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Overfishing in the Gulf of Thailand: policy challenges and bioeconomic analysis

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ABSTRACT. This paper estimates maximum sustainable yield and maximum economic yield from Schaefer and Fox surplus production bioeconomic models to find evidence of biological and economic overfishing, and their consequences in Gulf of Thailand demersal fisheries. The paper examines alternative policy instruments to reduce overfishing. The discussion emphasizes strengthening fishery management for implementing limited access, and a combination of co-management, and decentralization of fisheries management. The use of license fees that serves as a double dividend tax to reduce fishing effort and fund monitoring and enforcement has been proposed as one of the possible economic instruments.

1. Introduction

The rapid expansion of fisheries in the Gulf of Thailand has raised considerable economic and environmental concerns about its management. An increasing proportion of undersized fish and decreasing volume of commercially important species in the composition of fish catch in

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recent years suggest symptoms of biological overfishing and biologically overfished resource stocks, threatening the fisheries in the Gulf. Similarly, falling profits of individual vessels and low economic rents have implications for economic viability of the fishing industry, and point to the economic overfishing and economically overfished fish stocks.

The economics and management of fisheries in the Gulf of Thailand have received only a limited amount of attention. Panayotou and Jetanavanich (1987) evaluated the levels of catch and fishing effort that give rise to the static maximum economic yield (MEY) in fisheries for demersal (bottom-dwelling) species. They found that, under conditions of the 1980s, the optimum (MEY) catch and effort (given a mesh size of 2.5 cm) for demersal fisheries were 958,000 tons and 15.7 million standard fishing hours. The results implied that demersal catch in recent years had surpassed the level of static MEY. Panayotou and Jetanavanich recommended a license limitation program to bring the fishery into balance with MEY. Piumsombun (1992) drew similar conclusions on the status of the pelagic fishery on the Indo-Pacific mackerel, locally known as 'pla-tu' in the Gulf of Thailand, suggesting that this pelagic fishery is already economically overfished. Introduction of a license limitation scheme was proposed to curb the excessive effort in the fishery.

The purpose of this paper is to provide a current bioeconomic analysis of the Gulf of Thailand demersal fisheries, comprehensive across all relevant gear and fish species, to estimate both economic and biological maximum levels of yield and effort, and then to discuss corresponding measures to manage the fishery. The Pareto-inefficient levels of yield and effort found under open access are compared to the estimated economic and biological optimums – MEY and MSY (maximum economic and sustainable yields), respectively. This comparative static analysis would provide evidence of economic and biological overfishing and overfished resource stocks as a whole, and Pareto inefficiency for the fishery.[1] Using the bioeconomic assessment as a basis, we discuss (potential) Pareto-improving economic policies to shift the fisheries toward MEY and MSY. The paper updates the analysis of Panayotou and Jetanavanich in light of the current market, fishery and environmental conditions and provides policy recommendations that are consistent with Panayotou and Jetanavanich and Piumsombun, including license limitation. There is a national urgency as well as a global significance in targeting to move toward higher level of long-term economic and biological sustainability as it will ensure the role of fisheries as an engine for economic growth in the future, and at the same time respond to the WSSD (World Summit for Sustainable Development)

[1] More formally, our comparative statics analysis compares the Pareto-inefficient, non-cooperative Nash equilibrium of open access with the Pareto-efficient cooperative equilibrium, MEY. These two benchmark equilibriums, when the resource stock is in steady-state equilibrium, correspond to the open-access and sole-owner bionomic equilibriums traditionally discussed under the bioeconomic framework. The full cooperative equilibrium could arise from a sole owner, completely structured private or common property (the latter with effective management), or some other form of cooperation or fully structured property right (Baland and Platteau, 1996).

call for restoring fish stocks to sustainable levels globally (United Nations, 2002).

The bioeconomic analysis presented in this paper is aggregate across a number of demersal gear types and species due to our comprehensive focus upon the fishery and all sources of mortality on the demersal fish stocks in the Gulf of Thailand as a whole. Disaggregated population dynamics models and bioeconomic models are notoriously difficult to apply in tropical fisheries due to the complex multispecies nature of these fisheries and demanding data requirements. An aggregate analysis has limitations in that gear-specific policy conclusions are difficult to draw out of the empirical results, but single gear and species analyses do not comprehensively assess the overall biological and economic status of the fish stocks.[2]

The balance of this paper is organized as follows. Section 2 provides a background to the fisheries and issues. Section 3 summarizes the bioeconomic models – the Schaefer and Fox models – used to obtain estimates of maximum economic yield and maximum sustainable yield. Section 4 discusses the data. Section 5 reports the empirical results. Section 6 discusses the proposed policy to reduce overfishing and increase economic rents, and Section 7 provides concluding remarks and recommendations.

2. Fisheries in the Gulf of Thailand[3]

For a number of decades fisheries development in the Gulf of Thailand has concentrated on increasing fishing effort (tables 1 and 2) to maintain or increase the production volume (figure 1). Increasingly, the total catch has a higher proportion of "trash" fish (consisting of by-catch and undersized juveniles of various demersal and some pelagic species, much of which goes to fish meal or duck feed or is thrown overboard), aggregated across all species and gear types. Catch from Department of Fisheries research trawl surveys is comprised of 30–40% "trash" fish, of which about one-third is juvenile and undersized fish. The study from commercial fisheries also

[2] The traditional bioeconomic model implicitly assumes that there is an aggregate input and output due to homothetic input-output separability, a homogeneous habitat, and a population that is perfectly mixed throughout, or that there is non-joint production with a perfectly allocable composite input (fishing effort). Moroever, an analysis disaggregated by gear type and/or species has its own set of limitations, including presumed nonjointness. For example, bioeconomic models for a single gear type do not incorporate all sources of fishing mortality on the multispecies resource stocks, and thereby do not provide fully accurate empirical results for a policy aimed at all sources of fishing mortality on a given set of resource stocks. Moreover, policy conclusions from a single-gear bioeconomic analysis do not consider spillover effects from this other gear. Bioeconomic models for a single species in a multispecies fishery, even if incorporating all gear types, clearly do not capture all multi-species interactions in the population dynamics and implicitly assume nonjointness. In short, there are clear advantages and disadvantages for the different possible levels of aggregation. In this paper we are concerned with the overview status of the demersal fisheries of the Gulf of Thailand.

[3] The background discussion draws from Boonchuwongse and Dechboon (2002), Chullasorn (1997), Jirapanpipat (1992), Sripanpaiboon (1995), Suvapepun (1995), and Vadhanakul *et al*. (1985).

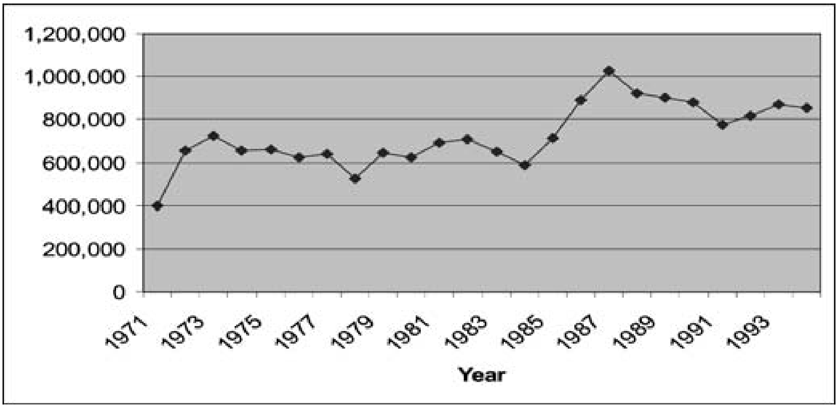

Figure 1. *Total Catch (metric tons) of Demersal and Trash Fish in the Gulf of Thailand, 1971–1995*
Source: Department of Fisheries, Thailand
Note: Total catch (metric tons) includes demersal "target" and "trash" fish of all species caught in demersal fisheries.

shows that "trash" fish contains at least 30% juvenile fish. Pair trawl catch has the highest composition of juvenile fish, namely Indo-Pacific mackerel, threadfin bream, lizard, big eye, scad, and sardine that represented 70% of total "trash" fish. Otter board trawl obtains juvenile fish, about 40% of total "trash" fish (Sripanpaiboon, 1995; Eiamsa-Ard and Amornchairojkul, 1997).

Table 2 displays standard total fishing effort, standardized across all gear types to be comparable to 14–18 m otter trawl vessels (this procedure is discussed in Section 3). Standard effort rises until reaching a peak in 1987, after which it falls. The most important fishing gear for the capture of demersal "target" and "trash" fish (of all species caught in demersal fisheries, but predominately demersal species) is otter board trawl, pair trawl and push net (table 2). The numbers of otter board and pair trawl vessels have increased over time, but the number of push net vessels has fallen (table 1). Trawl fishing provides the greatest source of fishing mortality of all the major gear types, and the number of trawl vessels is increasing over time.

A major source of the decline in demersal fisheries is overfishing by trawl gear at a depth of more than 50 m since 1973. Nominal catch per unit of effort or CPUE (kg/hour) by trawlers steadily declined, indicating declining resource stock abundance (Meemeskul, 1982; Vadhanakul *et al.*, 1985; Chotiyaputta, 1992; Intong *et al.*, 1993; Jirapanpipat, 1992), while the number of trawlers of all sizes and types continued to increase (table 1). Trawlers began to use the small cod-end mesh size, so that more "trash fish" could be caught to at least partly compensate for the declining production and value of targeted species and sizes of demersal fish. In addition, many trawlers, which formerly fished in foreign fishing grounds, returned to the Gulf of Thailand to fish after the declaration of Extended Economic Zones (EEZs) in the recent decades by the neighboring countries.

Table 1. *Number of fishing vessels in the Gulf of Thailand, 1972–1997*

Year	*Otter board trawl*	*Pair trawl*	*Push net*
1972	2,813	702	1,232
1973	3,927	824	1,470
1974	3,595	854	1,062
1975	3,397	850	933
1976	3,735	814	697
1977	4,536	878	946
1978	4,610	804	1,137
1979	6,273	1,120	1,394
1980	7,192	1,092	1,644
1981	5,285	910	883
1982	8,030	1,306	1,244
1983	6,849	1,180	941
1984	6,745	1,072	777
1985	6,108	1,122	663
1986	5,416	1,060	579
1987	5,343	1,078	554
1988	4,997	1,046	490
1989	8,825	1,943	1,111
1990	8,686	1,929	1,119
1991	6,941	1,822	765
1992	6,367	1,661	634
1993	6,242	1,539	663
1994	5,531	1,508	543
1995	5,463	1,392	534
1996	5,912	1,610	620
1997	6,036	1,561	771

Source: Department of Fisheries, 1972–1997.

Gear types other than trawl and push net also contribute to fishing mortality of demersal species and "trash" fish in the Gulf of Thailand (table 2). These other gear types include various types of purse seine and gill net gear. Total fishing effort, both nominal and standardized, of these other gear types is much smaller, and exerts substantially less fishing mortality, than trawl and push net gear. Standardized fishing effort of this other gear, although very small in comparison to trawl and push net gear, has been rising over 1971–1997.

With the decline in the catch of "target" demersal species in an increasingly impoverished fishery, "trash" fish provides an increasingly important source of total catch and revenue through its use for fish meal and to a lesser extent, duck feed. The increasing importance of "trash" fish and fishing for demersal species of lesser commercial importance or fishing demersal species further down the food chain is reflected in table 3, where standardized (discussed below) CPUE continues to climb due to the catch of these fish, even as the catches of the most desirable demersal species

Table 2. *Nominal Fishing Effort by Gear Type for Demersal and Trash Fish in the Gulf of Thailand, 1971–1995 ('000 hours)*

Year	*Otter trawl*	*Pair trawl*	*Beam trawl*	*Push net*	*Purse seine*	*Gill nets*	*Total*
1971	7,036	1,050	179	988	0	0	9,252
1972	10,268	1,349	980	467	0	0	13,064
1973	13,992	1,268	1,172	1,732	0	0	18,164
1974	12,159	1,312	593	1,147	0	0	15,211
1975	10,942	1,004	52	1,251	0	0	13,248
1976	11,352	1,302	475	930	0	0	14,059
1977	13,826	1,709	2,003	1,531	686	0	19,070
1978	12,151	1,292	753	1,636	242	162	15,832
1979	13,747	1,408	813	1,540	722	639	17,508
1980	11,109	1,266	691	1,534	709	408	14,600
1981	10,944	1,161	644	1,189	691	375	13,940
1982	12,402	1,116	1,364	2,553	972	352	17,435
1983	12,651	1,322	387	1,234	1,430	432	15,593
1984	11,452	1,195	248	948	1,401	467	13,844
1985	12,178	1,172	169	723	1,287	613	14,243
1986	14,551	1,554	96	616	1,527	722	16,816
1987	15,327	1,794	32	645	1,374	698	17,798
1988	14,395	1,748	53	456	1,647	740	16,652
1989	13,311	1,645	54	457	1,435	472	15,467
1990	13,808	1,610	54	459	2,041	554	15,931
1991	11,484	1,275	43	694	1,019	1,745	13,496
1992	10,492	1,220	31	450	1,114	406	12,193
1993	10,062	1,423	35	594	1,154	403	12,114
1994	11,922	1,324	125	700	1,045	268	14,071
1995	11,529	1,620	87	543	1,873	420	13,780

Source: Department of Fisheries, Thailand.

stagnate or fall. Standard CPUE also continues to climb due to productivity growth, which is largely due to technological innovations such as the increasing adoption and use of vessel electronics.

Most of the important pelagic fish (fish in the middle and upper parts of the water column) in the Gulf of Thailand are fully exploited, namely, Indo-Pacific mackerel, anchovies, round scad and sardines. Indian mackerel is not yet overfished (Chullasorn, 1997). Almost all of the demersal (bottom dwelling) resource stocks, namely fish, shrimps, squid, cuttlefish and others, are overfished (FAO, 1995).

The significant expansion of the Thai fishing fleet during the past three decades entails not only more fishing vessels, but also vessels which are larger in size. In 1997, there were 16,264 fishing vessels in Thailand, of which 77% were registered in the provinces located in the Gulf. Otter board trawl and pair trawl are the most important type of fishing vessels, comprising about 53% of the total fleet in 1997. The remainder of the fleet is comprised of purse seiners, gillnetters and other small boats employing traditional

Table 3. *Total catch, standard fishing effort, and catch per unit of effort, 1971–1995*

Year	*Total catch (metric ton)*	*Total standardized fishing effort (hours)*	*Catch per unit of standardized effort (kg/hour)*
1971	395,728	11,876,715	33.32
1972	656,695	14,540,695	45.16
1973	723,422	19,705,566	36.71
1974	656,601	17,177,347	38.22
1975	657,952	15,406,302	42.71
1976	622,349	15,767,966	39.47
1977	639,212	20,418,085	31.31
1978	522,979	17,359,494	30.13
1979	645,951	21,109,841	30.60
1980	625,453	17,523,633	35.69
1981	692,330	16,713,349	41.42
1982	707,190	21,007,226	33.66
1983	647,764	20,110,684	32.21
1984	585,004	18,760,727	31.18
1985	711,164	18,256,176	38.95
1986	888,945	22,938,792	38.75
1987	1,028,110	24,266,210	42.37
1988	920,622	23,363,011	39.41
1989	903,741	21,116,546	42.80
1990	880,614	22,366,674	39.37
1991	774,104	20,549,582	37.67
1992	816,095	16,528,634	49.37
1993	869,601	16,988,426	51.19
1994	852,428	18,619,483	45.78
1995	895,711	19,934,393	44.93

Source: Department of Fisheries, 1972–1997.
Note: Total catch includes demersal "target" and "trash" fish of all species caught in demersal fisheries.
Standardized fishing effort is standardized across gear types to 14–18 m otter trawl vessels.

gear. The fishing fleet is classified into four vessel sizes: less than 14 m, 14–18 m, 18–25 m and over 25 m. The smallest vessel size accounts for 28% of the total fleet.

Fishing vessels larger than 18 m in length employ advanced fishing and navigation technologies, involving the use of sonar systems, echo sounders, radios, radar and electricity generators. The continued adoption of vessel electronics contributed to continual growth in total factor productivity ("fishing power"), and thus increased effective fishing effort.

3. Schaefer and Fox surplus production models

Maximum sustainable and economic yields and the associated optimum levels of fishing effort can be estimated from surplus production models. The two most widely used surplus production models, the Schaefer (1957) and Fox (1970), are employed in this paper to estimate the biological and economic optimums. In light of the uncertainty that naturally arises over the most appropriate form of the population dynamics (Quinn and Deriso, 1999), we estimate these two models with their differing functional forms. If the empirical results from the two models signal consistent conclusions about the maximum economic and biological sustainable yields and effort levels relative to current levels, then the implications for the directions for catch and effort that lead to the social optimum can be considered robust. In addition, since market, environmental, and community and population ecological conditions do change over time, the estimated biological and economic optimums correspondingly change, requiring future re-estimation of these models. Hence, the steady-state optimum levels *per se* from these two models will change over time, but the current implied policy direction for catch and effort are the key pieces of information of interest to this study.

For stock assessments in developed countries, surplus production models have largely been superseded by various types of age-structured models (virtual population analysis) or even more sophisticated synthetic models that synthesize all of the available information, such as age structures and other demographic information, length-weight relationships, stock-recruitment, and other available information (Fournier *et al.,* 1998). These synthetic models are applied to individual species rather than overall catch. Nonetheless, age-structured and the more sophisticated synthetic species-specific models require more abundant and detailed data by species, such as age determination or length-frequency, which are simply unavailable in the fisheries of developing countries. In the tropics, for example, age determination on a broad scale – especially with so many species, is simply beyond the reasonable reach of analysts. Species sampling of landings on a consistent scale is seldom available. In contrast, production models can be applied when reasonable estimates are available of the total catch or CPUE and the related fishing effort over a number of years, and are the type of model frequently applied in tropical developing countries.[4] As Hilborn and Walters (1992, p. 298) observe, "Furthermore, in many fisheries, again tropical ones especially, the catch consists of many species, and the catch data are difficult if not impossible to collect by species. Management regulations are also difficult to make species specific. In these circumstances, treating the entire catch as a biomass dynamics pool may be more appropriate than trying to look at single species dynamics.

Two widely known and applied surplus production models, which are particularly applicable to multi-species fisheries in the tropics, are those developed by Schaefer (1957) and Fox (1970). The Schaefer and Fox models are based on the steady-state relationship between resource stock size, fishing effort, and yield. Sustainable yield is a function of total effort

[4] In addition, a major advantage of aggregating multiple species is in specification of fishing effort, and implicitly, the capital stock. As a general rule according to economic principles, capital services or fishing effort when production is joint cannot be allocated among different outputs or species. We thank an anonymous referee for raising these points.

and stock size. Stock size (biomass) is a function of fishing effort and a limited number of biological parameters, such as the intrinsic growth rate and environmental carrying capacity. Growth is assumed to be density-dependent. Given the biological and environmental parameters, sustainable yield is determined by the fishing effort applied. The models are long-run, since they reflect complete resource stock adjustment to changes in the level of fishing effort and fishing effort is a completely variable input. Table 4 provides the relevant formulae for the Schaefer and Fox models.

4. Data

The data for the demersal "target" and "trash" fish catches in the Gulf of Thailand by Thai vessels using otter board trawl, pair trawl, and push nets were available over the period 1971–1995.[5] These data exclude effort outside Thailand from the distant-water fleet. These data were collected from the Fisheries Statistics Base of the Sample Survey (various issues), officially reported by the Fisheries Economics Division of the Department of Fisheries.

The demersal harvests were divided into 17 species of demersal "target" and "trash" fish. The species of demersal fish included barracudas, croakers, threadfin breams, monocle breams, lizardfishes, hairtails, snappers, sweetlips, bigeyes, sand whitings, barbell eel, marine catfishes, rays, sharks, flatfishes, Indian halibut, and conger eels. For the period 1971–1984, the data reported the catch of the demersal species and "trash" fish from Thai waters, but were broken down by gear types and vessel sizes. The proportion of demersal catch from the Gulf of Thailand was estimated from the Marine Fisheries Statistics Base on the Sample Survey during 1985–1995. During 1985–1995, the report showed the catch of demersal and "trash" fish from the Gulf of Thailand and Andaman Sea, and was broken down by gear types and vessel sizes. Table 1 reports the number of fishing vessels in the Gulf of Thailand and table 2 reports the catch and catch per unit of standardized effort, where catch includes both demersal and "trash" fish.

To match demersal and "trash" fish catches with their corresponding levels of fishing effort, data were collected in the Gulf of Thailand on vessel fishing hours. During 1971–1995, (nominal) fishing effort data, reported in table 2, were obtained from the Marine Fisheries Statistics Base on the Sample Survey. Since demersal and "trash" fish resources are caught by various types of gear and sizes of vessels, fishing effort was

[5] To be perfectly clear, the directed demersal fishery on the "target" species focuses upon demersal species. However, part of the catch – "trash" fish – is comprised of juveniles of "target" demersal species, which are of small size and lesser or no market value, and bycatch of other, non-demersal species, which often have little or no commercial value. Thus, these bycatch species are undesirable outputs and there is joint production with desirable and undesirable outputs with unknown product transformation possibilities. In addition, the bycatch is comprised largely of demersal species, but also includes some pelagic species, *Cepharopod*, crab, shrimp, molluscs, and others. (Most trawl gear drag along the sea bottom, and hence bring up some animals from the benthic community plus other animals that dwell in the lower reaches of the water column.)

Table 4. *The Formulae Used To Fit The Schaefer And Fox Production Models And Estimate The Relevant Parameters*

	Schaefer model	*Fox model*
Catch-effort relationship	$Y_t = \alpha f_t - \beta f_t^2$	$Y = f e^{(\lambda+\theta f)}$
Linear relationship between catch per unit of effort and fishing effort	$\frac{Y_t}{f_t} = \alpha - \beta f_t$	$\ln(\frac{Y_t}{f_t}) = \lambda + \theta f_t$
Level of fishing effort at MSY (f_{MSY})	$f_{MSY} = \frac{\alpha}{2\beta}$	$f_{MSY} = -\frac{1}{\theta}$
Maximum sustainable yield (MSY)	$MSY = \frac{\alpha^2}{4\beta}$	$MSY = -\frac{1}{\theta} e^{\lambda-1}$
Total revenue (TR)	$TR = p(\alpha f_t - \beta f_t^2)$	$TR = p f e^{(\lambda+\theta f)}$
Marginal revenue (MR)	$MR = p(\alpha - 2\beta f_t)$	$MR = p\lambda(f\theta e^{\theta f} + e^{\theta f})$
Average revenue (AR)	$AR = p(\alpha - \beta f_t)$	$AR = pe^{(\lambda+\theta f)}$
The level of effort that maximizes economic yield (f_{MEY})	$f_{MEY} = \frac{(c-p\alpha)}{2\beta p}$	$\frac{c}{p\lambda} = f_{MEY}\theta e^{\theta f_{MEY}} + e^{\theta f_{MEY}}$
Maximum economic yield (MEY)	$MEY = \alpha f_{MEY} - \beta f_{MEY}^2$	$MEY = p f_{MEY} e^{(\lambda+\theta f_{MEY})}$
Maximum economic rent (MER)	$MER = p(\alpha f_{MEY} - \beta f_{MEY}^2) - c f_{MEY}$	$MER = p f_{MEY} e^{(\lambda+\theta f_{MEY})} - c f_{MEY}$
Nash equilibrium level of fishing effort in open access	$f_{OA} = \frac{(c-p\alpha)}{\beta p}$	$f_{OA} = \frac{\ln(\frac{c}{p})-\lambda}{\theta}$

Where:
Y_t denotes yield or total landing of fish at time t
f_t is fishing effort at time t
α and β are parameters of the Schaefer model
λ and θ are parameters of the Fox model
p is the constant price of the catch
c is the constant marginal. When estimating the level of effort that maximizes economic rents (f_{MER}) the marginal revenue (MR) and marginal cost of fishing are equated.

Table 5. *Distribution of Vessel Sizes and Annual Costs of Trawl and Push Nets by Size of Fishing Vessel in the Gulf of Thailand, 1995*

Type of fishing gear	*Size of vessel (meters)*	*No. of fishing units*	*Average annual cost (Baht/unit)*	*Amount cost (Baht × 10^6)*
Otter Trawl	< 14	1,784	825,380	1,472.49
	14–18	1,948	1,556,740	3,032.53
	18–25	1,496	2,275,200	3,403.70
Subtotal				7,908.71
Pair Trawl	< 14	16	1,947,864	31.17
	14–18	186	2,702,003	502.27
	18–25	491	4,608,520	2,262.78
Subtotal				2,796.52
Push Net	< 14	402	614,107	246.87
	14–18	85	1,173,753	99.77
	18–25	35	2,306,508	80.73
Subtotal				427.37
Grand Total				11,132.60

Source: Fisheries Economic Division, Department of Fisheries.

standardized into equivalent or standardized units. Nominal fishing effort was standardized for the fishing gears of otter board trawl, pair trawl, beam trawl, push net, purse seine, anchovy purse seine, mackerel encircling gill net, and king mackerel gill net. Since engine horsepower (HP) differs for different-sized vessels and types of gear, nominal fishing hours were standardized by using 14–18 m otter board trawl as the standard. That is, an index of vessel HP was computed using 14–18 m otter board trawl vessel engine HP as the basis. Table 5 reports the distribution of vessel sizes. Standard fishing effort, reported in table 3, is calculated by multiplying this standard HP index for each gear by the nominal fishing hours for that gear.

Standardization proceeded somewhat differently for small-scale fisheries and bamboo stake trap, since data on fishing hours were unavailable. Standard fishing effort was calculated by dividing catch by catch per hour of a 14–18 m otter board trawl vessel. The total standard fishing effort is the sum of the standard effort of all the gear types (table 3).

Since effective fishing effort is affected over time through gear improvement, a technological adjustment factor is calculated by dividing catch per hour of the standard vessel by catch per hour of the research vessel (Ahmed, 1991). The catching power of the research vessel remained unchanged over time, allowing it to serve as a technological standard. For 1990, 1992, and 1994, no experimental survey was conducted, and the mean catch per unit of effort of the preceding and following years was used as an estimate of CPUE. The adjusted fishing effort is calculated by multiplying standard fishing effort by the technological adjustment factor.

The unit cost of fishing effort is represented by costs per standard unit of fishing effort. The total cost of fishing for demersal fish was calculated from the result of the *Cost and Earnings Survey of Major Fishing Gear* in 1995 (Department of Fisheries, 1997). The major fishing gear was otter board trawl, pair trawl, and push net. By using the annual cost of major fishing gear per vessel, the major cost of each fleet is calculated by multiplying the annual major fishing gear cost per vessel by the total number of vessels in the Gulf of Thailand in 1995 employed in that fleet. The total fleet cost is the sum of the cost of all the gear types. This total cost represents the total cost of total catches in the Gulf of Thailand. The proportion of demersal and "trash" fish catch value was estimated from Fisheries Statistics of Thailand in 1995. The percentage of demersal fish value is 34.33. The demersal fish cost is calculated by multiplying percentage of demersal "target" and "trash" fish value by the total cost. The demersal fish cost of major fishing gear is divided by the total standard fishing effort of that gear. The cost per unit of fishing effort was estimated as 69.67 Baht per standard fishing hour (for a mesh size of 2.5 cm).

Demersal and "trash" fish prices from the Gulf of Thailand were obtained from Fisheries Statistics of Thailand in 1995. The 1995 price of fish per kilogram was estimated as 6.68 Baht/kg.

5. Empirical results

The CPUE forms of the Schaefer and Fox models were estimated by ordinary least squares over 1971–1995 for the commercial fleet and are summarized in table 6.[6] Based on these estimates, MSY for a mesh size of 3.4 cm for the standardized commercial fleet for demersal and "trash" fish and the corresponding level of standardized effort were calculated using equations from table 4.

The empirical results, along with the corresponding actual 1995 values, are reported in table 7 for the Schaefer model and table 8 for the Fox model and illustrated in figure 2 for both models. The results are fundamentally consistent for the MSY and MEY levels of catch, effort, and economic

[6] OLS estimation when there is f (fishing effort) on both sides of the CPUE equation is standard practice in the estimation of bioeconomic models. In addition, this is a standard approach to dealing with a common form of heteroscedasticity. If f is exogenous as a fixed explanatory variable, then division by f does not introduce simultaneous equation bias and inconsistent estimates of the regression coefficients since f is fixed. The fixed explanatory variables paradigm automatically leads to a lack of correlation between the disturbance term and the explanatory variable f (which in turn give consistent estimates). In contrast, when the explanatory variable f (along with the data on the response variable catch) is assumed to be random samples drawn from the population, fixed explanatory variables cannot be identically distributed across observations and the random sampling assumption technically excludes the classical regression model. We can reasonably consider f to be exogenous as a fixed explanatory variable, as opposed to a random sample, since the data are population data obtained by aggregating over all observations, vessels, and most gear types.

Table 6. *Estimation Results for Schaefer and Fox Models*

Schaefer model				Fox model			
Variable	*Estimated coefficient*	*Standard error*	*t-Ratio*	*Variable*	*Estimated coefficient*	*Standard error*	*t-Ratio*
Intercept (α)	57.1346	1.5892	35.95	Intercept (λ)	4.1903	0.0308	136.07
Fishing effort (f) (β)	8.2173E-07	5.5049E-08	14.9273	Fishing effort (f) (θ)	2.7533E-08	1.0667E-09	24.88
Adj. R^2 0.90				Adj. R^2 0.96			
Standard Error 4.0619				Standard Error 0.0787			
Overall F 222.82, df 24				Overall F 618.82, df 24			
No. Observations 25				No. Observations 25			

Table 7. *Catch, Revenues, Costs, Profits at Different Levels of Effort for Schaefer Model*

Items	*Effort ($\times 10^6$ std. hours)*	*Catch ($\times 10^3$ tons)*	*Revenues (Baht $\times 10^6$)*	*Costs (Baht $\times 10^6$)*	*Profit (Baht $\times 10^6$)*
MSY	34.76	993	6,634	2,422	4,212
MEY	28.42	960	6,413	1,980	4,433
Open access equilibrium	56.84	593	3,960	3,960	0
Actual (1995)	56.62	896	5,983	3,945	2,039

Table 8. *Catch, Revenues, Costs, Profits at Different Levels of Effort for Fox Model*

Items	*Effort ($\times 10^6$ std. hours)*	*Catch ($\times 10^3$ tons)*	*Revenues (Baht $\times 10^6$)*	*Costs (Baht $\times 10^6$)*	*Profit (Baht $\times 10^6$)*
MSY	37.69	916	6,116	2,626	3,491
MEY	25.86	860	5,745	1,802	3,943
Open access equilibrium	69.56	725	4,846	4,846	0
Actual (1995)	56.62	896	5,983	3,945	2,039

Note: Total catch includes demersal "target" and "trash" fish of all species caught in demersal fisheries.

rent under both the Schaefer and Fox models, as clearly demonstrated in figure 2. The model results differ only for the open-access levels of fishing effort, since the Fox model (with the Gompertz exponential growth function) allows for higher levels of fishing effort before reaching zero total sustainable revenues. Hence, the two different models signal consistent policy conclusions regarding the direction of changes in the levels of fishing effort and total catch of demersal "target" and "trash" fish that give MSY and MEY, thereby providing greater confidence in these policy conclusions even in light of the uncertainty over the appropriate population dynamics.

Highlighting the results from the Schaefer model (table 7), the MEY level of fishing effort is about 50% of the actual 1995 level and 82% of the MSY level. However, the actual catch of demersal fish is 93% of MEY and 90% of the MSY catch. Economic rents are, as expected, highest at MEY, amounting to 4,433 million Baht or 5% higher than at MSY. Highlighting the results of the Fox model (table 8), the MEY level of fishing effort is about 46% of the actual 1995 level and 69% of the MSY level. However, the actual catch is 98% of MSY catch. Economic rents are, as expected, highest at MEY, amounting to 3,943 million Baht or 5% higher than at MSY.

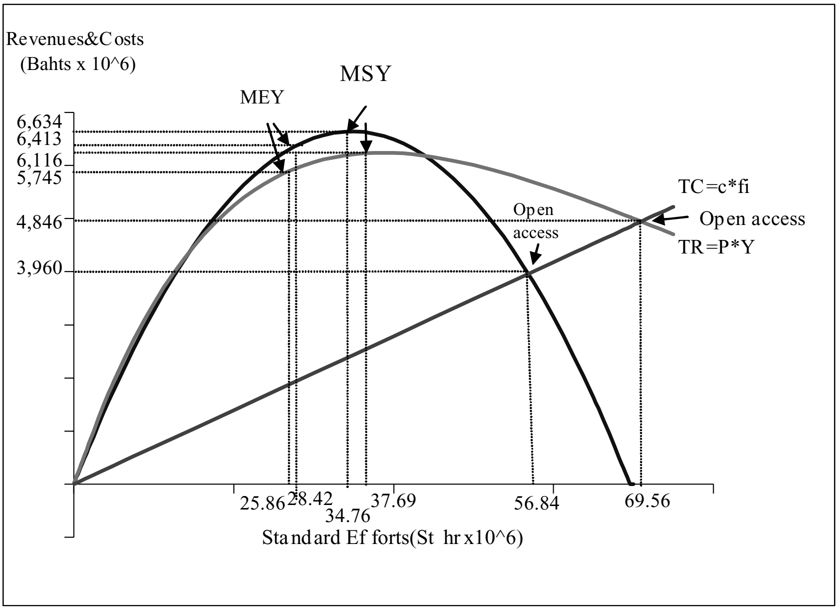

Figure 2. *Estimated Schaefer and Fox Model Results for Demersal Fisheries in the Gulf of Thailand*

The empirical results indicate that MEY management at the long-run, steady-state level of effort will earn the industry and the country additional economic rent, gross of management costs, ranging between 1,904–2,394 million Baht for the Schaefer and Fox models, respectively. If the fishery is left unmanaged, fishing effort is expected to reach an open-access Nash equilibrium, with rent dissipation, ranging between 56.62–69.56 $\times$ 10^6 standard hours, and with a sustainable catch ranging between 593,000–725,000 metric tons, and society would lose between 3,943–4,433 million Baht in resource rents per year according to the Schaefer and Fox models. These foregone resource rents represent a sizeable opportunity cost to society. Pareto-improving conservation and management policies that reduce fishing effort, and thereby increase sustainable yields, clearly increase social welfare compared to the Pareto-inefficient current levels of fishing effort and yields.

With the notable exception of joint fishing ventures for offshore pelagic fish stocks, management interventions that curtail fisheries production and employment will likely increase conflicts among gear types and between gainers and losers, at least in the short run, but probably also extending over the long run. As the empirical results have demonstrated, the Gulf of Thailand fishery is far removed from either a biological or economic optimum, thereby indicating biological and economic overfishing, along with economically and biologically overfished resource stocks, and attainment of either optimum requires Pareto-improving policies that work in the same direction by reducing fishing effort. The paper now turns to a discussion of these policies.

6. Policy implications

Our overview analysis of demersal fisheries in the Gulf of Thailand indicates that a policy addressing the biological and economic overfishing and biological and economically overfished resource stocks requires a substantial reduction in the current level of fishing effort across all gear types. This aggregate analysis does not indicate which gear, species, or geographical areas are most affected and require the greatest attention. Nonetheless, from our macro-bioeconomic analysis, some fundamental broad brush strokes of policy recommendations can be painted that are applicable across all gear types and species, which we discuss in this section. A set of more disaggregated analyses would be required before more detailed policies can be drawn. A policy aimed at reducing fishing effort, coupled with the effects of on-going technical change, will invariably reduce the amount of labor directly employed as fishers (Smith, 1981). Nonetheless, this broad and crucial topic largely lies beyond the scope of this particular paper. Moreover, the critical short- and longer-term distributional issues – which participants may gain and which may bear the burdens of adjustments – also largely lie beyond the scope of this overview bioeconomic analysis. Here, we narrow our focus to the main components of a Pareto-improving management policy for demersal fisheries throughout the Gulf of Thailand.

6.1. Rights-based fisheries management: individual transferable quotas

A policy of transferable private property rights over a portion of the catch or resource flow – individual transferable quotas (ITQs), could theoretically reduce fishing effort to eliminate biological or economic overfishing. ITQs are increasingly popular in the fisheries of more developed countries in temperate latitudes with comparatively few fish species (National Research Council, 1999). ITQs, however, are more difficult to implement in the complex multispecies fisheries of the tropics, such as in the Gulf of Thailand, where production is joint and the critical monitoring and enforcement problematic (Alam *et al.*, 2002; Squires *et al.*, 1998, 2003). Multiple gear types further compound the underlying complexity facing a multispecies ITQ program.[7] For these same reasons of wide species diversity and complexity,

[7] Additional factors often make ITQs problematic in many (although not all) developing countries, especially when there are multiple species. Total allowable catches have to be calculated for each species or assemblage, which is often exceedingly difficult in tropical multispecies fisheries of developing countries, particularly with age-structured or synthetic models with their demanding data requirements. ITQs are generally assigned to fishers based on species-by-species catch histories, which are often non-existent due to the absence of accurate census of fishers and catch histories. This limitation is particularly problematic, since the state's initial allocation of private property rights assigns wealth and income flows from the formerly state-owned resource stocks; this distributive impact is the most contentious part of any ITQ program. Only when the traditional users of

coupled with problems of resource stock assessment for individual species, monitoring, enforcement, and resource stock assessment, conventional catch quotas are likely to prove ineffective.

6.2. Limited access: a use right

Limited access, a weaker form of a property right than ITQs, curbs *access* or *use* to the fish stocks rather than establishing a private property right to a share of the demersal catch as provided by ITQs. Limited access, through restricting the number of licenses, more closely matches the current administrative and scientific capacity of the Thailand Department of Fisheries, since only vessel licenses and numbers for each gear type need to be monitored, enforced, and administered rather than the catches of different species or species assemblages for individual fishing vessels as with ITQs.

A limited access program was in fact promulgated in 1982 and its effect demonstrated over the 1982-1988 period by the gradual decline in the number of registered trawlers and push nets gradually decreased. However, the total number of registered trawlers and push nets has again increased.

The first step in a limited access policy entails a *de facto* – rather than the heretofore *de jure*, immediate and effective freeze in the number of trawlers and push nets, since trawlers are by far the single largest source of fishing mortality and component of fishing effort (table 2).[8] Push nets, which are used in inshore waters and in the process collect juvenile shrimps and fish, contribute to economic and biological overfishing, and are viewed as a destructive gear. This moratorium on trawlers and push nets prohibits the construction of new vessels in more than just name, and stiffens compliance of the current compulsory registration of the existing vessels with the Department of Fisheries.

The Fisheries Act of 1947 provides the legal basis for limited access and other fishing regulations and for the authority to enforce these measures.[9]

a resource are made private owners or when the proceeds from the sale of property rights in the resource are remitted to the former users does the competitive private property equilibrium unequivocally Pareto-dominate the alternatives. (See Baland and Platteau (1996) and Weitzman (1974) for further discussion along these lines.) Moreover, limited infrastructure – biological to make population assessments for the total allowable catches, informational to establish well-functioning quota markets with minimal transactions and information costs, and administrative for compliance through monitoring and enforcement of the property right – also makes ITQ programs difficult to establish in many developing countries.

[8] Much of the discussion in this section builds upon the recommendations first posited by Panayotou and Jetanavanich (1987).

[9] Under the 1947 Fisheries Act, a series of ministerial rules and regulations concerning the conservation of marine resources has been issued in six groups: (1) Prohibition of the use of certain types of fishing gear during the spawning and breeding seasons of some commercially important species; (2) Prohibition of certain types of fishing gear in some areas; (3) Protected areas are those adjacent to temples and monasteries or any other area designated as such by the governors of provinces. All such areas are considered as fish sanctuaries where fishing of any sort is not permitted; (4) Prohibition in catching of endangered and threatened

The Department of Fisheries has issued measures to control the construction of new trawl vessels, including issuance of fishing licenses for the trawl fishery.[10] Licenses are non-transferable to another person, except as family inheritance, and thereby contribute to reducing fishing effort. Only licenses and navigation certificates of the holders are renewed, thereby furnishing an additional policy handle to reduce effort. Licenses of vessels which become involved in trespassing and encroachment into the jurisdictional waters of other countries are forfeited and not reissued.

Implementation of, and compliance with, the limited entry program currently on the books, rather than the broad intent of the laws and regulations, is the key issue for demersal fisheries in the Gulf of Thailand. Enforcement of the regulations has been comparatively ineffectual to date for a variety of reasons. These regulations apply to an extensive geographical area spread over the entire coastline of Thailand, which is compounded by the huge number of fishing boats operating different types of fish gear. The number of officials in the field and patrol boats to inspect and enforce the regulations is too few. Moreover, the laws of the country require that fishers need to be caught in the actual act of illegal fishing or violating the regulations to be upheld in a court of law. Additional factors hampering effective enforcement include insufficient cooperation and collaboration from fishers, high enforcement costs, and lack of coordination and cooperation among relevant agencies.

Additional factors impede the licensing scheme. Because fishing vessels are registered with the Harbor Department while the gear is licensed by Department of Fisheries, a loophole enables registered fishing vessels to operate without a license for gear. Moreover, with the current budget and manpower it is not easy for the Department of Fisheries to enforce the licensing system over an extensive and technologically advanced fleet, some of which can operate from foreign ports. There is also a need for more officials in the field, better infrastructure and facilities for enforcement, and delegation of sufficient authority for enforcement of the regulations to the provincial authority, such as an appointed committee for this purpose, rather than only to the provincial fisheries officers.

Modifications to the design of the license limitation program are possible, which could boost the policy effectiveness. A freeze on vessel numbers applied to other gear types prevents spillover effects that would occur when fishing effort limited in one gear type spills over to another, unregulated gear type as fishers expand and/or redirect fishing effort. A licensing

species; (5) Ban on the use of poisons and stupefying chemicals, explosives and electric stunning; and (6), Prohibition and restrictions on certain types and sizes of fishing gear.

[10] In 1978, the Thai Cabinet adopted a resolution to take measures to control and reduce the number of trawlers and push nets. The basic objective of a Ministry regulation issued in March, 1990 is to gradually reduce the number of trawlers and push nets and thereby bring down demersal catches to the optimum sustainable level.

scheme can also be tailored to favor less environmentally destructive or more profitable gear.

The broad species diversity of tropical fisheries can complicate license limitation programs if single and multiple fishery licenses are issued (Ooi, 1990). Some vessels may have too little flexibility to survive declines in individual stocks, while some species may be excessively harvested (Tussing *et al*., 1974). These problems suggest that, given the joint production of multiple species found with many gear types such as trawls, individual species assemblages cannot be individually regulated as if the production process is non-joint.

Limited access has a number of limitations, several of which are already manifested in Thai fisheries. Limited access, an imperfect right, has the problem that the excludability characteristic of the property right is still not fully specified and developed, but the fish stocks remain common resources and thus accessible to the remaining fishing vessels. As a consequence, the underlying economic incentives compelling individual fishers to catch as many fish as soon as possible are diminished but are not eliminated (Townsend, 1990; Scott, 1993, 2000). That is, economic incentives do not sufficiently guide players to invest in future catches by delaying current catches and to improve their economic efficiency and the dominant strategy of players remains non-cooperation. The common-pool technological resource stock externality also remains, albeit on a reduced basis.

Because of the imperfect excludability of limited access, a major shortcoming of limited access is the indirect relationship between fishing effort, which is multidimensional, and fishing capacity and total factor productivity ('fishing power') (Wilen, 1979, 1988; Hannesson, 1983; Squires, 1992).[11] Coupled with the remaining – albeit attenuated – incentive structure found under limited access, players have both economic incentives (especially when prices rise or costs of production fall) and the potential technological ability to expand the unregulated components of fishing effort, such as fishing time or vessel or engine size.

To counter this expansion in effective fishing effort, limited access programs frequently stipulate a maximum limit on one or more of the components of the composite input fishing effort, such as vessel size

[11] Without a fishery management program that directly and comprehensively addresses the ill-structured property right, a problem of asymmetric information and moral hazard is created between the principal (fishery manager) and the agents (fishers) (Salvanes and Squires, 1995; Jensen and Vestergaard, 2000, 2002a,b; Squires *et al*., 2003; Kirkley and Squires, 1999). This information problem arises because the fishery manager does not have complete information about all variables relevant for regulation (Jensen and Vestergaard, 2002b). Hence, the regulator cannot easily and at low cost monitor and enforce the number of vessels, the zones they fish in, gear conflicts, levels of harvest and species composition, discards and illegal landings, levels and mixes of inputs, and the like. In turn, the fishers face economic incentives to shirk through avoiding license registration, payment of license fees and other taxes, ignoring gear regulations and other requirements for monitoring, enforcement, and regulation.

(Campbell and Lindner, 1990; Wilen, 1979, 1988; Hannesson, 1983; National Research Council, 1999). Increases in vessel size in the demersal fisheries of the Gulf of Thailand could be allowed by simultaneously retiring smaller vessels in the fishery and consolidating these licenses, and perhaps even retiring some portion of the combined capital stock as measured by length or gross tonnage. Nonetheless, the unregulated components of the composite input fishing effort may often be expanded as discussed. In addition, attempts to control size can lead to adaptations that are inefficient or are not seaworthy. Wilen (1979, 1988) observes that controlling fishing effort through terminal gear restrictions is perhaps more important than restrictions on other inputs. Even this terminal gear restriction does not curb advances in total factor productivity due to process innovations, increases in size economies, or gains in technical efficiency. In sum, the limited access program might constrain vessel length and terminal gear characteristics to slow down the expansion of effective fishing effort, but nonetheless recognize that effective fishing effort will most likely continue to expand, albeit at a reduced rate and in unexpected dimensions.

6.3. Individual or group transferable effort quotas and vessel buybacks

Limited access programs, while a necessary cornerstone to fisheries management in Thai demersal Gulf fisheries, by themselves are unlikely to sufficiently reduce fishing effort or capacity to MEY or MSY levels (suitably modified by the Precautionary Principle). The restrictiveness of a limited access program is correlated to its economic success (Townsend, 1990). The most restrictive programs have either reduced fishing effort significantly or closed entry before fishing effort reaches rent-dissipating levels. Less restrictive programs have been only marginally successful. Moratoria on entry that included a phased reduction in fishing effort have similarly been only marginally successful.

Two potential effort-reducing management programs are vessel or license buybacks and individual or group transferable effort quotas (ITEs). ITEs are another form of rights-based management, in which shares (proportions) of total allowable fishing effort (TAE) (e.g. total allowable days at sea for the fishery), are allocated to players – individuals or groups of different types – with vessels of larger size or in more profitable fisheries as property rights and which can be freely transferred among players. (ITEs are likely to prove prohibitively expensive and cumbersome in small-scale fisheries due to costs of transactions, monitoring, and enforcement.) ITEs are not widely applied, although they are used in the New England trawl fishery and the Hawaiian longline fishery for swordfish, and will soon be used in the Western and Central Pacific tuna purse fishery. As a property right, ITEs can help align conservation and economic incentives. ITEs can ideally be set at levels that target overall short- and long-term sustainable target yields and allow for stock rebuilding, but setting the TAE is difficult because of the nonlinear and dynamic relationship between effort and catch. Moreover, ITE programs are vulnerable to a continued "race to fish" for desirable "target" species, bycatch and "trash" fish concerns, and some species can be overfished and other species can even be underfished, and different sustainable target levels for different species can be reached prior to others.

That is, ITEs are very inexact and indirect for multispecies fisheries and joint production. ITE programs need to be built upon the foundation of a limited access program to: prevent both entry into the fishery during allocation of ITEs and as conditions improve; preclude uneconomically small ITE holdings by an excessive number of vessels, which inevitably would create pressures to expand the TAE beyond the sustainable target level; and establish an identified universe of participants during the initial allocation. A fractional TAE system is possible, comparable to a fractional license limitation program (Townsend and Pooley, 1994), which would force consolidation of ITEs and hence vessel exit from the fishery.

At first blush, ITEs are more promising than ITQs, because ITEs do not directly face the complex multispecies issues of the tropics, and compliance and enforcement are potentially possible through vessel monitoring systems (VMS), which are increasingly tractable and affordable. However, fishing effort, usually measured in fishing time, is in fact a heterogeneous vector of inputs, and fishing time is simply a proxy variable for a single-valued, composite input (which theoretically exists only under homothetic input separability) (Hannesson, 1983). As a consequence, ITEs inherently increase through productivity growth (technical change, technical efficiency, size economies), investment in capital stock, increases in other inputs, and improvements in fishing skill. Allocation of ITEs *gratis* transfers public wealth to the private sector players, but helps create acceptance of the program, and through transfers among players, players themselves – rather than the public sector – finance effort reduction. Allocation formulae are numerous and face inadequate documentation and political concerns, but equal allocation to individuals or groups based on a physical measure of the size of capital stock or numbers of persons involved are potential approaches that help circumvent these issues. In spite of their short-comings, ITEs remain a promising if largely untested form of rights-based management for complex multispecies tropical fisheries, and hence a first-best policy option, and decidedly deserve further consideration. Because of administrative and transactions costs, ITEs might best be applied to larger and/or more profitable vessels.

Vessel or license buyback programs have largely been used in developed countries, but also in Malaysia and high seas tuna longline fisheries in the Pacific (Hatcher, 1998; Holland *et al.*, 1999; Kirkley and Squires, 1999; World Bank, 2004; Curtis and Squires, 2004). The general view of their effectiveness is that buyback programs seldom effectively reduce fishing effort over the long term and restore stock size, but can help stem further deterioration in resource stocks. Buybacks also tend, in practice, to remove the largely inactive vessels that hold licences. Buybacks that restore profitability also give breathing room for players to figure out what to do next and enhance positive economic behavior, since players behave very differently when a fishery is profitable.

The key issue of concern for Thailand and other developing countries is the likely high cost of an effective program and who finances it, the public or private sector. Willmann *et al.* (2003) estimate that the necessary 25 percent reduction in the Thai trawler fleet requires at least US$136 million, effectively precluding a vessel buyback program financed by either the private or public sectors of Thailand. A potentially valuable role exists for the international community, such as proposed by the World Bank (2004), in financing transparent, market-based buyback systems without spillovers to other fisheries (moral hazard) for a management program that might not otherwise pass a strict cost-effectiveness test compared to the opportunity cost of such funds if domestically supplied and appropriately shadow-priced.

6.4. Co-management and decentralization of fisheries management

Effectiveness of fisheries management can be improved by more than "sticks" such as enhanced enforcement, but also by creating positive incentives through co-management coupled with decentralization of fisheries management from the capital city, Bangkok, to the provinces and districts.[12] Co-management reshapes, "...the state interventions so as to institutionalize collaboration between administration and resource users and end those unproductive situations where they are pitted against one another as antagonistic actors in the process of resource regulation" (Baland and Platteau, 1996: 347). Co-management thus increases the ability to effectively monitor and enforce a limited access program and strengthens incentives for cooperation and conservation. Such a program has to rely on the cooperation and participation of the industry with the government (Ahmed *et al.*, 1997; Nielsen *et al.*, 2004), thereby promoting cooperation between fishers and the Department of Fisheries. Co-management would enhance the economic incentives of fishers toward investing in future catches by reducing current catches through limited fishing effort. Co-management could also help in the establishment of protected areas for spawning grounds or areas of threatened biodiversity. As part of the process of co-management, decentralization of the state's fishery management would strengthen the hand of local and regional government, which in turn would further enhance co-management by shortening the chain of communication, reducing the number of parties involved, and align local government incentives with local events.

Co-management in the Gulf of Thailand has been implemented, in part, by the government in coastal areas – especially in Bang Sapan Bay, through community-based fisheries management. These projects aim to alter the perceptions and attitudes of fishers from that of a user to a manager. Activities on grouping, training, social development programs, and fish landing site management, which unite fishers and their communities, including awareness-building and participation in resource conservation, have been implemented in the target villages. Regular meetings among working committees of each village have been organized to monitor the progress and problems of implementation. Visits to the target villages have also been regularly carried out. When the fishers learn how to manage and conserve the fisheries resources for sustainable utilization in the near future, the laws governing the provision of fishing grounds in their village or group

[12] For additional discussion of co-management in fisheries see Ahmed *et al.* (1997), Nielsen *et al.* (2004), Pinkerton (1989), Pomeroy and Berkes (1997) and for rural development in general see Baland and Platteau (1996).

of villages as part of village property and as a source of their livelihood will be extended to them.

6.5. *Area-based rights*

The effectiveness of the limited access or use right for any gear type might be enhanced, to some degree, by further attenuating the access right to a specific and naturally definable geographic area, creating a well-defined group with exclusive access (use), and thereby restructure and enhance fishers' incentives, creating an area licensing scheme (cf. Wilen, 1988).[13] To the extent that such a geographic focusing for a gear type can be meaningfully defined, implemented, monitored and enforced, the numbers and homogeneity of players in the non-cooperative strategic game may be reduced to an extent that may make coordinated group action a Pareto-dominant strategy from each player's standpoint.[14] In essence, a common use right is created. The key point here is that players' incentives require restructuring and redirection toward cooperation and investing in future catches by reducing current catches, and that geographically tailoring the access (use) or property right – perhaps further customized by gear type – may be one way to nudge incentives in this direction.

Such an approach of area limited access has been applied in Malaysia through creating zones for certain vessel sizes and gear types (Ooi, 1990). Establishment of a similar system of zonal license areas for many or all gear types could be established in Thailand, although it should be noted that monitoring and enforcement is critical for such a system to effectively function. In Malaysia, enforcement of zonal license areas relies, in part, upon reporting by legal fishers of illegal fishers, i.e. self-policy, which is enhanced by the color-coded demarcation of vessels and zones (different zones have different colors, which are prominently displayed on the vessel).

[13] When the area of access is sufficiently restricted and a well-defined group of resource exploiters is created, cooperative behavior by the individual players should be boosted. This has been found to improve the conservation and management for other types of common-pool resources (Baland and Platteau, 1996; Ostrom, 1990; Seabright, 1997). When area use rights are actually assigned, thereby creating a more well-specified property right than limited access (largely through enhancing the exclusive use and universality characteristics), such a program is called territorial use rights for fisheries or TURFs (Christy, 1982). A management strategy predicated on well-defined areas or even TURFs might or might not be fully effective, and little evidence, if any, is available for commercial fishing in developing countries. Nonetheless, the idea has theoretical merit and has worked with other common-pool resources, and hence deserves serious consideration, particularly when developed through co-management.

[14] More technically, non-cooperation is often the initial dominant strategy for each vessel and a Pareto-inefficient Nash equilibrium and overfishing of the resource stock remain the expected outcome without alternative measures under open access. The intent of these measures is to help transform the underlying non-cooperative game to a cooperative one. The process of treaty negotiation can be borrowed from international environmental agreements, since this process transforms strategic incentives and non-cooperation into cooperation. See Barrett (2003) for additional discussion.

6.6. Complementary conservation measures

Additional policies can complement and strengthen the effectiveness of a fishery management program built upon limited access or use rights, co-management, decentralization, and well-defined user groups such as areas and gears. One of these consists of establishing a minimum mesh size (especially for the cod end of trawl gear to 4 cm) and perhaps mesh design (e.g. square versus diamond for trawls) through at-sea gear research to both increase yield per recruit through enhanced survival and growth of small-sized fish that can escape the net. Another conservation policy prohibits fishing by all type of fishing gear at all times in the protected areas of critical habitats such as coral reef, seagrasses, and mangroves, which are important nursing and spawning grounds of several living marine resources.

6.7. Trash fish

Effective policies that substantially reduce catches of "trash" fish are not easy to introduce because of the monitoring and enforcement required for effective implementation, the limited product transformation possibilities under a vessel's joint production, and the growing economic incentives to catch fish of all species as resource stocks of the most desirable species are overfished. A large proportion of "trash" fish consists of juveniles or species with limited market value. To the extent that fleet sizes (and hence fishing effort) are reduced and even redirected through license limitation, some relief to catches of "trash" fish may be found (a negative expansion effect). Similarly, reducing fishing effort in inshore areas, where juvenile fish are often found, can reduce catches of "trash" fish. Limitations on types of gear and on smaller mesh sizes and perhaps different mesh designs can also lower catches of "trash" fish. Moreover, as a fishery deteriorates to low resource stock levels, catches of species that were formerly "trash" fish – either juveniles of "targeted" species or bycatch of previously undesirable species – may now become valued in their own right as a "target" species for consumption or fish meal. In this case, policies to reduce what was formerly "trash" fish really become, in effect, policies to reduce overall fishing effort in a fishery facing substantial levels of biological and economic overfishing.

7. Concluding remarks

This study estimated Schaefer and Fox bioeconomic models of demersal and "trash" fish in the Gulf of Thailand to provide an overview analysis and an effective foundation for a set of policies for the utilization and management of the demersal fisheries. The results from both models indicate that demersal fish stocks are both biologically and economically overfished and subject to both biological and economic overfishing. The fishery could earn additional economic rents by curtailing both excessive fishing effort and exploitation rates. Whether maximum sustainable or economic yields (modified by the Precautionary Principle) serve as the sustainable target yield in comparison to unregulated open access, the direction of Pareto-improving policy that also enhances the biological basis of the demersal fishery is clear.

The cornerstone to effective conservation and management of the Gulf of Thailand demersal fisheries is effective implementation of the current license limitation program for all gear types enhanced by co-management, decentralization of management, and area-specific considerations. This limited access policy includes prohibiting construction of new trawlers and phasing out of the biologically destructive push net fishery. The limited access program might also be tailored to specific geographic areas for some gear types to both protect juvenile species in inshore areas, reduce gear conflicts by separating some gear types (e.g. trawlers and artisanal gear), and potentially enhance conservation and economic incentives by limiting players in an area. Cod end mesh size limits for trawl gear are also warranted.

Monitoring and enforcement are critical for the compliance that underpins all effective fisheries conservation and management. Decentralization of authority, enhanced coordination among government agencies, self-policing, co-management, and improved funding would all greatly contribute in this regard. In addition, a lump sum license fee for gear types that are sufficiently profitable to bear such a fee serves as a double dividend tax that both reduces fishing effort and helps fund monitoring and enforcement and implementation in general. Effort reduction requires serious consideration of rights-based management in the form of transferable effort quotas for players – individuals or groups, an imperfect and largely untested approach, but the most potentially tractable property right available in complex multispecies fisheries of tropical developing countries.

Optimal resource utilization based solely on achieving economic efficiency inadequately addresses broader social issues. In this regard, a policy aimed at maximum sustainable yield, modified by the Precautionary Principle, rather than maximum economic yield, has it advantages, since it helps alleviate employment and distributional concerns in the Gulf of Thailand fisheries. Side payments from gainers to losers or the disenfranchised, perhaps financed by license fees or limited access formula favorable to the disenfranchised, may also help address social issues.

The international community and external funding may be useful in introducing and funding governance and structural reforms and some management programs such as vessel buyback programs, experimental individual transferable effort programs, and enhanced compliance and enforcement. Such programs may require additional funding or impetus.

The ultimate success of a national fisheries policy lies in the correct and timely mix of fisheries management and non-fisheries development. Only broad-based rural development will put an end to the continual drift into common resources and major urban centers. In its absence, fisheries regulation cannot be effective and, if effective, will simply push the problems into some other sector: unemployed fishers have little choice but to encroach on reserved forests, mineral concessions and public lands or simply move into the urban centers creating a host of social and environmental problems.

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