VALUING MANGROVE CONSERVATION IN SOUTHERN THAILAND

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Mangroves are ecologically important coastal wetland systems that are under severe threat globally. In Thailand, the main cause of mangrove conversion is shrimp farming, which is a major source of export income for the country. However, local communities benefit from many direct and indirect uses of mangrove ecosystems and may have a strong incentive to protect these areas, which puts them into direct confrontation with shrimp farm operators and, by proxy, government authorities. The article examines whether or not the full conversion of mangroves into commercial shrimp farms is worthwhile once the key environmental impacts are taken into account. The estimated economic value of mangrove forests to a local community is in the range of $27,264–$35,921 per hectare. This estimate includes the value to local communities of direct use of wood and other resources collected from the mangroves as well as additional external benefits in terms of off-shore fishery linkages and coastline protection from shrimp farms. The results indicate that, although shrimp farming creates enormous private benefits, it is not so economically viable once the externalities generated by mangrove destruction and water pollution are included. There is also an incentive for local communities to protect mangroves, which in turn implies that the rights of local people to guard and protect this resource should be formally recognized and enforced by law. (*JEL* Q2, Q12, O1)

I. INTRODUCTION

Mangroves are ecologically important coastal wetland systems. In the tropics, they are especially rich in flora and fauna. In addition, mangrove ecosystems perform a major environmental role in sheltering coastlines and estuaries through, for example, storm protection, shore stabilization, and the control of coastal soil erosion and flooding. Mangroves also serve as a breeding ground and nursery habitat for marine life, which is an essential ecological support function for many coastal and offshore fisheries. Local communities in tropical coastal areas may also directly exploit mangrove resources for basic commercial

ABBREVIATIONS

CBA: Cost-Benefit Analysis
CORIN: Coastal Resources Institute
DOF: Department of Fisheries
EEPSEA: Economy and Environment Program for Southeast Asia
IDRC: International Development Research Centre
RFD: Royal Forestry Department
UNEP: United Nations Environment Programme

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and subsistence commodities, such as food, medicines, fuel wood, and wood products.

In Thailand, mangroves are disappearing at the alarming rate of approximately 6,037 ha per year. In 1961, Thailand had 368,000 ha of mangroves. Today it has only 168,000 ha (CORIN, 1995). One of the major causes of rapid mangrove deforestation has been intensive shrimp farming, especially along the Gulf of Thailand coast. Mangrove swamps are prime targets for shrimp farming because the areas are flooded with brackish water, making them particularly suitable for aquaculture (Hassanai, 1993). Although the farming of banana shrimps (*Peneaus merguinsis*) and greasy shrimps (*Metapeneaus* spp.) has been practiced in Thailand for more than 50 years, these traditional methods require only partial clearance of mangroves. However, the intensive cultivation of black tiger shrimp (*P. monodon*), which requires full conversion of mangrove areas, was introduced in 1974; this type of shrimp culture that has been responsible for the widespread mangrove conversion in southern Thailand. The boom in intensive shrimp farming, and thus mangrove clearing, has been particularly noticeable since 1985, when the increasing demand for shrimp in Japan pushed up the price to $100 per kg (Bantoon, 1994).

Current government policy in Thailand has been criticized as being biased toward the promotion of shrimp culture while ignoring the impacts of any subsequent mangrove deforestation on local communities. As Thailand earns more than $1.2 billion annually from exporting frozen shrimps (OEPP, 1995), the Department of Fisheries (DOF) has actively promoted intensive shrimp farming in the coastal areas in southern Thailand to take advantage of this lucrative trade. However, the resulting widespread loss in mangrove areas has raised concerns over the potential ecological and economic impacts of the DOF policy.

The excessive clearance of mangrove areas for shrimp farms in southern Thailand has been exacerbated by ill-defined and poorly enforced property rights for these resources. According to current legislation, all mangrove forests in Thailand are publicly owned state property, and it is the responsibility of the Royal Forestry Department (RFD) to guard and protect these areas. However, in practice, the RFD has failed to enforce any protection, and mangroves have become a de facto open-access resource on which anyone can encroach. This has led to land use conflicts over the use of remaining mangrove areas, which has also exposed a glaring conflict in overall policy objectives, namely, between promoting mangrove conservation versus encouraging export-earning shrimp aquaculture (Sathirathai, 1997).

In particular, local communities, which have traditionally utilized mangrove resources for a variety of products ranging from fuel wood and other wood products to honey, and which have exploited coastal fisheries that benefit from the nursery and breeding ground function of mangrove habitat fisheries, believe that there is insufficient government protection of mangrove forests from conversion to shrimp ponds. There is also widespread concern over the water pollution in coastal areas, which is a by-product of intensive shrimp farming. As shrimp culture is capital intensive and the technology is too expensive for small-scale farmers, investors in shrimp farm enterprises are generally from outside of local communities, and very little of the returns to farming are invested locally. At the same time, local people do not have the legal right to protect mangrove forests from conversion to shrimp farming—that is, unless the RFD recognizes their efforts. Some local communities that have been affected severely by the loss of mangroves have sometimes reacted violently to encroachment by shrimp farmers. Many have also begun to guard the forests themselves instead of waiting for the authorities to do something.

However, there have been signs of recent shifts in policy toward actively promoting the conservation of mangroves and the participation of local communities. The Ministry of Agriculture and Cooperatives, which governs the RFD, has announced that mangrove conservation has to be taken more seriously. As a result, the RFD is considering banning mangrove forest concessions and regulating the use of mangrove areas, particularly those affected by shrimp farming. Furthermore, new legislation on community management of forests is being introduced, which offers the hope that the right of local communities to protect mangrove forests may receive legal recognition.

The motivation for this potential change in policy arises from the recognition that the economic benefits of mangroves to local communities may be substantial and could possibly even outweigh the returns to intensive shrimp farming that lead to mangrove conversion. However, little is known about the economic value of local direct use of mangrove resources in southern Thailand, and the intangible ecological benefits of mangroves to the local communities in terms of habitat–fishery linkages and coastline protection have never before been evaluated. Without such an assessment, it is not possible to compare the economic benefits of mangroves to local communities with the returns to shrimp aquaculture or to determine whether there are sufficient benefits from conserving the mangrove systems to provide the incentives for local communities to participate in their protection.

To address these key policy issues, this article assesses the benefits of mangroves compared to the net returns from converting the areas into shrimp farms in a case study area of southern Thailand. The analysis was conducted as part of a research project into land-use conflict and policy issues arising from mangrove conversion conducted by one of the authors (Sathirathai, 1998). The area selected for the study is Ban Tha Po Moo 2, in Tha Thong subdistrict, Kanjanadit District of Surat Thani Province, in which 400 ha of mangroves are utilized by the local community, Tha Po Village. The villagers have also organized their own means of protecting some of this mangrove forest area from outside encroachment, including from conversion by shrimp farmers.

Local direct uses derived from mangrove areas are valued by determining the net income generated from harvesting timber, fuel wood, and other wood products, as well as nonwood resources, such as birds and crabs. In addition, two important ecological services are also assessed: the role of mangroves in serving as breeding grounds and nursery habitats for offshore fisheries and in protecting the coastline from erosion. Other possible ecological functions, including carbon sequestration and the control of flooding, are not included in the analysis.

II. THE ECONOMIC VALUE OF MANGROVES IN SOUTHERN THAILAND

A. *Background Information*[1]

Tha Po Village in Surat Thani Province in southern Thailand was selected for the case study because it is a representative example of a Thai coastal fishing community on the Gulf of Thailand with mangrove areas. The village is more than 100 years old, and its present population is 652 people (131 households). The villagers are mainly involved in fishing, although they also used to rely considerably on directly exploiting the forest resources for their livelihoods.

However, mangrove deforestation has affected the area significantly. Until recently, this part of Surat Thani Province was extensively covered with mangrove swamps of approximately 1,120 ha. In the past decade, 640 ha along the coast has been cleared for commercial shrimp farms, which are mostly owned by businesspeople from Bangkok and outside investors from other Thai cities. Since 1993, the villagers have been protesting seriously to the government against the forest encroachment by shrimp farmers, especially as the local community has noted several problems of resources and environmental degradation, such as a drastic decline in offshore fishery yields and water pollution from the ponds. There was also an incident in which some villagers had to move temporarily from their houses during a storm because the mangroves were no longer there to shield them from strong gales. A further problem is that the shrimp farms in the areas have begun experiencing viral disease. Several operations have had to be closed down, leaving the area with a large number of abandoned farms. Yet the demand for converting mangroves to establish new shrimp ponds continues. After additional areas of mangroves were deforested recently, without any government intervention, the local villagers decided to take unilateral action to protect the remaining 400 ha of mangrove area available to them.

The remaining mangrove forest left to Tha Po Village consists of a variety of tree species with *Avicennia marina* (55%), *Excoecaria*

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[1] The background information in this section is based on the initial EEPSEA study by Sathirathai (1998). All values from the latter study have been converted at the rate of 40 Thai baht = US $1 and 6.25 Thai rai = 1 ha.

agallocha (35%), *Thespesia populnea* (5%), and *Rhizophora apiculata* (5%) being predominant. The average stand density of the mangrove forest is 2,256 tree/ha, with an average biomass of about 45.24 ton/ha. It is important to note as well that the forest is mainly composed of small-sized trees, as this appears to have affected the availability of forest resources, especially wood products, for use by the local community.

B. The Economic Valuation Approach

As discussed in the introduction, the total economic value of the remaining 400 ha of mangroves to the local community may comprise many diverse benefits. However, due to limited data, the case study of the Tha Po Village was able to estimate only the value of three key economic benefits: the value to the villagers of their direct use of wood and nontimber products from the forest and the ecological values of the mangrove area in terms of off-shore fishery linkages and coastline protection. These values of the mangrove forest were estimated to obtain the net benefits of protecting the remaining mangrove area, which in turn are compared to the returns of the alternative use of the mangroves, which in this case is conversion to shrimp farming. The rest of this section discusses the economic valuation of the three key benefits to local villagers of protecting the remaining mangrove area. Section III contains the estimation of the returns from converting the mangroves to shrimp farming.

C. Local Direct Use Value of Forest Resources

The direct use value of mangrove resources was assumed to be equivalent to the net income generated from the forests in terms of various wood and nonwood products. If the extracted products were sold, market prices were used to calculate the net income generated (gross income is minus the cost of extraction). If the products were used only for subsistence, the gross income was estimated based on surrogate prices, that is, the market prices of the closest substitute.

To estimate these local use values, two field surveys were conducted. The first was a detailed household survey that took place in February 1996 to obtain data on the frequency and quantity of the different products collected from the mangroves, as well as the labor input used in collecting these products. The follow-up survey in June 1996 used in-depth household interviews to acquire more specific data. The surveys revealed that the major products collected by the households were various fishery products, honey, and wood for fishing gear. The second survey also revealed that the villagers collected fuel wood, although most of the interviewees stated that the quality of the wood found in the remaining forest area was not suitable for fuel wood, so they actually collected only small amounts. Moreover, as the trees are relatively small, the villagers could not use them for timber, except for repairing fishing gear.

The net income estimated from the major mangrove products collected by the Tha Po villagers is indicated in Table 1.

TABLE 1
Net Income from the Major Mangrove Products Collected by Tha Po Households

Products	Number of Households Engaged in Collection	Average Annual Returns per Household (US $)	Total Annual Net Income of Village (US $)
Fish	11	385	4,235
Shrimp	3	2,079	6,237
Crab	13	1,279	16,627
Molluscs	6	17	102
Honey	88[a]	55	4,840
Wood for fishing gear	44[a]	9	396

[a] Estimated from survey sample.

The estimated returns on fishery products are based on actual survey results of respondents who reported regular collection of these products. However, because of monsoon conditions, an extensive survey of the whole village could not be conducted on other collected products. Instead, based on the survey results, it was assumed that 10% of the village households collect fuel wood, 40% collect tree trunks for repairing fishing gear, and 80% collect honey. Moreover, the surveys also revealed that the villagers tend to use their leisure (i.e., nonworking) time to collect the various mangrove products. At the time of the surveys, the local daily wage rate was $3.75 for men and $3 for women. Based on United Nations Environmental Programme (UNEP) calculations, the wage rate for leisure time is considered to be one-third of the daily wage rate in rural Thailand (UNEP, 1994). The opportunity costs of labor used in calculating the net returns from all of the major products were therefore based on hourly rates for leisure time in terms of these adjusted daily wage rates.

Based on the estimed net income from all mangrove products (including fuel wood and other minor products), the mean annual value per household from direct use of the mangrove forest resources was calculated to be around $924. However, the surveys revealed that only 38 households collected mangrove products on a regular basis. Based on this conservative estimate of village use rates, the aggregate annual value of the 400 ha of remaining mangrove forest was estimated to be $35,135, or approximately $88 per ha.

D. Value of Off-Shore Fishery Linkages

As noted in the introduction, one important ecological service of mangroves is their support of an off-shore fishery by serving as a nursery ground. Even though the reduction in production of off-shore fishery is normally attributed to overexploitation, the situation is worsened as mangrove areas decrease. From the interviews in Tha Po Village, Surat Thani, it became apparent that after the shrimp farms had cleared out a vast area of the mangrove forest, the villagers could clearly observe a sharp decline in the yields of their fishery products. When asked about the causes of the decline in their off-shore fishing harvests, 50% of respondants cited mangrove forest clearing by shrimp farming activity as the main cause of the problem (Sathirathai, 1998).

The "production function approach" is regarded as a promising valuation method to be used in capturing the indirect use value of wetland resources in terms of their ecological support for an off-shore fishery (Barbier, 1994). Several empirical studies have been conducted utlizing this approach to measure the value of coastal mangroves and marshlands as inputs in fishery production (Barbier and Strand, 1998; Ellis and Fisher, 1987; Freeman, 1991; Lynne et al., 1981). Here, we have attempted to value the off-shore fishery linkages provided by the mangroves in the Tha Po Village area by applying a model originally developed by Ellis and Fisher (1987) and updated by Freeman (1991).

The Ellis-Fisher-Freeman model is based on a static optimization framework using the Cobb-Douglas form to represent production of an off-shore fishery in which the mangrove area is included as one of the input factors (see Appendix). After this production relationship is estimated, the supply function for off-shore fishery products can be derived. This is the concept of the "production function approach" as earlier discussed. The value of mangroves in terms of off-shore fishery linkages is determined by the net welfare change (consumer and/or producer surplus) associated with the change in the area of mangroves.

From the model, both equilibrium quantity and price associated with different levels of mangrove areas can be computed (see Appendix). An increase in mangrove area will lower the cost and hence drive the price of the off-shore fishery products down. However, as Freeman (1991) has demonstrated, the welfare effects of the resulting impacts on price and harvest in the fishery will depend on the prevailing management regime. In the case of a typical Thai fishing community, such as Tha Po village, there are two alternative management regimes for its off-shore fishery, that is, an open-access situation and a fishery that is "managed" by the local community. In an open-access situation, the value of the mangroves in terms of support for the off-shore fishery is determined by a change in consumer surplus only. Under open access, the lower cost resulting from an increase in mangrove area will attract new entrants into the fishery, which will eventually dissipate all producer surplus. However, it is likely that in the case of Tha Po Village its off-shore fishery is not completely open access. Even though the community does not regulate fishing per se, there are no outsiders coming into their fishing ground. Such a "managed" off-shore fishery regime is more likely to resemble the case of a private property regime in the original Ellis and Fisher model (see Appendix). In this case, the value of the mangrove in terms of support of the off-shore fishery is measured by changes in both consumer and producer surplus.

To assess the net welfare change associated with the change in the area of mangroves, the market demand and supply of offshore fishery products had to be obtained. This involved employing both data from the Tha Po Village survey, our representative fishery village with mangroves, and estimating a production function for the key fisheries based on panel data for the entire Gulf of Thailand region. Following the Ellis-Fisher-Freeman model, the production function was assumed to take the following Cobb-Douglas form

$$(1) \qquad X = f(E, \bar{A}) = mE^{a}\bar{A}^{b},$$

where X is fish harvest (in kg), E is fishing effort, and $\bar{A}$ is the area of coastal mangroves.

The surveys of Tha Po identified the important mangrove-dependent fish species in the study area. These were in turn classified into two main categories, specifically, demersal fish and shellfish (i.e., crabs and shrimps).[2] The major fishing instruments were also identified, and the time spent on fishing by per instrument were recorded and used as a proxy for human effort. Detailed data on the costs of fishing effort were also collected. However, because it was not possible to collect time series primary data from the local area for the amount of catches, effort per fishing instrument, and the area of mangroves, this survey data could not be employed to estimate the above production function (1) for the Tha Po shellfish and demersal fisheries. Therefore, empirical data used in this estimation had to be based on secondary data collected by the DOF and the RFD across all fishing zones in the Gulf of Thailand. The following approach was used.

First, a panel analysis was employed to estimate a log-linear version of equation (1) for all shellfish and all demersal fish in the Gulf of Thailand. The analysis combines harvesting, effort, and mangrove data across all five zones of the Gulf of Thailand and over the 1983–1993 time period.[3] This allows estimation of the parameters m, a, and b in equation (1), for two separate Cobb-Douglas production functions, one each for demersal fish and shellfish. Combining this information with the data on unit cost of effort, c, from the Surat Thani survey allowed the supply function to be specified for both the shellfish and demersal fisheries. As discussed above and indicated in the Appendix, these conditions will vary under the two alternative management regimes.

Under an open-access situation, equilibrium harvest in the fishery will occur where price, P, equals average cost, AC:

$$(2) \qquad \begin{aligned} P = AC &= C(c, X, \bar{A})/X \\ &= cm^{-1/a}\bar{A}^{(-b/a)}X^{(1-a)/a}. \end{aligned}$$

Substituting the estimated parameters from the production function (1) and the survey estimate of c, the above average cost function were computed for the case of demersal fish and shellfish, respectively, as

$$(3) \qquad AC = 2.0363 * 10^{5}X^{0.723467} * \bar{A}^{-1.26701} \qquad \text{(demersal fish)}$$

$$(4) \qquad AC = 2.6191 * 10^{2}X^{0.090366} * \bar{A}^{-0.20884} \qquad \text{(shellfish).}$$

In the case of managed off-shore fisheries, as under a private property regime, equilibrium harvest will occur where price equals

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[2] Mangrove-dependent demersal fish include those belonging to the Clupeidae, Chanidae, Ariidae, Pltosidae, Mugilidae, Lujanidae, and Latidae families. The shellfish include those belonging to the families of Panaeidae for shrimp and Grapsidae, Ocypodidae, and Portnidae for crab.

[3] In this analysis, total fishing effort per year is the number of fishing instruments (e.g., gill net boats) recorded per annum times the average number of hours spent on fishing per fishing instrument each year. For further details of the panel analysis, see Sathirathai (1998).

marginal cost, MC:

$$(5)\quad P = MC = \partial C/\partial X = \frac{c}{a} m^{-1/a} \overline{A}^{(-b/a)} X^{(1-a)/a}.$$

After again substituting for all the known parameters, the above marginal cost function was also computed for the case of demersal fish and shellfish, respectively:

$$(6)\quad MC = 2.0363 * 10^5 X^{0.723467} * \overline{A}^{-1.26701} \quad \text{(demersal fish)}$$

$$(7)\quad MC = 2.6191 * 10^2 X^{0.090366} * \overline{A}^{-0.20844} \quad \text{(shellfish).}$$

To solve for the above equilibrium market conditions, five alternative hypothetical demand functions were used. Because no data on the demand for fish products in Thailand were available for this study, the hypothetical demand functions were created based on different choices of demand elasticity (η) of −10, −2, −1, −0.5, and −0.1 to test for sensitivity. To simplify the analysis, this approach was conducted at the national level under the assumption that the national and local demands for fishery products in Thailand are the same. Finally, using 1993 as the base case year, it was assumed that all the linear demand functions passed through the observed (1993) national price and harvest data, with price equal to \$0.95/kg and harvest 1,545,000 kg for demersal fish and price equal to \$1.61/kg and harvest 1,917,000 kg for shellfish.

Following the methodology indicated in the Appendix, it was then possible to use the resulting equilibrium supply and demand conditions to estimate the likely welfare impacts of a change in mangrove area on a typical Gulf of Thailand fishing community, such as Tha Po Village, assuming alternatively open access and managed fishery conditions. Table 2 shows the results of the welfare calculation for the impact of a per-hectare change in mangrove area on the shellfish and demersal fisheries used by the Tha Po villagers. For all mangrove-dependent fisheries, the value of a change in mangrove area ranges from \$21–\$69/ha, depending on whether the fisheries are open access or managed. Similar to the outcome reported by Freeman (1991) for the Florida Gulf Coast blue crab fishery, when the demand for Gulf of Thailand fish is inelastic, the value of a change in mangrove area is higher under open access than under optimal regulation, whereas the wetlands are more valuable under optimal regulation when demand is elastic. Under managed fishery conditions, different demand elasticity assumptions hardly affect the welfare estimates of a change in mangrove area, which are estimated to be around \$52/ha for all fish.

TABLE 2
Value of a Change in Mangrove Area in Terms of Off-Shore Fishery Linkages

		Economic Value of a Change in Mangrove Area (US \$ per ha)		
Management Regime	**Demand Elasticity**	**Demersal Fish**	**Shellfish**	**All Fish**
Open access	0 = −10	5.24	15.58	20.82
	0 = −2	17.53	25.01	42.54
	0 = −1	24.82	27.06	51.88
	0 = −0.5	31.34	28.22	59.56
	0 = −0.1	39.68	29.22	68.90
Managed fisheries	0 = −10	24.41	27.90	52.31
	0 = −2	24.34	27.83	52.17
	0 = −1	24.30	27.81	52.11
	0 = −0.5	24.26	27.80	52.06
	0 = −0.1	24.21	27.79	52.00

E. Value of Coastline Protection and Stabilization

Another important ecological function of mangroves is to serve as a wind break and shoreline stabilizer. In this case, a replacement cost method has been adopted to assess the net benefits of this mangrove service.

According to the Harbor Department of the Ministry of Communications and Transport, several areas along the coastline where there is no mangrove cover experience severe erosion. The unit cost of constructing breakwaters to prevent such erosion is estimated to be around $875 per meter of coastline. Based on ecological studies, the Cabinet Resolution of December 15, 1987, stated that it is necessary to preserve mangrove forests with a width of at least 75 m along the coastline to stabilize the shore to the same degree as breakwaters. Given the above per-unit cost of breakwater construction, and assuming that breakwater is approximately 1 m wide, then the equivalent cost of protecting the shoreline with a 75-m-width stand of mangroves is approximately $11.67 per m^2, or $116,667 per ha. Over a 20-year period, the annualized value of this protection and stabilization function provided by mangroves amounts to $12,263 per ha.[4]

However, one of the limitations of the replacement cost approach is that it tends to overvalue the benefits of an ecological function (Barbier, 1994; Ellis and Fisher, 1987). For example, if all the mangrove area was "replaced" with breakwaters, there is no guarantee that there would be sufficient demand for this protection function to make such an investment worthwhile. This in turn implies that not all of the mangrove area is valued for its stabilization function. There is evidence that this may be the case for the mangroves in Surat Thani. According to the Harbor Department, approximately 30% of the coastal areas in the region have experienced severe erosion and require some kind of protection or stabilization, either natural or human-made. If the latter is considered a proxy for the current "demand" for shoreline stabilization, then as a conservative estimate we adjust the average replacement cost value of mangroves in terms of coastline protection to $3,679 per ha.

F. Summary of the Value of Mangrove Benefits

Table 3 summarizes the values of the three main mangrove benefits, the net income derived by the local community from the use of forest resources ($88/ha), the value of mangrove–fishery linkages ($21–$69/ha), and the value of coastline protection and stabilization ($3,679/ha). The latter value is clearly the most important benefit, although it is interesting to note that the survey of Tha Po villagers indicated that they were most concerned about the threats from shrimp farming to the other two benefits of the remaining mangrove area (Sathirathai, 1998). One possible explanation is that mangrove deforestation more directly affects the economic livelihoods of the community through the loss of net income from collecting timber and nontimber products and from declining fishing yields than through coastal erosion.

Over a 20-year time period, and depending on the discount rate used, the net present value of all three values of the mangrove system ranges from $27,264 to $35,921 per ha (see Table 3). In contrast, the net present value to the Tha Po villagers of harvesting various mangrove resources ranges from $632 to $823 per ha.

III. MANGROVE CONVERSION TO COMMERCIAL SHRIMP FARMS

The above economic benefits of maintaining mangroves need to be compared to the returns of the alternative use of the mangrove area, which is conversion to shrimp farming. Only by comparing the returns to these two alternative uses is it possible to determine whether or not full conversion of mangroves into commercial shrimp farms, which is occuring in the study area and throughout southern Thailand, has been worthwhile.

To facilitate this comparison, two analyses are discussed in this section. The first is a financial cost-benefit analysis (CBA) of the private returns to a typical commercial shrimp farm in southern Thailand established through mangrove conversion. This analysis indicates the overall commercial profitability of shrimp aquaculture and determines the extent to which there is a private incentive to invest in such operations. However,

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[4] This annuity value with a present value of $116,667 was estimated using a 10% discount rate.

TABLE 3
Net Present Value of Mangrove Forest Benefits[a]

Benefit	Value (US $) per ha
Direct use value:	
Net income from timber and nontimber products	87.84
Indirect use value:	
Off-shore fishery linkages	20.82–68.90
Coastline protection	3,678.96
Total direct and indirect use value	3,787.62–3,835.70
Direct use value only:	
Net present value (10% discount rate)	822.59
Net present value (12% discount rate)	734.83
Net present value (15% discount rate)	632.27
Direct and indirect use values:	
Net present value (10% discount rate)	35,470.72–35,920.98
Net present value (12% discount rate)	31,686.34–32,088.57
Net present value (15% discount rate)	27,264.13–27,610.22

[a] All net present value calculations are based on a 20-year time line.

shrimp farming also imposes certain external costs, such as water pollution and severe land degradation. Thus, the second part of the section examines an extended CBA of commercial shrimp ponds that includes these external costs. In this latter analysis all input costs are also adjusted to reflect their full economic costs. This allows the economic returns of commercial shrimp farming to be more readily compared to the economic benefits of conserving mangrove forests.

A. Financial Returns to Commercial Shrimp Farming

The productive life of a typical commercial shrimp farm in southern Thailand is normally 5 years. After this period, there tend to be problems of drastic yield decline and disease; shrimp farmers then usually abandon their ponds and find a new location. Even though the initial investment (in terms of fixed costs alone) in the first year can be as high as $9,375 per ha (Rawat, 1994), the gross return is so large that it leaves a very high profit for the venture throughout the project life. Table 4 provides various estimated of the net present value of the operating returns per ha during a 5-year period for a commercial shrimp farm. These returns range from $7,707 to $8,336 per ha, which suggests a considerable profit on the overall operation.

The financial CBA demonstrates that, from a private investor's standpoint, it is worthwhile to convert mangrove forests into a commercial shrimp farm. The de facto open access availability of mangrove swamps means that the investor incurs only the direct costs (mainly labor and dredging) of conversion and usually pays nominal land rent and taxes (if any) to the government after conversion. Moreover, as the initial investment requirement for a commercial shrimp farm is rather high, only wealthier households in local villages can afford the venture. Thus, those investors who benefit from the financial returns from shrimp farm enterprises are generally outside of local communities; very little of the returns to farming are invested locally. For example, the survey of Tha Po Village indicated that only 11 households were engaged in shrimp farming with a total area of 112 ha. The remaining shrimp farm area of 528 ha in the vicinity was owned by outside investors, mainly businessmen from Bangkok and other large cities (Sathirathai, 1998).

B. Economic Returns to Commercial Shrimp Farms

Although converting mangrove forests into commercial shrimp farms in southern Thailand is clearly financially rewarding, one

TABLE 4
Financial Analysis: Net Present Value of Commercial Shrimp Farms

	Year				
Values (US $/ha)	**1**	**2**	**3**	**4**	**5**
Benefits					
Gross returns[a]	17,932	17,932	17,932	17,932	17,932
Costs					
Variable costs[b]	12,940	12,940	12,940	12,940	12,940
Annualized fixed costs[c]	2,992	2,992	2,992	2,992	2,992
Net present value (10% discount rate)			8,336.47		
Net present value (12% discount rate)			8,071.54		
Net present value (15% discount rate)			7,706.95		

[a] Assumes nondeclining yields over 5-year period of investment and based on RFD estimates for Surat Thani Province of average shrimp yields of 3,856.25 kg/ha and farm price of $4.65/kg.

[b] Includes costs of shrimp larvae, feed, gasoline, oil and electricity, pond cleaning, pond and machine maintenance, labor, and miscellaneous variable costs.

[c] Land tax and rent, interest payments, opportunity cost of land and pond clearing costs, and depreciation.

Source: Based on data from MIDAS (1995) and Rawat (1994).

major external cost of shrimp ponds is the considerable amount of water pollution they generate. This consists of both the high salinity content of water released from the ponds and agrochemical runoff. In addition, there is the problem of the highly degraded state of abandoned shrimp ponds after the 5-year period of their productive life. Across southern Thailand those areas with abandoned shrimp ponds degenerate rapidly into wasteland because the soil becomes very acidic, compacted, and too poor in quality to be used for any other productive use, such as agriculture. In addition, without considerable additional investment in restoration, these areas do not regenerate into mangrove forests. Finally, many of the conventional inputs used in shrimp pond operations are subsidized, below–border equivalent prices, thus further increasing the private returns to shrimp farming.

Table 5 summarizes the results of the economic CBA of the returns to commercial shrimp farming in southern Thailand, which includes accounting for the external costs of water pollution and rehabilitating the mangrove forest as well as the full economic (i.e., border equivalent) costs of conventional inputs. Two estimates of the net present value of the economic returns are depicted in the table. The first estimate does not include the additional costs of restoring the mangrove forest from years 6 to 20, after the shrimp farm has been abandoned. The second estimate does include mangrove rehabilitation costs.

The results indicate that, even if mangrove restoration does not take place, the economic returns to commercial shrimp farming are considerably less than the financial returns that investors receive (see Tables 4 and 5). Depending on the discount rates used, the economic returns range from $194 to $209 per ha. If the costs of regenerating the mangrove forest over the years 6–20 are included, then the economic returns to shrimp farming are actually negative.

C. *Comparison with the Economic Benefits of Mangrove Forests*

Although the estimates in Table 4 confirm that the conversion of mangrove forests in southern Thailand into commercial shrimp farms is financially attractive, it is clear that once some of the external and foreign exchange costs of shrimp farming are accounted for, conversion of mangroves into

TABLE 5
Economic Analysis: Net Present Value of Commercial Shrimp Farms

	Year						
Values (US $/ha)	**1**	**2**	**3**	**4**	**5**	**6**	**7–20**
Benefits							
Gross returns	17,932	17,932	17,932	17,932	17,932		
Costs							
Variable costs[a]	14,540	14,540	14,540	14,540	14,540		
Annualized fixed costs[b]	3,113	3,113	3,113	3,113	3,113		
Cost of pollution[c]	228	228	228	228	228		
Costs of forest rehabilitation[d]						8,240	118
Without forest rehabilitation:							
Net present value (10% discount rate)				209.36			
Net present value (12% discount rate)				202.71			
Net present value (15% discount rate)				193.55			
With forest rehabilitation:							
Net present value (10% discount rate)				−5,447.97			
Net present value (12% discount rate)				−4,917.66			
Net present value (15% discount rate)				−4,239.75			

[a] Adjusted using the standard conversion factor of 0.89 for construction costs in Thailand.

[b] Adjusted using the standard conversion factor of 0.961 for capital costs in Thailand.

[c] Based on costs of treatment of chemical pollutants in water and loss of farm income from rice production from saline water released from shrimp ponds, from Rawat (1994).

[d] Based on costs of rehabilitating abandoned shrimp farms, replanting mangrove forests, and maintaining and protecting mangrove seedlings, from RFD.

commercial shrimp farms is not economically worthwhile. This is the case even if the costs of restoring mangrove forests after shrimp pond abandonment are ignored. For example, Table 3 indicates that the net present value of local uses of the mangrove forests by a small coastal community such as Tha Po Village are around $632 to $823 per ha. This is three to four times higher than the economic returns to shrimp farming, excluding the costs of mangrove rehabilitation, that are reported in Table 5. Once the values of off-shore fishery linkages and coastline protection are also included, it is clear that the economic benefits of conserving mangroves far exceed the economic returns from mangrove conversion to commercial shrimp ponds.

Table 5 also indicates that, if commercial shrimp farmers are required to restore mangrove forests, then shrimp farming in mangrove areas may not be economically viable. This result suggests that the de facto open access availability of mangrove forests for conversion to shrimp farming in southern Thailand may cause economic distortions in commercial shrimp farming in two ways. First, as shrimp farmers do not have to compensate anyone for conversion of mangrove forests, they tend to overexploit these resources. Shrimp farm operations are essentially subsidized in their use of coastal land resources; hence, the operations are financially profitable but lead to economically irrevocable degradation of mangroves. Second, the free availability of mangrove resources for conversion in southern Thailand means that the shrimp farm operations are economically inefficient. They will tend to use too much converted mangrove area relative to other inputs, leading to extensive and lower-yielding rather than intensive and higher-yielding operations.

There is evidence that shrimp farms in Surat Thani are not as high yielding as they could be. As reported in Table 4, average shrimp yields in Surat Thani Province are around 3,856.25 kg/ha. Ideally, however, intensive shrimp farming yields should be double this amount (Rawat, 1994). It is easy to demonstrate that an intensive shrimp farm that attains the latter yields would be able to generate sufficient economic returns to cover the full economic and external costs of its operation, including the costs of replanting and restoring the converted mangrove forest. However, as long as mangrove conversion remains essentially "costless," shrimp farm operators will not have the incentive to invest either in more intensive operations or in the restoration of degraded mangrove areas.

IV. CONCLUSION

In this study, the economic value of mangroves in southern Thailand in terms of local use of forest resources, off-shore fishery linkages, and coastline protection was estimated to be in the range of $27,264 to $35,921 per ha (see Table 3). However, much of this value is accounted for by the replacement cost estimate of the coastal protection and stabilization function of mangroves. As noted in the literature, the use of the replacement cost method to value an ecological function is prone to overestimation (Barbier, 1994; Ellis and Fisher, 1987). Thus, the above estimations of the economic benefits of mangroves must be considered an upper bound. As noted in Table 3, the net present value to a local community, such as Tha Po Village, of harvesting various mangrove resources ranges from $632 to $823 per ha. If the value of off-shore fishery linkages is also included, then the net present value (at a 10% discount rate) of these two benefits is $1,018–$1,468 per ha. The latter figures must therefore be the lower bound on our estimates of the value of mangrove benefits in southern Thailand.

However, it is important to note that lack of data has meant that this article has ignored other potential economic values of a mangrove system, such as tourism, carbon fixation, option values, and nonuse values. Thus, the overall value of mangroves in southern Thailand may be considerably higher than the results reported here.

Conversion of mangrove forest into commercial shrimp farming in southern Thailand appears to be financially attractive to investors, but this does not necessarily make conversion of mangroves into shrimp ponds economically worthwhile. Once inputs are priced at border-equivalent levels and the costs of water pollution from shrimp ponds are taken into account, the economic returns from commercial shrimp farming are considerably lower than the financial profits that investors receive (see Tables 4 and 5). More important, these economic returns, which range from $194 to $209 per ha, are significantly less than the economic benefits of conserving the mangroves. If the costs of restoring the mangrove forest after shrimp pond abandonment are also included, then extensive shrimp farming as practiced throughout Surat Thani and much of southern Thailand is no longer economically viable.

The case study of Tha Po Village in Surat Thani also suggests that there is a major distributional concern with respect to shrimp farming. Even though such operations are financially profitable, those who gain are mainly outsiders who can afford the high initial investment requirement. In comparison, the local people tend to experience losses in terms of the net forgone benefits of mangrove deforestation and the damage costs of saline water and agrochemical pollution released from shrimp ponds.

Surat Thani is in fact not a unique example of mangrove forests that have been severely encroached upon by shrimp farms. The problem is pervasive throughout southern Thailand, Southeast Asia, and many other coastal tropical regions. Our case study indicates that there is a strong incentive for local coastal communities to protect mangrove forests. For example, the RFD estimates that the cost of effective mangrove forest protection in southern Thailand is around \$4.70 per ha. As the annual net income from local use of mangrove forest resources alone is around \$88 per ha in the case of Tha Po Village (see Table 3), there is certainly an incentive for the local community to protect the forest.

However, the long-term success of any local initiative will depend on how well organized and effective are the resulting institutions for common property management. This will, in turn, depend on whether the national legal system recognizes the rights of the local people to protect and manage mangrove forests.

There is substantial evidence that, in similar cases throughout the developing world, common or communal property can be a effective management regime for common pool resources (McCay and Acheson, 1987; Ostrom, 1991; Bromley and Chapagain, 1984; Baland and Platteau, 1996). In fact, provided that exclusivity is well enforced, a common property regime is similar to private property for the group (Bromley and Cernea, 1989). It is only when exclusivity completely breaks down that the resource becomes essentially open access (Ostrom et al., 1994; Runge, 1981; Sandler, 1992; Seabright, 1993). Cultural norms and traditions can help to build up "trust" for assurance and form "punishment" to enhance the costs of retaliation (Seabright, 1993). A secured communal property regime is vital to ensure the net long-term streams of benefits from cooperation. For the Tha Po Village and other similar cases, it is therefore essential that the rights of local communities should be well recognized by the law.

As discussed in the introduction, recent policy developments regarding the conservation of mangroves and the participation of local communities in such activities are encouraging. The Ministry of Agriculture and Cooperatives, to which the RFD belongs, has recently announced that the conservation of mangroves has to be taken seriously; the ministry is considering banning mangrove forest timber concessions and the use of mangrove areas for shrimp farming nationwide. At present, however, the ban has not yet been applied to mangroves. Finally, new legislation on community forests is about to be promulgated in Thailand, which will for the first time support local communities' rights to protect mangroves and other forests that they have traditionally used. This new law will certainly be welcomed in southern Thailand. At a village gathering led by the headman to discuss protection of their local mangroves, more than 60% of the villagers in Tha Po attended. All of them unanimously express their desire to have the remaining mangrove forest in the vicinity designated as a protected community forest under the prospective community forest law (Sathirathai, 1998).

APPENDIX

Based on data and information from the work of Lynne et al. (1981), which studied the relationship of natural marsh to the economic productivity of blue crab on Florida's Gulf Coast, Ellis and Fisher (1987) developed a static optimization model using a Cobb-Douglas relationship to represent production of blue crab. The cost-minimization problem faced by a price-taking fishing industry is

$$\text{(A1)} \qquad \min_{E} L = cE + \lambda(X - mE^{a}\bar{A}^{b}),$$

where E is human effort as measured by the number of crab traps set; $\bar{A}$ is coastal wetland area in acres, which is considered exogenous in this problem; and c is the unit cost of effort. X is the quantity of crabs caught, which depends on human effort and the area of wetland as represented by the Cobb-Douglas production function

$$\text{(A2)} \qquad X = f(E, \bar{A}) = mE^{a}\bar{A}^{b}.$$

Solution of the above problem for E leads to the following optimal cost function:

$$\text{(A3)} \qquad C(c, X, \bar{A}) = cm^{-1/a}X^{1/a}\bar{A}^{-b/a}.$$

Ellis and Fisher assumed that the fishery is under a private property regime, and therefore equilibrium price, P, is equal to marginal cost, MC. Thus from equation (A.3), this equilibrium condition can be expressed as

$$\text{(A4)} \qquad P = MC = \frac{\partial C}{\partial X} = \frac{c}{a}m^{-1/a}\bar{A}^{(-b/a)}X^{(1-a)/a}.$$

Assuming an isoelastic demand function, $X = DP^{-d}$, the equilibrium quantity of crabs harvested can be solved as

$$\text{(A5)} \qquad X = \left[\frac{a}{c}D^{1/d}m^{1/a}\bar{A}^{b/a}\right]^{da/[d+(1-d)a]}.$$

However, Freeman (1991) has argued that most fishery resources are under an open-access situation in which rents are dissipated. In this situation, the market equilibrium occurs where price equals average cost, AC, that is,

$$\text{(A6)} \qquad P = AC = \frac{C(c, X, \bar{A})}{X} = cm^{-1/a}\bar{A}^{(-b/a)}X^{(1-a)/a}.$$

Given an isoelastic demand, the equilibrium quantity harvested under open access is

$$\text{(A7)}\qquad X=\left[\frac{1}{c}D^{1/d}m^{1/a}\overline{A}^{b/a}\right]^{da/[d+(1-d)a]}.$$

Both equilibrium quantity and price associated with different levels of wetland area can therefore be calculated, and the resulting welfare impacts will vary depending on the fishery management regime. For example, an increase in wetland area will lower the cost of harvesting and hence drive the price of fish down. In the case of an open access of fishery, the lower cost will attract new entrants (and increase effort), which will eventually dissipate all producer surplus. Only consumers will benefit. The value of the increase in wetland area can then be measured in terms of the associated increase in consumer surplus. In contrast, under a private property regime, the value of the increase in wetland area should be measured in terms of the associated increase in both producer and consumer surplus.

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