring fish stock. The basic element of the fish stock is a cohort, fish born (hatched) on the same date. The number of fish in the cohort is thus decreasing over time due to natural mortality, and when exploited, fishing mortality. Each fish that survives, however, is increasing in weight over time. In the initial phase total biomass must be increasing as the effects of individual growth exceeds that of mortality. Since each species has its maximum individual weight, due to the decreasing number of fish in the cohort over time, the time path of total weight (biomass) for each cohort must eventually decline. There are basically two approaches to the modeling of fish biomass (Hilborn and Walters 1992, Gulland 1983, Schaefer 1957). Analytical models describe the dynamics of the stock in terms of number, and therefore the age of fish, individual fish growth and mortality. Production (or biomass) models describe the stock dynamics in terms of total biomass, which is the aggregation of weight over all individuals. The approach taken here is that of the biomass models.

In the biomass model, the time path of biomass (X_t) is normally assumed to follow the logistic equation;

$$X_t = K \,/\, \{1 - [1 - (K \,/\, X_0)]e^{-rt}\} \qquad (6)$$

where r is the intrinsic growth rate of the stock and K is the maximum carrying capacity of the environment, i.e. maximum X.

Notice that when the stock is not exploited (i.e. no fishing) the biological equilibrium of the biomass is K. If the stock is below this equilibrium, rate of growth is positive as the effects of individual growth exceeds that of mortality (more vigorous growth with ample food, and less mortality due to diseases and predation). As biomass increases, the effects of mortality overtake that of growth. The rate of growth begins to decline and approaches zero as the maximum carrying capacity is realized. This relationship between growth and biomass is depicted by the following equation:

$$dX_t/dt = rX_t\,[1 - (X_t / K)] \qquad (7)$$

Fishing Effort

The fishery biomass is also affected by the intensity of fishing (or effective effort), measured by biologists as the proportion of fish population surviving the fishing. In practice the fishing effort in the harvesting sector is usually measured by the number of boats, the power of the engines, the number of fishing days, etc., each having different impacts on the fish stock. Hence there is a need to aggregate these various measures of effort (or nominal effort) and then convert this aggregated effort into effective effort. In effort standardization, the relative fishing power of various categories of gear and vessel are first estimated by comparing the catch per unit of each type of vessel and gear against the catch per unit of a standard vessel and gear. The relative fishing power is then used to convert the number of vessels in each category into standardized vessel units which represent the standardized effort. Once the effort has been standardized, the catch function can be represented as;

$$H_t = qE_t^{\alpha}X_t^{\beta} \qquad (8)$$

In equation (8) q is the catchability coefficient which relates the nominal effort unit to the biological intensity of fishing and E is the standardized effort. It is usually assumed that α and β have unitary values. This relationship between effort and harvest is clearly a short-run relationship, as biomass is exogenous in the equation. Catch is sustainable only if it equals the biomass growth rate. Hence, by equating equations (7) and (8), solving for X and substituting it back into equation (8) yields the sustainable (long-run) catch equation:

$$H_{EQ} = q\,E_t\,[K - (qK / r)E_t] \qquad (9)$$

This is sometimes written as

$$H_t / E_t = U_t = qK - (q^2K / r)\,E_t \qquad (10)$$

where U is the catch per unit effort (CPUE). Various alternative forms of this long run relationship have been examined in the literature. The Fox model (1970) uses the Gompertz instead of the logistic curve and the corresponding equations are:

$$dX_t / dt = rX_t \ln(K / X_t) \quad (7a)$$

$$H_t = qE_t K e^{-qEt/r} \quad (9a)$$

$$U_t = qKe^{-qEt/r} \quad (10a)$$

Schnute (1977) modifies the basic Schaefer (logistic) model and derived his corresponding equation;

$$\ln(U_{t+1} / U_t) = r - q[(E_{t+1} + E_t) / 2] - (r / qK)[(U_{t+1} + U_t) / 2] \quad (10b)$$

Clarke, Yoshimoto and Pooley (1992) modify the Fox (Gompertz) model to derive:

$$\ln(U_{t+1}) = [2r/(2+r)]\ln(qK) + [(2-r) / (2+r)]\ln U_t - [q/(2+r)](E_t + E_{t+1}) \quad (10c)$$

All these forms are estimated in this study.

Data

The Department of Fisheries Sabah publishes the Annual Fisheries Statistics (AFS). Data on number of vessels, landings by gear and by individual species, and prices of fish are obtained from the AFS. Landings by individual species (more than 70 species) have to be aggregated by the species groups used in this study: demersal, pelagic, crustaceans, and molluscs. The individual species prices have to be averaged by species group. Only retail prices are available by species. Ex-vessel prices are estimated as percentages of prices at the nearest market level. The Japan International Cooperation Agency (1991) estimated that the producer shares of retail fish prices are high in Malaysia (between 48.7 – 81 percent). It is assumed here that ex-vessel prices are 64.85 percent of retail prices for Sabah. Another problem with the price data is the missing values. Prices for some years are missing for some species and, more importantly, no price data are available beyond 1993 for Sabah. Missing values are extrapolated from the nearest available year using the consumer price index values obtained from the Department of Statistics.

Cost data by gear type are not available in the AFS. Fishing cost data for Sabah are based on a survey conducted with the help of the DOF Sabah. In total 99 questionnaires were obtained from 13 trawlers, 8 seiners, 38 drift-net operators, and 40 other traditional gear operators. By region, 36 were from Tawau; 33, Kota Kinabalu; and 30, Beaufort.

III. RESULTS AND DISCUSSION

Sustainable Catch

The sustainable catch for each species group in Sabah computed from the estimated dynamics models is presented in Table 1. As mentioned earlier, although all equation forms were estimated, only the Fox model (Equation 9a) is selected because the model provided the best fit for each species group in Sabah. Due to the possible presence of first-order autocorrelation, these models were estimated using the Cochrane-Orcutt procedure. Based on the estimated equations and the parameters, the sustainable catches for each species group, as shown in Table 2, fluctuated over the years from 1979 to 1993. For the demersal species, the highest sustainable catch occurred in 1986 which was associated with a standardized fishing effort of about 3509 drift net vessels. On the other hand, the lowest sustainable demersal catch occurred in 1992 (at standardized effort of 10,300 drift net vessels). These results showed biological overfishing at effort levels higher than 3509 drift net vessels. Similar results were obtained for the sustainable catches of the pelagics (highest in 1979, lowest in 1992), the crustaceans (highest in 1987 and lowest in 1982), and the molluscs (highest in 1980 and lowest in 1992).

Rent and Depreciation

From the sustainable catch, the fishery resource rent can be computed. The first step in the computation of fishery rent is the calculation of total revenues. For this purpose information on ex-vessel prices are needed. The ex-vessel prices estimated from the retail price series for each species group are shown in Table 3.

The next step in the computation of rent is the estimation of costs. As mentioned earlier, information on costs are not reported in the Sabah AFS and thus have to be estimated from primary data. From the 1997 survey results, cost per vessel by vessel types was obtained. These were then multiplied by the number of vessels to get the total fishing costs by vessel type. It should be noted that these costs include the opportunity cost of labour for the operators. These 1997 estimates are then extrapolated based on the consumer price indices for various years. The cost estimates by vessel type are then converted to costs by species group based on the percentage contribution to total revenue by each species group. This seems logical as effort tends to expand among species groups according to their contribution to total revenues. The total costs by species group are then converted to a unit cost estimate by dividing the former by total standardized effort for each species group. The estimates of the unit cost per standardized effort by species group are shown in Table 3.

TABLE 1
PARAMETER ESTIMATES OF THE BIOMASS DYNAMICS MODELS FOR THE SABAH FISHERY RESOURCES BY SPECIES GROUPS

	Demersal	**Pelagic**	**Crustacean**	**Molluscs**
Model type [a/]	Fox[b/]	Fox[b/]	Fox[b/]	Fox[b/]
Dependent variable	$\ln U_t$	$\ln U_t$	$\ln U_t$	$\ln U_t$
Constant	2.8748	2.3444	2.4614	1.4381
	(24.76)[c/]	(18.97)	(20.18)	(2.098)
E_t	-1.7922×10^{-4}	-0.9938×10^{-4}	-0.7815×10^{-4}	-1.1435×10^{-4}
	(-8.743)	(-7.337)	(-3.723)	(-3.113)
R_2	0.8966	0.8583	0.6124	0.6455
Adj-R^2	0.8872	0.8454	0.5771	0.6133
Durbin Watson	1.5945	1.6809	1.9542	1.1677
Parameters				
r	0.7476	0.7502	0.9473	0.5289
q	2.4×10^{-4}	2.39×10^{-4}	1.89×10^{-4}	3.39×10^{-4}
K	74209	74446	94012	52484

[a/] Only the model that best fit the data for each species group is presented.
[b/] Models have been corrected for first-order autocorrelation using the Cochrane-Orcutt procedure.

TABLE 2
STANDARDISED EFFORT AND SUSTAINABLE CATCH OF THE SABAH FISHERIES BY SPECIES GROUP, 1979-93

Year	Demersal		Pelagic		Crustacean		Molluscs	
	Std. Effort[a] (No. of vessels)	Sustainable Catch[b] (mt)	Std. Effort[a] (No. of vessels)	Sustainable Catch[b] (mt)	Std. Effort[a] (No. of vessels)	Sustainable Catch[b] (mt)	Std. Effort[a] (No. of vessels)	Sustainable Catch[b] (mt)
1979	2,317	19,614	3,301	20,519	2,317	25,930	3,301	7,079
1980	1,491	16,454	2,011	18,854	1,491	19,676	2,011	9,859
1981	1,535	16,702	2,224	19,483	1,535	20,079	2,224	9,512
1982	583	8,611	807	11,103	583	9,221	807	8,560
1983	3,831	19,946	5,860	16,120	3,831	31,696	5,860	2,437
1984	4,741	18,431	7,409	12,442	4,741	32,713	7,409	1,142
1985	6,231	15,014	10,082	7,225	6,231	31,937	10,082	280
1986	3,509	20,259	5,249	17,542	3,509	30,959	5,249	3,230
1987	4,607	18,697	7,288	12,720	4,607	32,649	7,288	1,214
1988	3,876	19,891	6,325	15,003	3,876	31,782	6,325	1,953
1989	4,969	17,954	8,643	9,797	4,969	32,761	8,643	604
1990	6,491	14,388	10,828	6,118	6,491	31,588	10,828	186
1991	9,635	7,784	15,070	2,204	9,635	25,041	15,070	17
1992	10,300	6,722	16,801	1,416	10,300	23,443	16,801	6
1993	7,571	11,865	13,273	3,442	7,571	29,702	13,273	48

[a] Standardised effort is in terms of drift net vessel equivalent.
[b] Computed based on the estimated parameters values in Table 1 and Equation 9a.

TABLE 3
AVERAGE EX-VESSEL PRICES PER MT OF FISH AND COST PER STANDARDISED EFFORT OF THE SABAH FISHERIES BY SPECIES GROUP, 1979 - 1993

Year	Ex-Vessel Price (RM/mt)				Cost per Standardised Effort (RM/vessel)			
	Demersal	Pelagic	Crustacean	Molluscs	Demersal	Pelagic	Crustacean	Molluscs
1979	798	1,239	1,991	1,647	1,767	2,413	4,795	912
1980	1,602	2,185	3,275	3,281	1,887	2,578	5,122	974
1981	1,978	2,743	4,079	3,949	2,061	2,815	5,594	1,064
1982	1,770	2,438	3,599	2,996	2,182	2,980	5,922	1,126
1983	1,777	2,458	3,826	3,307	2,287	3,125	6,208	1,181
1984	1,751	2,471	3,910	3,268	2,315	3,163	6,285	1,196
1985	1,706	2,354	3,949	3,061	2,336	3,192	6,341	1,206
1986	1,770	2,516	4,254	2,944	2,317	3,166	6,290	1,197
1987	1,673	2,471	4,034	2,581	2,295	3,135	6,229	1,185
1988	1,680	2,419	4,540	2,361	2,312	3,159	6,277	1,194
1989	1,978	2,756	4,533	2,464	2,361	3,225	6,408	1,219
1990	1,816	2,698	4,773	2,510	2,419	3,305	6,566	1,249
1991	1,868	2,776	4,916	2,588	2,492	3,404	6,763	1,286
1992	1,952	2,899	5,143	2,704	2,603	3,556	7,065	1,344
1993	2,004	2,970	5,266	2,769	2,666	3,642	7,235	1,376

With the above information in place, fishery resource rent is then calculated as the difference between total revenue (product of sustainable catch and price) and total cost (product of standardized effort and unit effort cost) as in Equation (1). Since all costs have been accounted for, this can be regarded as the returns to the fish stock, the natural capital. Note, however, this is not a measure of the private financial profitability of the fishing enterprises.

As shown in Equation (2), the fishing rents as estimated above was amortized at a social discount rate of 5 percent. The amortized values of the rents, as shown in Table 4 represent a valuation of the fish stock. The amortized rent for the fisheries in Sabah as a whole were all positive, with the highest and lowest amortized rent occurring in 1988 and 1992 respectively. Amortized rents from the crustaceans were all positive while the other three species groups had some years with negative amortized rents. The molluscs had nine, the pelagics had six, and the demersals had two out of fifteen years with negative rents. Notably, the amortized rents for the pelagics were negative from 1989 to 1993, while those for the molluscs were negative between 1987 and 1993. Since negative rents can occur in the short-run, the persistence of negative rents for these species groups point to the need for more effort in collecting accurate data and a more thorough analysis of the data. The likely candidates for scrutiny are the price and cost variables and the landing data for these species groups.

The change in the amortized rents, as shown by Equation (3) which is the moving difference between the rows for the amortized rents in Table 4, is a measure akin to that of depreciation of man-made capital. As mentioned earlier year to year changes in rent are also due to the effects of changes in prices of fish and unit costs of effort. The amortized rents need to be readjusted by taking into consideration the price effects (see Equation 4). The price effects for various species groups in Sabah are shown in Table 4. Note that positive price effects indicate the increase in the amortized rents which are partly due to the fall in price and/or rise in unit cost of effort from previous to current year.

The final step in computing resource depreciation/appreciation is adjusting the changes in amortized values by the price effects. This then represents the change in amortized values due to the change in effort level and its long-run effect on the stock only, with the influence of price changes removed. Table 5 shows the results for Sabah. Positive changes in amortized values indicate that they are increasing and that the fishery stock is appreciating in values. This is the amount that has to be added to the value of the output from the fishery. On the other hand, negative changes in amortized values indicate that the fishery stock is depreciating in value. This amount then has to be deducted from the value of output from the fishery.

TABLE 4
AMORTISED VALUE OF FISHING RENT AND PRICE EFFECT OF THE SABAH FISHERIES BY SPECIES GROUP, 1979 - 1993

Year	Demersal[a]		Pelagic[a]		Crustacean[a]		Molluscs[a]		Total[a]	
	Amortised Value[b] (RM mil.)	Price Effect[c] (RM mil.)	Amortised Value[b] (RM mil.)	Price Effect[c] (RM mil.)	Amortised Value[b] (RM mil.)	Price Effect[c] (RM mil.)	Amortised Value[b] (RM mil.)	Price Effect[c] (RM mil.)	Amortised Value[b] (RM mil.)	Price Effect[c] (RM mil.)
1979	231.17		349.13		810.34		172.98		983.32	
1980	470.91	(13.05)	720.24	(17.51)	1,136.01	(24.78)	607.79	(15.99)	1,703.04	(71.32)
1981	597.46	(6.01)	943.63	(10.34)	1,466.34	(15.42)	703.95	(6.15)	2,148.71	(37.93)
1982	279.39	1.86	493.30	3.52	594.71	4.62	494.72	8.21	1,102.26	18.21
1983	533.64	0.26	426.23	0.52	1,949.73	(6.10)	22.80	(0.44)	1,966.00	(5.75)
1984	425.89	0.61	146.17	0.12	1,962.20	(2.38)	(102.52)	0.15	1,857.45	(1.49)
1985	221.13	0.81	(303.41)	1.13	1,732.15	(0.89)	(226.08)	0.17	1,505.34	1.21
1986	554.54	(1.36)	550.34	(2.98)	2,192.51	(9.62)	64.56	0.33	2,247.77	(13.63)
1987	414.16	1.71	171.66	0.35	2,060.23	6.90	(110.05)	0.36	1,957.43	9.31
1988	489.08	(0.07)	326.22	0.93	2,399.24	(15.90)	(58.83)	0.49	2,325.00	(14.55)
1989	475.63	(5.11)	(17.53)	(2.73)	2,333.31	0.88	(180.94)	0.15	2,153.41	(6.81)
1990	208.54	2.71	(385.50)	1.21	2,163.04	(6.56)	(261.11)	0.32	1,895.69	(2.32)
1991	(189.30)	0.29	(903.50)	1.32	1,158.82	(1.68)	(386.83)	0.56	770.86	0.50
1992	(273.77)	0.58	(1,112.73)	2.38	955.97	(2.21)	(451.22)	0.96	503.50	1.72
1993	71.93	(0.14)	(762.25)	0.89	2,032.67	(2.36)	(362.70)	0.43	1,668.04	(1.18)

[a] Figures in parentheses denote negative values.
[b] Computed by Equation (2) using a social discount rate of 5%.
[c] Computed by Equation (4).

For the Sabah fishery as a whole, depreciations occurred in eight years from 1980 to 1993 (Table 5). The highest depreciation occurred in 1991 while the lowest in 1984. For individual species group, depreciations occurred in nine years for the pelagics and molluscs, eight years for the demersals and seven years for the crustaceans. Table 5 also shows the correlation coefficients between the level of fishing effort and depreciations of the fishery resources in Sabah. All the correlation coefficients are negative which indicate that high level of fishing effort for a particular year results in higher depreciations (or larger negative adjusted change in armortised rents). These results imply that fishing effort currently applied to the Sabah fisheries are too high and need to be curtailed in order to reduce the depreciation of the resource stock.

Optimal Rent and Depreciation

The estimated bioeconomic optimal effort, harvest and resource rent for various species groups for Sabah are presented in Table 6. Depending on the ratio of unit cost of effort and the ex-vessel fish price, it can be observed in Table 6 that the optimal level of effort for crustaceans was the highest from 1979 to 1993 (ranged from 3,762 to 4,314 standard drift net vessels) while those for the molluscs were the lowest (from 1,554 to 1,625 standard drift net vessels). The optimal levels of effort for the demersals and pelagics ranged from 2,424 to 2,840 and 2,528 to 2,867 standard drift net vessels respectively. Similarly, optimal rent for crustaceans was the highest among the various species groups in Sabah, ranging from RM45 to RM139 million from 1979 to 1993. On the other hand, the optimal rent for demersals was the lowest from 1979 to 1985, but in more recent years from 1986 to 1993, the optimal rent for the molluscs was the lowest among the various species groups.

The optimal depreciation values for the various species groups in Sabah from 1979 to 1994 are presented in Table 7. The optimal depreciation was calculated by subtracting the optimal rent from the current rent and then amortized at a social discount rate of 5%. The aggregated optimal depreciations for all species groups ranged from RM245 million in 1979 to RM5746 million in 1992. In terms of individual species groups, all the values were negative except for the demersals in 1979 and the crustacean in 1983. The negative values indicate that the amortized values of the optimal rent were higher than the amortized values of the current rent. This result implies that it is possible to increase the values of the fishery resources for all species groups in Sabah from the current levels. An inspection of Table 7 reveals that the demersals registered the lowest optimal depreciations while the pelagics had the highest in Sabah.

Comparisons of the percentage change in annual and optimal levels of fishing effort and depreciations from 1979 to 1993 are shown in Table 8. The percentage changes

TABLE 5
ADJUSTED CHANGE IN ARMORTISED VALUE OF FISHING RENT (RM MILLION) IN THE SABAH FISHERIES BY SPECIES GROUP, 1979 - 1993

Year	Demersal[a]	Pelagic[a]	Crustacean[a]	Molluscs[a]	Total[a]
1979					
1980	252.79	388.62	350.45	450.79	1,442.65
1981	132.56	233.73	345.75	102.32	814.36
1982	(319.93)	(453.85)	(876.24)	(217.44)	(1,867.46)
1983	253.98	(67.59)	1,361.12	(471.48)	1,076.03
1984	(108.36)	(280.19)	14.85	(125.48)	(499.18)
1985	(205.57)	(450.70)	(229.16)	(123.73)	(1,009.15)
1986	334.77	856.72	469.98	290.32	1951.79
1987	(142.09)	(379.03)	(139.18)	(174.97)	(835.27)
1988	74.99	153.63	354.91	50.74	634.27
1989	(8.33)	(341.02)	(66.81)	(122.27)	(538.43)
1990	(269.80)	(369.19)	(163.71)	(80.49)	(883.19)
1991	(398.14)	(519.32)	(1,002.54)	(126.29)	(2,046.29)
1992	(85.05)	(211.61)	(200.63)	(65.36)	(562.65)
1993	345.84	349.59	1,079.07	88.09	1,862.59
Correlation[b]	(0.30)	(0.32)	(0.19)	(0.21)	

[a] Figures in parentheses denote negative values.
[b] Correlation coefficient between level of fishing effort and adjusted change in amortized values of fishing rent.

TABLE 6
ESTIMATED BIOECONOMIC OPTIMAL LEVELS OF EFFORT, CATCH AND RENT OF THE SABAH FISHERIES BY SPECIES GROUPS, 1979-1993

Year	Demersal			Pelagic			Crustacean			Molluscs		
	Effort[b] (Std. vessels)	Catch[a] (mt)	Rent[c] (RM mil.)	Effort[b] (Std. vessels)	Catch[a] (mt)	Rent[c] (RM mil.)	Effort[b] (Std. vessels)	Catch[a] (mt)	Rent[c] (RM mil.)	Effort[b] (Std. vessels)	Catch[a] (mt)	Rent[c] (RM mil.)
1979	2,424	19,826	11.54	2,528	20,102	18.81	3,762	31,557	44.79	1,554	10,152	15.30
1980	2,786	20,287	27.24	2,805	20,421	37.39	4,204	32,287	84.21	1,618	10,143	31.70
1981	2,840	20,325	34.35	2,867	20,464	48.06	4,314	32,413	108.08	1,625	10,141	38.32
1982	2,765	20,270	29.85	2,800	20,417	41.43	4,157	32,227	91.37	1,598	10,147	28.60
1983	2,744	20,253	29.71	2,770	20,392	41.47	4,170	32,244	97.48	1,603	10,147	31.66
1984	2,731	20,241	29.12	2,767	20,389	41.63	4,178	32,255	99.86	1,600	10,147	31.25
1985	2,713	20,224	28.16	2,738	20,363	39.20	4,179	32,256	100.88	1,593	10,148	29.14
1986	2,736	20,245	29.50	2,775	20,397	42.53	4,251	32,344	110.85	1,590	10,149	27.97
1987	2,712	20,223	27.61	2,771	20,393	41.70	4,214	32,300	104.05	1,577	10,151	24.33
1988	2,710	20,222	27.71	2,757	20,381	40.59	4,307	32,406	120.09	1,566	10,152	22.10
1989	2,780	20,282	33.56	2,809	20,424	47.23	4,289	32,387	119.33	1,569	10,151	23.10
1990	2,727	20,237	30.15	2,788	20,407	45.85	4,311	32,410	126.39	1,568	10,151	23.52
1991	2,726	20,237	31.01	2,787	20,407	47.16	4,311	32,410	130.17	1,568	10,151	24.26
1992	2,726	20,237	32.41	2,787	20,407	49.25	4,312	32,412	136.23	1,568	10,151	25.34
1993	2,728	20,238	33.29	2,787	20,407	50.46	4,312	32,412	139.48	1,568	10,151	25.95

[a] Computed using $H_t^* = rX_t^* \ln(K/X_t^*)$ where X_t^* is the optimal stock estimated from Equation (5).

[b] Computed using $E_t^* = Ht^* / (qXt^*)$.

[c] Computed using $Rent_t^* = p_tH_t^* - c_tE_t^*$.

TABLE 7
ESTIMATED OPTIMAL DEPRECIATION (RM MIL.) OF THE SABAH FISHERIES BY SPECIES GROUPS, 1979-1993

Year	Demersal[a]	Pelagic[a]	Crustacean[a]	Molluscs[a]	Total[a]
1979	0.40	(27.00)	(85.48)	(133.08)	(245.16)
1980	(73.95)	(27.52)	(548.20)	(26.26)	(675.94)
1981	(89.54)	(17.63)	(695.31)	(62.39)	(864.87)
1982	(317.53)	(335.35)	(1,232.69)	(77.33)	(1,962.89)
1983	(60.63)	(403.13)	0.10	(610.43)	(1,074.09)
1984	(156.51)	(686.46)	(34.97)	(727.44)	(1,605.38)
1985	(342.17)	(1,087.32)	(285.48)	(808.93)	(2,523.89)
1986	(35.37)	(300.31)	(24.55)	(494.93)	(855.16)
1987	(138.03)	(662.43)	(20.78)	(596.64)	(1,417.88)
1988	(65.04)	(485.62)	(2.54)	(500.79)	(1,053.98)
1989	(195.48)	(962.12)	(53.20)	(642.95)	(1,853.75)
1990	(394.55)	(1,302.41)	(364.73)	(731.54)	(2,793.22)
1991	(809.47)	(1,846.73)	(1,444.66)	(871.94)	(4,972.80)
1992	(921.88)	(2,097.69)	(1,768.57)	(958.06)	(5,746.20)
1993	(593.77)	(1,771.39)	(756.94)	(881.73)	(4,003.84)

[a] Figures in parentheses denote negative values.

TABLE 8
COMPARISON OF PERCENTAGE CHANGE IN ANNUAL AND OPTIMAL LEVELS OF FISHING EFFORT AND DEPRECIATION OF THE SABAH FISHERIES BY SPECIES GROUPS, 1979-1993

Year	Demersal[a]		Pelagic[a]		Crustacean[a]		Molluscs[a]	
	Effort[b] (%)	Depreciation[c] (%)	Effort[b] (%)	Depreciation[c] (%)	Effort[b] (%)	Depreciation[c] (%)	Effort[b] (%)	Depreciation[c] (%)
1979	5	0.17	(23)	(7.73)	62	(10.55)	(53)	(76.93)
1980	87	(15.70)	40	(3.82)	182	(48.26)	(20)	(4.32)
1981	85	(14.99)	29	(1.87)	181	(47.42)	(27)	(8.86)
1982	374	(113.65)	247	(67.98)	613	(207.27)	98	(15.63)
1983	(28)	(11.36)	(53)	(94.58)	9	0.01	(73)	(2,676.83)
1984	(42)	(36.75)	(63)	(469.65)	(12)	(1.78)	(78)	(709.56)
1985	(56)	(154.74)	(73)	(358.37)	(33)	(16.48)	(84)	(357.80)
1986	(22)	(6.38)	(47)	(54.57)	21	(1.12)	(70)	(766.60)
1987	(41)	(33.33)	(62)	(385.91)	(9)	(1.01)	(78)	(542.15)
1988	(30)	(13.30)	(56)	(148.86)	11	(0.11)	(75)	(851.30)
1989	(44)	(41.10)	(67)	(5,489.42)	(14)	(2.28)	(82)	(355.34)
1990	(58)	(189.19)	(74)	(337.85)	(34)	(16.86)	(86)	(280.17)
1991	(72)	(427.61)	(82)	(204.40)	(55)	(124.67)	(90)	(225.40)
1992	(74)	(336.74)	(83)	(188.52)	(58)	(185.00)	(91)	(212.33)
1993	(64)	(825.49)	(79)	(232.39)	(43)	(37.24)	(88)	(243.10)
Correlation[d]	-0.849**		-0.970**		-0.447**		-0.923**	

[a] Figures in parentheses denote negative values.
[b] % change in effort = {[(Annual effort at year t) - (Optimal effort at year t)/(Annual effort at year t]x100%}.
[c] % change in depreciation = {[(Annual depreciation at year t) - (Optimal depreciation at year t)/(Annual depreciation at year t]x100%}.
[d] Significant at 1% level.

in effort level showed that the annual effort levels were higher than the optimal effort level for the various species groups from 1984 to 1993. Note that 1982 was an exceptional year for Sabah where the level of annual effort was rather low for the various species groups compared to the optimal effort.

Table 8 also reveals that the percentage changes in depreciation values were all negative for the various species groups in Sabah from 1979 to 1993 except for the demersals in 1979 and the crustaceans in 1983. The negative percentage changes show that the annual depreciations were much lower than the optimal depreciations. The average percentage change ranged from negative 47% for the crustaceans, negative 148% for the demersals, negative 488% for the molluscs and negative 536% for the pelagics. The significant correlation coefficients in Table 8 show that the percentage change in effort was negatively related to the percentage change in depreciations for all species groups in Sabah. These results imply that if fishing effort can be reduced from the current level for the various species groups, the rents from the fisheries can be increased and consequently would lead to the reduction in resource depreciation.

IV. CONCLUSION

This paper has presented the analyses of the contributions of the fishery resources to the income of the Sabah state for the period 1979 to 1993. Data were drawn mainly from the Annual Fisheries Statistics of the Sabah State's Department of Fisheries and a cost survey of fishing enterprises in Sabah. Data were aggregated into four species groups: demersal, pelagic, crustacean, and molluscs.

The results show that the fishery resources in Sabah depreciate (contributed negatively to income) in eight years from 1979 to 1993. A more significant result is that there exists a negative relationship between the levels of fishing effort and depreciation. This implies that a high level of fishing effort has resulted in a large depreciation for the Sabah fishery resources. Similarly, the results of the bioeconomic optimal analysis show that the values for the various species groups in Sabah experience substantial optimal depreciation between 1979 and 1993. Furthermore, there appears to be an inverse relationship between optimal depreciation and the intensity of fishing.

These results imply that the fishery resources in Sabah are currently overexploited. Moreover, they had been exploited far beyond their bioeconomic optimal levels. There exists tremendous potential to improve the income contributions of fishery resources in Sabah if fishing effort can be curtailed. In this regard, policies designed to reduce fishing effort should be actively pursued. The potentially higher rents foregone from the fishery resources in Sabah should be treated as costs of exploiting the fishery stocks. These costs have been largely ignored in the present system of accounting for the contribution of fishery resources to the Sabah State's income.

The study shows that there exists considerable scope for the potential application of the resource accounting framework in fisheries. Further work is clearly needed in this area. Refinements of data relating to landings, prices, costs, gear and species of fish by region are clearly needed to reduce the impacts of missing and questionable data.

REFERENCES

Atkinson, G., D. Richard, H. Kirk, M. Mohan, P. David and Y. Carlos. (1997). *Measuring Sustainable Development: Macroeconomics and the Environment*, Cheltenham, UK: Edward Elgar.

Clark, C.W. and G.R. Munro (1975). "The Economics of Fishing and Modern Capital Theory: A Simplified Approach." *Journal of Environmental and Economic Management* 1975(2), 92-106.

Clarke, R.P., S.S. Yoshimoto and S.G. Pooley. (1992). "A Bioeconomic Analysis of the Northwestern Hawaiian Islands Lobster Fishery." *Marine Resource Economics* 7: 115-140.

Crowards, T.M. (1996). "Natural Resource Accounting: A Case Study of Zimbabwe." *Environmental and Resource Economics* 7, 213-241.

Devarajan, S. and R.J. Weiner (1990). "Natural Resource Depletion and National Income Accounting." *Development Discussion paper* no. 332, Harvard Institute for International Development, Cambridge, Mass.

Department of Fisheries Sabah (various years). *Annual Fisheries Statistics, Sabah*, various issues, Sabah.

Department of Statistics Sabah (various years). *Annual Bulletin of Statistics*, Sabah, various issues, Sabah.

El Serafy, S. (1989). "The Proper Calculation of Income from Depletable Natural Resources." in Y. Ahmad, S. El Serafy and E. Lutz, (eds.), *Environmental Accounting for Sustainable Development*, Word Bank, Washington D.C.

Fox, W.W. Jr. (1970). "An Exponential Surplus-Yield Model for Optimizing Exploited Fish Populations." *Transaction of the American Fishery Society* 98: 80-88.

Gulland, J.A. (1983). *Fish Stock Assessment: A Manual of Basic Methods*, Wiley Interscience, New York.

Hartwick, J. (1991). "Natural Resources, National Accounting and Economic Depreciation." *Journal of Public Economics* 43, 291-304.

Hilborn, R. and C. J. Walters. (1992). *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*, New York: Chapman and Hall.

Japan International Cooperation Agency (1991). The Study on Fish Marketing and Distribution System in Malaysia. Final report.

Landerfeld, J.S. and J.R. Hines. (1985). "National Accounting for Nonrenewable Natural Resources in the Mining Industries." *Review of Income and Wealth* 31(1): 1–20.

Repetto, R., W. Magrath, M. Wells, C. Beer, and F. Rossini. (1989). *Wasting Assets: Natural Resources in the National Income Accounts*, World Resources Institute, Washington, D.C.

Schaefer, M. B. (1957). "Some Considerations of Population Dynamics and Economics in Relation to the Management of Commercial Marine Fisheries." *Journal of Fisheries Research Board of Canada* 14(5): 669-681.

Schnute, J. (1977). "Improved Estimates from the Schaefer Production Model: Theoretical Consideration." *Journal of Fisheries Research Board of Canada* 34: 583-603.

Solorzano, R., R. de Camino, R. Woodward, J. Tosi, V. Watson, A. Vasquez, C. Villalobos, J. Jimenez, R. Repetto and W. Cruz. (1991). *Accounts Overdue: Natural Resource Depreciation in Costa Rica*, World Resources Institute, Washington, D.C.

Stauffer, T.R. (1986). "Accounting for Wasting Assets: Measurement of Income and Dependency in Oil Renter States." *The Journal of Energy and Development* 11(1): 69-93.

Tai, S.Y., Ishak Hj. Omar, K. Kuperan, Kusairi Mohd. Noh, Mohd. Ariff Hussein, Nik Mustapha R. Abdullah, and L.T. Tan. (1996). "Fishery Resource Accounting in Peninsular Malaysia," Intensification of Research in Priority Areas (IRPA) Report, Ministry of Science, Technology and the Environment Malaysia, Kuala Lumpur.

Tai, S.Y., Kusairi Mohd. Noh, and Nik Mustapha R. Abdullah. (2000), "Valuing Fisheries Depreciation in Natural Resource Accounting: The Pelagic Fisheries in Northeast Peninsular Malaysia." *Environmental and Resource Economics*, 15: 227-241.

Vincent, J.R. (1997). "Resource Depletion and Economic Sustainability of Malaysia." *Environment and Development Economics* 2(1): 19-37.

Ward, M. (1982). *Accounting for the Depletion of Natural Resources in the National Accounts of Developing Countries*. OECD Center, Paris.