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Optimal Bioeconomic Exploitation of the Demersal Fishery in Northwest Peninsular Malaysia

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ABSTRAK

Kadar eksploitasi bioekonomi optimum bagi perikanan demersal di barat daya Semenanjung Malaysia (BDSM) ditentukan dalam kertas ini. Sebuah model bioekonomi dibentuk dan dianggarkan. Keputusan kajian menunjukkan walaupun kadar eksploitasi perikanan demersal kini diperbaiki sedikit berbanding tahap penggunaan terbuka, stok demersal telah ditangkap secara berlebihan dari segi biologi dan ekonomi. Suatu keputusan penting ialah pembaikan yang amat besar bagi perikanan demersal di BDSM dapat dicapai jika usaha penangkapan dikurangkan sebanyak 60 hinga 78 peratus daripada tahap kini. Ini bermakna perlunya pembentukan polisi pengurangan usaha penangkapan yang sesuai supaya dapat memperolehi faedah maksimum daripada perikanan tersebut.

ABSTRACT

The optimal bioeconomic rate of exploitation of the demersal fishery in northwest Peninsular Malaysia (NWPM) is determined in this paper. A bioeconomic model for the fishery is developed and estimated. The results show that even though present rate of exploitation of the demersal fishery shows slight improvement compared to the open access level, the demersal stock is overfished biologically and economically at this rate. An important result is that tremendous improvement for the demersal fishery in NWPM can be achieved if fishing effort is reduced by 60 to 78 percent from the present leveI. This implies an urgent need to formulate appropriate effort reduction management policies in order to derive maximum benefits from the fishery.

INTRODUCTION

The need to manage fisheries resources is well established (Gordon 1954). Fisheries resources are renewable and common property resources. Without management, these resources will be exploited to the extent that the rate of catch will surpass the maximum yields that the resources can sustain, leading to biological overfishing. In addition, economic rent obtainable from the fisheries resources will be completely dissipated, causing economic losses.

The fisheries resources in Malaysia, in particular those on the west coast of Peninsular Malaysia are alleged to be biologically overexploited (Jahara and Yamamoto, 1988). This allegation stems from the fact that total catch and catch per unit of effort have been declining; proportion of trash fish in landings has been increasing; and there is disappearance of certain commercially valuable species from the catch, notably *Lactarius lactarius* (Ch'ng and Chee 1983). Thus, there is a need to manage the fisheries resources. It is crucial in fishery management to determine the level of exploitation commensurate with the objectives of management. The main objectives of this paper were to determine the optimal bioeconomic levels of exploitation for the demersal fishery in the Northwest Peninsular Malaysia and to compare the present and optimal states of exploitation of the fishery.

A description of the demersal fishery system in Northwest Peninsular Malaysia is presented in the next section, followed by bioeconomic model and the derivation of the conditions for optimal level of management based on vious alternative management objectives. The results of the bioeconomic analyses will be presented followed by discussion and conclusion.

Demersal Fishery System

The Northwest Peninsular Malaysia (NWPM) encompasses four states, namely Perlis, Kedah, Pulau Pinang and Perak. Historically, the area is an important fishing region in the country, being the centre for fishing techno-logies adoption (Yap 1977). An important characteristic of the fishery resources in NWPM is the presence of a large number of species (about seventy species or species groups have been listed in the Annual Fisheries Statistics published by the Department of Fisheries Malaysia). The demersal species or species groups, which number more than forty, are among the most important species harvested in NWPM. Between 1980 and 1992, the proportion of demersal species to total marine production and total finfish catch ranged from 8 to 26 percent and 19 to 37 percent, respectively (Ministry of Agriculture 1980-92). In terms of average landings between 1980 and 1992, the important demersal species or species groups in NWPM are Kerisi (*Namipterus spp/Pristipomoides typus*), Gelama (*Sciaena spp/Johnius spp/Otolithus spp/Otolithoides spp*), Pari (*Gymnura spp/Dasyatis spp*), Timah (*Trichiurus lepturus*) and Duri/Pulutan/Utek (*Tachysurus spp/Arius spp/Osteogenius spp*). These species constituted about half the demersal landings in the area during the period. Owing to the presence of a large number of species and the biological interactions among these species are not exactly known these relationships are not considered in the analyses and a bioeconomic model of a mixed species demersal fishery is adopted here.

Another important characteristic of the demersal fishery in NWPM is the use of many fishing gear types and various sizes of vessels. Traditional fishing gears, notably gill or drift nets are dominant in NWPM. Others include handlines, portable traps, barrier nets, bag nets, lift nets, stationary traps and push or scoop nets. Majority of the vessels using traditional gears are below 25 gross registered tonnage (GRT) and are fitted with outboard engines (Ministry of Agriculture 1980 – 1992). The proliferation of the small sized vessels is mainly due to the narrow strip of fishing area along the Straits of Malacca. Trawl nets are the most important commercial gear used in exploiting demersal fishery in NWPM. These trawlers are of various sizes, but a majority of them are small trawlers less than 40 GRT. Seine nets, in particular the beach seines, are also used in catching demersal fish species. The various gear types and vessel sizes will have differential impacts on the demersal stock. Thus there is a need to standardize these impacts through the standardization of fishing effort, which will be discussed later.

Bioeconemic Model

The bioeconomic model comprises the biological and economic components. In the biological component, it is assumed that the demersal species in NWPM are biologically and ecologically independent. The overall biomass of the demersal stock is assumed to be adequately represented by a state variable X(t). The instantaneous rate of change in biomass is given by

$$\dot{X} = dX(t)/dt = F(X(t)) - h(t) \qquad (1)$$

where $\dot{X}$ is the time derivative of the stock biomass, F(X(t)) is net natural growth and h(t) is commercial harvest.

The economic component takes into account the revenues and costs of fishing operations. Denoting the constant price of fish as p and the cost of harvest which depends on stock abundance as C(X(t)), the net revenues, $\pi(t)$, from commercial harvest h(t) can be represented by

$$\pi(t) = [p - C(X(t))]h(t) \qquad (2)$$

The present value of the net revenue is thus

$$PV = \int \pi(t)e^{-\delta t}\, dt \qquad (3)$$

where δ is the instantaneous discount rate.

The optimal bioeconomic solution can be

derived by employing the Maximum Principle (Pontryagin et al. 1962), that is, maximizing (3) subject to equation (1) and an initial condition on the biomass $X(0) = X_0$. The current value Hamiltonian for this problem is

$$\mathcal{H}(t) = \{[p - C(X(t))]h(t)\}e^{-\delta t} + \lambda(t)[F(X(t)) - h(t)] \quad (4)$$

where $\lambda(t)$ is the current value shadow price associated with an incremental change in the biomass. The first-order conditions for a maximum require

$$\partial\mathcal{H}(t)/\partial h(t) = [p - C(X(t))]e^{-\delta t} - \lambda(t) = 0 \quad (5)$$

$$\lambda(t) = C'(X(t))h(t)e^{-\delta t} - \lambda(t)F'(X(t)) \quad (6)$$

$$\dot{X}(t) = F(X(t)) - h(t) \quad (7)$$

In steady state $\dot{X}(t) = 0$. Solving equations (5) and (6) together with the steady state condition, the fundamental equation for the basic optimal bioeconomic solution is (Clark and Munro 1975):

$$\delta = F'(X(t)) - \{[C'(X(t)F(X(t))]/[p - C(X(t))]\} \quad (8)$$

where $F'(X(t))$ is the rate of change in net growth associated with an increment in the fish stock. The second term on the right-hand side of (8) is the marginal stock effect. The steady state optimal solution as represented in (8) equates the market rate of return obtainable on other assets to the resource's own rate of return (Clark and Munro 1975).

Objectives of Fisheries Management

The optimal exploitation of the demersal fishery in NWPM will depend on the objective of management to be achieved. Over the years, various objectives of fishery management have been proposed and declared. They include biological, economic and social objectives (Charles, 1988).

The biological objectives are concerned mainly with resource conservation and maximizing sustainable yield (MSY) from a fish stock. Harvesting at effort levels exceeding the MSY level will cause reductions in the population level of the stock and constitute biological overfishing. The condition for obtaining the MSY level of exploitation for the demersal fishery in NWPM is

$$F'(X(t)) = 0 \quad (9)$$

The economic objective of fishery management is concerned with maximizing the economic wealth obtainable from the fishery by equating the marginal revenue to marginal cost of fishing. Levels of exploitation in which the marginal cost of fishing exceeds marginal revenue will constitute economic overfishing. The condition for obtaining the maximum economic yield (MEY) level of fishery exploitation depends on whether future benefits are discounted or not. If benefits in all future periods are equally important, then the benefit in each period is maximized. This is the static maximum economic yield (SMEY). The SMEY implies that $\delta = 0$. Then equation (8) becomes

$$F'(X(t)) = C'(X(t))F(X(t))/[P - C(XCE))] \quad [10]$$

However, if future benefits are discounted, then the dynamic maximum economic yield (DMEY) is the appropriate objective to pursue. The DMEY implies that δ is positive, then equation (8) is the condition for obtaining DMEY level of exploitation.

Since the early seventies, it was felt that fishery management objectives based solely on biological or economic criteria are too narrow. Reference is made to the fact that real world fishery systems are extremely complex since there is a myriad of social, cultural, political and institutional factors which impact on fishery management (Rothschild 1983). As a result, the optimum social yield (OSY) which incorporates some or all the factors above was proposed. However, much confusion and difficulties exist in defining and estimating OSY as indicated by the plethora of methods developed (Roedel 1975; Larkin 1977). Due to the above reason, the OSY level of fishery exploitation will not be discussed in this paper.

In addition to the biological and bioeconomic optima, it will be useful to note the open-access equilibrium level of exploitation of the demersal fishery in NWPM. The open-access equilibrium (OAE) occurs when a fishery is not subjected to any form of management which results in total revenue being equal to total costs of harvesting, leading to complete dissipation of resource rent from the fishery. OAE implies $\delta = \infty$ and from (8), the condition for OAE is

$$p = C(X(t)) \quad (11)$$

Empirical Model Specification and Data

Biological Model

The surplus production model is used to specify the biological relationship of the demersal fish stock in NWPM because only time-series data on catch and effort are available (Sparre et al. 1989). Two types of functional forms, the logistic and the Gompertz forms are commonly used for the surplus production models. With the logistic form, the growth rate of the stock is

$$\dot{X} = rX[1 - (X/K)] - h \quad (12)$$

where r is the intrinsic growth rate, K is the environmental carrying capacity and h is the catch rate. The Gompertz form for the stock growth rate is

$$\dot{X} = rX\ln(K/X) - h \quad (13)$$

The basic difference between the two functional forms is that the logistic form is symmetrical while the Gompertz form is not, implying, in extreme cases, the potential extinction of the fisheries. The estimation of the parameters in equations (12) and (13) requires nonlinear techniques. If we define $U = h/E$ and assume that $h = qEX$, where E is the fishing effort, q is the catchability coefficient and U is the catch per unit of effort, equations (12) and (13) can be linearized by using U such that ordinary least squares method can be used. The transformation of the logistic function has been performed by Schaefer (1957) while the Gompertz form has been transformed by Fox(1970). Using the finite difference approximation $dU/dt \approx (U_{t+1} - U_{t-1})/2$, where U_t is the average catch per unit of effort for a given year t, the Schaefer and Fox models become respectively

$$(U_{t+1} - U_{t-1})/2U_t = a - b_1U_t - b_2E_t \quad (14)$$

where $a = r$, $b_1 = r/(qK)$ and $b_2 = q$.

$$(U_{t+1} - U_{t-1})/2U_t = a - b_1\ln U_t - b_2E_t \quad (15)$$

where $a = r\ln(qK)$, $b_1 = r$ dan $b_2 = q$.

Even though the Schaefer and Fox models have been used in many bioeconomic studies, they have been criticized on two grounds (Schnute 1977). First, the finite difference approximation used in these models may not be valid for non-equilibrium conditions and may not represent the dynamic nature of fishery yield and effort interactions. Second, they can predict next year's catch per unit of effort without specifying next year's anticipated effort. Due to these shortcomings, these models will not be used in this study.

Schnute (1977) modified the Schaefer model using an integration procedure and the resultant Schnute model is as follows:

$$\ln(U_{t+1}/U_t) = a - b_1(U_t + U_{t+1})/2 - b_2(E_t + E_{t+1})/2 \quad (16)$$

where $a = r$, $b_1 = r/(qK)$ and $b_2 = q$.

In a similar vein, Clarke, Yoshimoto and Pooley (1992) modified the Fox model using a Taylor approximation and derive the CYP model as follows:

$$\ln(U_{t+1}) = a\ln(qK) + b_1\ln(U_t) - b_2(E_t + E_{t+1}) \quad (17)$$

where $a = 2r/(2 + r)$, $b_1 = (2 - r)/(2 + r)$ and $b_2 = q/(2 + r)$.

Thus, $r = 2(1 - b_1)/(1 + b_1)$,

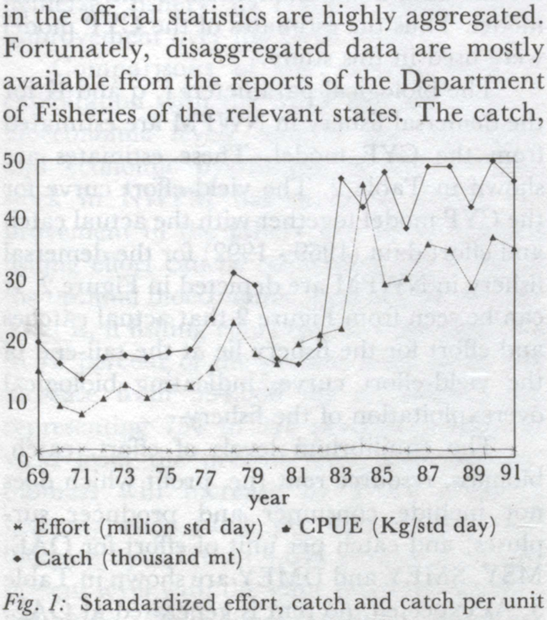
$q = -b_2(2 + r)$, and $K = e^{a(2+r)/(2r)}$.

Fishing Effort

An important variable in the surplus production model is fishing effort, which is a composite input used in catching fish. It comprises the gears, the vessels and all other inputs such as labour, fuel, ice, etc. As discussed earlier, a variety of gears and different sizes of vessels are used in catching the demersal fish in NWPM. These vessels and gears will exert different impacts on the fish stock. Thus, appropriate choice and standardization of units of fishing effort is essential to reflect the relative change in the fishing power of vessels and gears.

The relative fishing power for the vessels and gears used in catching the demersal fish is estimated using an approach outlined by Gulland (1983). First, the ratio of the average catch per vessel using gear type j and the average catch per small trawler vessel (less than 40 GRT), which is used as the standard vessel, is estimated. Once the fishing power is calculated, the standard fishing effort in number of small-trawler days (standard days) can be computed by summing the product of fishing power, average fishing days and the number of operating vessels of gear type j.

The data used for estimating standardized effort and the surplus production models are obtained from the Annual Fisheries Statistics. However, the data available in the official statistics are highly aggregated. Fortunately, disaggregated data are mostly available from the reports of the Department of Fisheries of the relevant states. The catch,



* Effort (million std day) ◆ CPUE (Kg/std day)
◆ Catch (thousand mt)

Fig. 1: Standardized effort, catch and catch per unit effort for the demersal fishery in NWPM, 1969-1991

standardized effort and catch per unit of standardized effort for the demersal fishery in NWPM from 1969 to 1991 are shown in Figure 1. In general, landings and catch per unit of effort show slight increasing trend over the years while fishing effort does not show any clear trend. Using these data, the empirical estimates of the biological relationships and paremeters were obtained and these will be discussed in later sections.

Harvesting Cost

Total cost of harvesting is equal to

$$C(E) = cE_t, \tag{18}$$

where c is the constant harvesting cost per standard day. If it is assumed that the catch function takes the form $h = qEX$, then $E = (h/(qX))$, and the cost function in terms of fish stock, $C(X)$ becomes

$$C(X) = c[h/(qX)] \tag{19}$$

Data on cost per standard day c are not available in the Annual Fisheries Statistics, but they can be obtained and adapted from studies by various authors. In estimating the cost per standard day, the costs pertaining to small trawler vessels have been used since effort of other gear types have been converted to small trawler day equivalent.

Fishing costs comprise operating, fixed, labour and opportunity costs. Operating costs include expenses on fuel, ice, food and maintenance of vessels and gears. Include in the fixed costs are items such as depreciation of fixed assets, insurance premia and license fees. The operating and fixed costs per trawl vessel are obtained from a survey in 1989 by Md. Ferdous. These costs are adjusted to per standard small trawler day equivalent. Crew members of trawl vessels are remunerated based on sharing (50%) of the net proceeds from sales of fish (Md. Ferdous 1990). The net sale proceed is equivalent to revenues from sales of fish minus the operating costs. The per vessel labour cost is converted to per standard day equivalent. The opportunity cost is obtained from an estimate by Tai (1993). However, the estimate was RM 9.07 per standard drift-net day and the conversion to per standard small trawl day yields an opportunity cost of RM 114.83.

The cost per standard day is the sum of the costs discussed above. However the gears used in exploiting demersal fish also catch other species as well. Therefore, the cost has to be apportioned such that it reflects only the cost relevant to demersal fish catch. The cost is apportioned based on the ratio of demersal to total fish landed in 1989 (i.e. 17%). After taking into account the rate of inflation, the cost per unit of standard day in 1992 is estimated at RM 122.56.

Price of Fish

Ex-vessel price of demersal fish is used in this study since it is the price directly received by fishers. It is assumed that price changes at other levels of the marketing chain will be transmitted to the ex-vessel level in the long-run. The ex-vessel price remains constant in this study because individual fishers are considered as price takers whose landings are insignificant to affect prices. Data on ex-vessel prices of selected demersal fishes are published in the Annual Fisheries Statistics. The average of these prices for the year 1992 is RM 4.15 per Kg.

RESULTS

The Schnute and CYP production models (equations 16 and 17 respectively) are estimated by OLS using catch and effort data from Figure 1. The estimated results are shown in Table 1. The Schnute model has a poor fit with a low R^2 value eventhough the parameters have the correct signs. The poor fit was probably due to the problem as pointed out by Schnute (1977) that it is unclear whether to use $\ln(U_{t+1}/U_t)$ or $((U_t + U_{t+1})/2)$ as the regressand. The estimated results of the CYP model give a good fit of the data. However, first-order autocorrelation appears to be present in the model based on the Durbin-Watson statistic. This problem can be corrected using the Cochrane-Orcutt procedure (Maddala 1992). The results of the first-order autocorrelation corrected CYP model as presented in Table 1 show that all the coefficients have the proper signs. However, only the coefficient bl is significant at the 1% level. This may probably be due to data problem and/or the assumptions made in deriving the CYP model (Clarke et al., 1992). Nevertheless, the high R^2 values of CYP model show that the model fits the data better compared to the Schnute model. Thus the estimates of the CYP model were used in this study.

TABLE 1
Empirical estimates of the surplus production model for the demersal fishery in NWPM.

	Model	
	Schnute	CYP#
a	0.2855	1.8485
	(0.2372)	(1.5700)
b_1	-0.4013×10^{-2}	0.7799
	(−0.4987)	(6.637)*
b_2	-0.7772×10^{-7}	-0.3783×10^{-6}
	(−0.1079)	(−1.2590)
R^2	0.0265	0.8593
R^2-bar	−0.1033	0.8406
DW	2.4474	2.0276
D-h	−1.0892	−0.8018

*P = 0.01.
\# = Cochrane-Orcutt procedure for correcting first-order autocorrelation.
Figures in parentheses show t-ratio.

The biological parameters r, q and K for the demersal fishery in NWPM are estimated from the CYP model. These estimates are shown in Table 2. The yield-effort curve for the CYP model together with the actual catch and effort data (1969 - 1992) for the demersal fishery in NWPM are depicted in Figure 2. It can be seen from Figure 2 that actual catches and effort for the fishery lie at the tail-end of the yield-effort curve, indicating biological overexploitation of the fishery.

The equilibrium levels of effort, catch, biomass, resource rent (i.e. profit which does not include consumer and producer surpluses) and catch per unit of effort for OAE. MSY, SMEY and DMEY are shown in Table 3. As expected, no rent is generated at OAE.

TABLE 2
Definitions and values of biological parameters estimated by the CYP Model for the demersal fishery in NWPM.

Parameter	Definition	Value
r	Intrinsic growth rate per year	0.2474
q	Catchability coefficient per standardized fishing day	0.8502×10^{-6}
K	Maximum biomass in MT	5,216,471

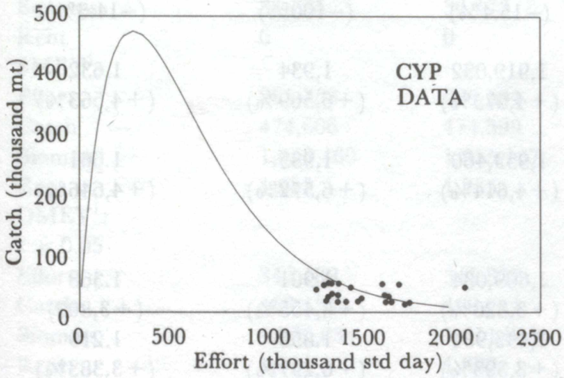


Fig. 2: Yield-Effort relationship for the CYP Model

At this point, yield is approximately 6.7 percent lower while fishing effort is 10.3 percent higher compared to the yield and effort in 1991. These figures indicate that the present (1991) level of exploitation of the demersal fishery in NWPM shows slight improvement over the OAE level.

Comparisons of the present level of exploitation with the MSY and the optimal bioeconomic levels confirm that biological and economic overfishing of the demersal stock in NWPM has occurred. Great improvement in the fishery can be achieved if fishing effort can be reduced to the MSY or the optimal bioeconomic level of exploitation. That is, if fishing effort can be reduced by 62 to 78 percent of the present level, yield will increase from 394,080 mt to 474,682 mt, representing 754 to 928 percent increase in yield from the present level. Likewise, the biomass will increase by 2,131 t0 4,614 percent, while catch per unit of effort will increase by 2,126 to 4,646 percent from the present level with the same quantum of effort reduction. More importantly, tremendous increase in resource rent can be achieved by reducing effort. With a 62 percent reduction of present level of fishing effort, resource rent increases from RM 29 million to RM 1,573 million, representing an increment of 5,324 percent. If fishing effort is reduced to the SMEY level, resource rent increases to RM 1,935 million or an increment of 6,572 percent.

Various discount rates used result in different DMEY levels of exploitation. As discount rate increases from 5 to 20 percent, fishing effort increases from 342,189 days to 506,204 days respectively. However, these levels of effort are still much lower than the 1991 level. On the other hand, discount rate increases will reduce DMEY level of yield, biomass, catch per unit of effort and resource rent.

Increases in cost per unit of effort and ex-vessel price will have significant effects on the optimal levels of exploitation of the demersal fishery in NWPM. When cost per unit of fishing effort is raised from the present (base-case) cost of RM 122.56 per standard day, equilibrium fishing effort and resource rent will be reduced while biomass will be increased for OAE, SMEY and various DMEY (Table 4). However, catches for OAE and DMEY will be increased while catch levels for SMEY are reduced slightly. On the contrary with increases in ex-vessel price, fishing effort and resource rent will be increased while biomass will be decreased for OAE, SMEY and DMEY levels (Table 5). Yield will be decreased for OAE and DMEY but will be increased slightly for SMEY level with increases in ex-vessel prices.

CONCLUSIONS AND DISCUSSION

A requisite for managing the demersal fishery in NWPM is to determine the optimal level of

TABLE 3
Open access, MSY and optimal bioeconomic levels of effort, yield, biosmass, rent and catch per unit effort for demersal fishery in NWPM.

	Effort (SD)	Catch (MT)	Biomass (MT)	Rent (RM mill.)	CPUE (MT/SD)
Present (1991)	1,322,494	46,154	41,048	29	0.035
OAE[1]	1.458,094 (+10.3%)	43,061 (−6.7%)	34,735 (−15.4%)	0 (−100%)	0.030 (−14.3%)
MSY[1]	290,931 (−78.0%)	474,682 (+928%)	1,919,032 (+4,575%)	1,934 (+6,569%)	1.632 (+4,563%)
SMEY[1]	285,758 (−78.4%)	474,606 (+928%)	1,953,460 (+4,614%)	1,935 (+6,572%)	1.661 (+4,646%)
DMEY[1]:					
δ = 0.05	342,189 (−74.1%)	468,125 (+914%)	1,609,034 (+3,820%)	1,901 (+6,455%)	1.368 (+3,809)
δ = 0.08	375,698 (−71.6%)	458,051 (+892%)	1,433,984 (+3,393%)	1.855 (+6,297%)	1.219 (+3,383%)
δ = 0.10	397,868 (−69.9%)	449,489 (+874%)	1,328,769 (+3,137%)	1,817 (+6,166%)	1.130 (+3,129%)
δ = 0.12	419,888 (−68.3%)	439,787 (+853%)	1,231,907 (+2,901%)	1,744 (+5,914%)	1.047 (+2.891%)
δ = 0.15	452,610 (−65.8%)	423,630 (+818%)	1,100,860 (+2,582%)	1,703 (+5,772%)	0.936 (+2,574%)
δ = 0.20	506,204 (−61.7%)	394,080 (+754%)	915,646 (+2,131%)	1,573 (+5,324%)	0.779 (+2,126%)

Note: Figure in parentheses represent percentage increase (+) or decrease (−) from the present (1991) level.

[1] OAE = open access equilibrium, MSY = maximum sustainable yield, SMEY = static maximum economic yield, and DMEY = dynamic maximum economic yield.

exploitation based on some pre-determined objectives of management. These objectives may include maximizing the biological sustainable yield or maximizing economic yield from the fishery. There are two kinds of maximum economic yields: (1) the static economic yield which treats the planning horizon to be myopic and (2) the dynamic economic yield which takes account of the welfare of future generations into the planning horizon.

In fisheries management, resource managers are frequently forced to make management decisions based on relatively limited biological and economic data. In such situations, surplus production models may be useful because they require relatively limited data, although some (e.g. Townsend 1986) question their applicability. The surplus production model specified following the procedure developed by Clarke, Yoshimoto and Pooley has the best fit of the catch and effort data for the demersal fishery in NWPM. Thus the CYP model is used as the basis for computing the biological parameters for estimating the optimal bioeconomic levels of exploitation.

A comparison of the optimal bioeconomic and current levels of exploitation of the demersal stock in NWPM indicates that the stock has been biologically and economically overfished even though present level of exploitation shows slight improvement compared to the open access level. The results also

TABLE 4
Effects of increases in cost per unit effort on OAE and optimal bioeconomic level of exploitation for demersal fishery in NWPM

	Cost per unit effort(RM/SD)				
	Base case	+5%	+10%	+15%	+20%
OAE[1]:					
Effort	1,458,094	1,443,895	1,430,357	1,417,441	1,405,055
Catch	43,061	44,775	46,468	48,138	49,793
Biomass	34,735	36,473	38,210	39,944	41,682
Rent	0	0	0	0	0
SMEY[1]:					
Effort	285,758	285,504	285,250	284,997	284,745
Catch	474,606	474,599	474,591	474,582	474,573
Biomass	1,953,460	1,955,167	1,956,872	1,958,572	1,960,274
Rent	1,935	1,933	1,931	1,929	1,928
DMEY[1]:					
$\delta = 0.05$					
Effort	342,189	341,822	341,455	341,090	340,725
Catch	468,125	468,214	468,301	468,388	468,474
Biomass	1,609,034	1,611,068	1,613,100	1,615,126	1,617,153
Rent	1,901	1,899	1,897	1,896	1,894
$\delta = 0.10$					
Effrot	397,868	397,354	396,841	396,331	395,822
Catch	449,489	449,702	449,914	450,124	450,333
Biomass	1,328,769	1,331,120	1,333,467	1,335,807	1,338,146
Rent	1.817	1,815	1,814	1,812	1,811
$\delta = 0.15$					
Effort	452,610	451,909	451,212	450,520	449,829
Catch	423,630	423,994	424,356	424,714	425,071
Biomass	1,100,860	1,103,514	1,106,161	1,108,798	1,111,433
Rent	1,703	1,701	1,700	1,699	1,698
$\delta = 0.20$					
Effort	506,204	505,273	504,347	503,429	502,514
Catch	394,080	394,616	395,148	395,676	396,200
Biomass	915,646	918,582	921,509	924,423	927,333
Rent	1,573	1,573	1,572	1,571	1,570

[1] OAE = open access equilibrium, SMEY = static maximum economic yield, and DMEY = dynamic maximum ecoonomic yield.

highlight the need to reduce fishing effort by as much as 60 to 78 percent from the present level. With this quantum of effort reduction, catches of demersal fish can be increased by as much as 7 to 9 times while resource rent can be increased by 53 to 65 times using current ex-vessel prices and per unit cost of effort. The implication is that there is an urgent need to formulate appropriate effort reduction management policies for the fishery in order to derive maximum benefits. These effort reduction policies may include non-replacement of aging vessels, implementing a vessel buy-back scheme to accelerate attrition of vessels, allowing the use of fishing vessels on a rotating basis, and encouraging and facilitating fishermen to seek alternative employment outside the fishery sector.

Fishing effort reduction which leads to increased catch and resource rent provides incentives for fishers to increase participation in the fishery, thereby eroding the rent accruable from the fishery. Thus in addition to the biological dynamics of fish stock, the

TABLE 5
Effects of increase in ex–vessel prices on OAE and optimal bioeconomic level of exploitation for demersal fishery in NWPM

	Ex–vessel Price (RM/Kg.)				
	Base case	+5%	+10%	+15%	+20%
OAE[1]:					
Effort	1.458,094	1,472,456	1,486,141	1,498,603	1,511,137
Catch	43,061	41,391	39,856	38,505	37,190
Biomass	34,735	33,062	31,543	30,220	28,946
Rent	0	0	0	0	0
SMEY[1]:					
Effort	285,758	286,003	286,226	286,420	286,607
Catch	474,606	474,613	474,619	474,625	474,629
Biomass	1,953,460	1,951,816	1,950,321	1,949,020	1,947,764
Rent	1,935	2.034	2,134	2,229	2,329
DMEY[1]:					
$\delta = 0.05$					
Effort	342,189	342,544	342,867	343,149	343,421
Catch	468,125	468,040	467,961	467,892	467,826
Biomass	1,609,034	1,607,072	1,605,289	1,603,735	1,602,236
Rent	1,901	1,999	2,097	2,190	2,288
$\delta = 0.10$					
Effort	397,868	398,365	398,818	399,213	399,595
Catch	449,489	449,282	449,094	448,928	448,768
Biomass	1,328,769	1,326,501	1,324,438	1,322,640	1,320,905
Rent	1,817	1,910	2,003	2,092	2,186
$\delta = 0.15$					
Effort	452,610	453,287	453,905	454,445	454,967
Catch	423,630	423,277	422,955	422,673	422,400
Biomass	1,100,860	1,098,300	1,095,969	1,093,937	1,091,975
Rent	1,703	1,790	1,877	1,960	2,048
$\delta = 0.20$					
Effort	506,204	507,107	507,931	508,652	509,350
Catch	394,080	393,560	393,084	392,668	392,264
Biomass	915,646	912,810	910,228	907,975	905,798
Rent	1,573	1,654	1,734	1,811	1,891

[1] OAE = open access equilibrium, SMEY = static maximum economic yield, and DMEY = dynamic maximum economic yield.

response of fishing effort to resource rent and other social, cultural and psychological factors are also important considerations in determining the optimal exploitation of the fishery. Moreover, social objectives such as maintaining the viability of fishing communities and improving income distributions are important in practical fishery management. These aspects need to be incorporated into the model to determine the biosocioeconomic optimal levels of exploitation (Charles 1989).

Even though the CYP model appears to have a good fit, the analysis treats the demersal fishery as one aggregated stock rather than separating into various major species. At the same time, there is noticeable, although not quantifiable, targeting behaviour on different species by the major gear types. A more accurate representation of the bioeconomics of the demersal fishery could be obtained if a model is developed that integrates the biological and economic differences of the major species.

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