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Economic Valuation of a Mangrove Ecosystem Threatened by Shrimp Aquaculture in Sri Lanka

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ABSTRACT / Mangrove ecosystems in Sri Lanka are increasingly under threat from development projects, especially aquaculture. An economic assessment is presented for a relatively large (42 ha) shrimp culture development proposed for the Rekawa Lagoon system in the south of Sri Lanka, which involved an extended cost–benefit analysis of the proposal and an estimate of the "total economic value" (TEV) of a mangrove ecosystem. The analysis revealed that the internal benefits of developing the shrimp farm are higher than the internal costs in the ratio of 1.5:1. However, when the wider environmental impacts are more comprehensively evaluated, the external benefits are much lower than the external costs in a ratio that ranges between 1:6 and 1:11. In areas like Rekawa, where agriculture and fisheries are widely practiced at subsistence levels, shrimp aquaculture developments have disproportionately large impacts on traditional livelihoods and social welfare. Thus, although the analysis retains considerable uncertainties, more explicit costing of the environmental services provided by mangrove ecosystems demonstrates that low intensity, but sustainable, harvesting has far greater long-term value to local stakeholders and the wider community than large shrimp aquaculture developments.

Mangrove ecosystems in Sri Lanka are increasingly under threat from development projects, especially shrimp aquaculture. Despite covering only 0.19% of Sri Lanka's total land area, shrimp sales from these areas and associated coastal waters are an important source of foreign exchange and account for 40–50% of total aquaculture exports (Senarath and Visvanathan 2001). Many of Sri Lanka's mangroves have either been developed or are earmarked for shrimp ponds. It is also widely observed that when successful shrimp farms are introduced into new areas' they encourage further development until only a remnant of the original area remains or until the entire mangrove area has been converted into ponds (Amarasinghe 1988).

Mangroves have contributed significantly to the livelihood of coastal communities through products used for fuel, construction, fishing, agriculture, forage for livestock, medicines, and food items (Primavera 1997). Furthermore, mangroves supply multiple ecosystem services such as: nursery grounds and shelter for fish, crabs, and shrimp; buffers against storm surge and shoreline erosion; and absorption of pollutants; maintenance of biodiversity and water conservation (Dierberg and Kiattisimkul 1996). The productivity of aquaculture systems such as shrimp ponds is also heavily dependent on the surrounding mangroves, which provide a range of free services such as seed, food inputs, and clean water for culture practices (Beveridge and others 1997). They also offer protection against floods, hurricanes, and erosion and so protect aquaculture operations against natural hazards. Rönnbäck (1999) discussed that the life-support functions of mangroves are crucial for the sustainability of aquaculture systems and that failure to acknowledge this function is one explanation for the boom-and-bust pattern of shrimp aquaculture. Considerable amounts of energy and money would be required if free mangrove goods and services were to be substituted with human technology. However, the market price of the cultured product captures only a fraction of the services provided by the host environment.

Shrimp aquaculture is widely considered to be one of the most environmentally destructive forms of modern agriculture. Aquaculture projects not only destroy mangroves for shrimp ponds but also deplete groundwater resources to fill ponds and pollute surface waters with pond effluent (Goldburg 1997; McKinnon and others 2002). One of the most unfortunate aspects of the expansion of the shrimp culture industry is the

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lack of consideration given to the long-term conservation and management of natural resources (Flaherty and Karnjanakesorn 1995; Corea and others 1995).

High profitability and the opportunity to generate foreign exchange have provided the main driving forces for the expansion of shrimp culture in Sri Lanka and are used to justify the conversion of mangroves to shrimp ponds. The external costs associated with the removal of mangroves for shrimp ponds have hitherto been overlooked in project valuation in Sri Lanka. This is because the total value of mangrove ecosystems has not been fully realized; indeed, these ecosystems are often considered as wastelands by planners, developers, and politicians and, therefore, their conversion to shrimp ponds has witnessed little resistance (cf. Hamilton 1989).

Development-oriented financial analyses typically focus on monetary profit. They seldom capture all environmental effects and thus consistently underrepresent the wider welfare of society. Financial assessments favor the higher returns of intensive shrimp farming over intact mangroves, which are typically viewed as common-property resource systems (cf. Armitage 2002). However, when the goods and services of mangroves and the short-term viability and sustainability of shrimp operations are considered, the economic analysis can reveal a substantially different benefit and cost profile. It is, therefore, important to monetize the total value of mangrove ecosystems in order to provide comprehensive information to national governments and international funding organizations as a check for the continued promotion of industrial-scale shrimp aquaculture development programs (Davenport and others 1999).

Most mangrove valuation efforts have covered only marketed resources and ignored subsistence-level uses and nontraded uses such as the conservation of biodiversity. When only mangrove fishery and forestry benefits are included, the annual value of mangroves has been estimated between to be US$ 500/ha/year and 2500/ha/year (Dixon 1989). However, when complete mangrove systems are considered, much higher figures of between US$ 1000/ha/year and 11,600/ha/year were obtained (Primavera 1997). The value of a mangrove area in Sarawak (Malaysia) was estimated as approximately US$ 25 million/year when forestry, fisheries, and tourism revenues were considered (Bennett and Reynolds 1993).

Khor (1995) reported the results of cost–benefit analysis (CBA) in India, which concluded that the shrimp culture caused more economic harm than good, the damage outweighing the benefits by as much as 4 to 1 in Andhra Pradesh. Net present value (NPV) is often used to evaluate the economics of a project by comparing current costs to undertake the development versus the potential future benefits. Lal (1990) reported negative NPV results (i.e., loss making) for converting mangrove forest to shrimp and rice farming over a 50-year planning horizon. These examples illustrate the need for greater awareness of economic analysis within environmental impact assessment and project appraisal (Gunawardena 2001). The present study attempts to make a contribution to this resource management debate by undertaking an extended cost–benefit analysis (ECBA) of a moderately large shrimp aquaculture project proposed for a relatively pristine mangrove ecosystem in the south of Sri Lanka. The ECBA was designed to reveal the costs and benefits of the project, the number of individuals affected, and the different social groups to which the costs and benefits of the project accrue. However, the main focus of the present article is to report on the determination of the total economic value (TEV) of the mangrove system, which systematically identifies and values the wider range of environmental services offered by the mangroves (cf. Pearce and Turner 1990). The combined approach was then used to assess whether the proposed shrimp project will result in greater or less social well-being than the predevelopment condition.

Methodological Considerations

It is widely acknowledged that the "true" economic value of mangroves is underestimated because most mangrove valuation studies cover only marketed resources such as forestry and fishery benefits (Primavera 1997). Rönnbäck (1999) posits that undervaluation further stems from the general lack of ecological knowledge among economic analysts, the failure to adopt a holistic approach that fully recognizes the complex interdependency of marine, coastal, and terrestrial ecosystems, along with the difficulties involved in placing monetary values on the relevant factors. As a result, many environmental goods and services provided by mangroves have been ignored, either because these are nonmarketed or they occur off-site and tend to be overlooked.

Ideally, the full range of goods and services of mangroves should be evaluated, including those produced on-site and off-site. Off-site goods and services include fisheries caught both within the mangrove lagoon and in nearby coastal waters. The valuation of subsistence-level goods is also needed, but this is especially difficult to achieve in developing countries because of the lack of quantitative data on products harvested and the absence of markets for most of these goods (Ruitenbeek 1994). However, these traditional, untraded goods can be a substantial component of local economies and thus must be acknowledged, even if only in a qualitative framework (Rönnbäck and Primavera 2000).

In the assessment of the TEV of ecosystems, the full range of indirect services is often aggregated into a composite term including option, existence, and bequest values. However, it is important that TEV components be shown to be mutually exclusive; if not, double-counting among the various component values can occur (Winpenny 1991). This is especially true because most of the indirect benefits of environmental goods and services occur off-site, at a distance from the ecosystem itself, and because most environmental systems have a large range of functions that are interlinked. Thus, judgment has to be used in selecting the most economically significant uses for the valuation procedure. Therefore, once external benefits have been traced to their initial source within the ecosystem concerned, there is little advantage in further disaggregation (Aylward and Barbier 1992). Also, trade-offs between the different components of TEV can occur, again emphasizing the need to ensure that double-counting and possible trade-offs are explicitly taken into account. A further problem in economic valuation is predicting the environmental response to a given development activity in the presence of discontinuity; that is, the effects of a development activity in one location might not be replicated in another. Economic analysis tends to assume that change takes place in a fairly continuous fashion, but changes in an ecosystem might be discontinuous. Therefore, predicting the environmental response to economic change can be difficult in the presence of discontinuity. Prediction is made more difficult because the various links within and between the ecosystems might be unknown or poorly understood.

In developing countries, particularly in remote rural areas, such as southern Sri Lanka, the logistics of data collection are difficult and accessing reliable "official" data (government, local government, and associated research agencies) can be additionally problematic (cf. Lee and George 2000). Valuation strategies in developing countries often differ from those in developed countries; that is, willingness-to-pay methods might be replaced by more tractable methods such as replacement-cost analysis, damage-cost analysis, and related methods of valuation (Winpenny 1991). Although such methods might be suboptimal, they might be the best available given constrained resources. However, their main drawbacks are that the ecosystem under investigation might have limited baseline data and so system dynamics might be subject to considerable dispute and scientific uncertainty. Unfortunately, it is often the case that the true value of the protection services provided by natural ecosystems only becomes known once they are lost—often irreversibly (Aylward and Barbier 1992). These general methodological issues are now considered in detail within the case study presented.

Study Site

The Rekawa mangrove–lagoon ecosystem is located in the Hambantota District, southern Sri Lanka. The dominant features of the area are the 250-ha lagoon and its fringing mangrove forest of approximately 200 ha (Figure 1). The mangrove–lagoon ecosystem is bounded on the seaward side by a broad sandy beach, which is approximately 10 km long, and on the landward side by extensive tracts of abandoned rice fields. The mangrove–lagoon ecosystem supports rich and diverse habitats, including mangrove forest, lagoon, beach, coral reefs, and sea grass beds—all of which are interconnected by tidal flows, current patterns, and trophic relationships.

There are 20 villages within 7 GN (Grama Niladhari) Divisions at the Rekawa site, which supports a population of 1184 households and 5373 people (Ranaweera and others 1994). The rural communities are closely connected with the natural resources of the area and depend on mangroves for a range of direct and indirect benefits. The former includes firewood for domestic use, timber for house construction, material for fish and prawn traps, and other minor uses such as extraction of medicinal plants, whereas the later includes nursery grounds for coastal fisheries and protection from coastal flooding. Human-induced pressures on the system include declining lagoon water quality, overfishing of shrimp and fish in the lagoon, forest encroachment, coral mining, and poaching of turtle eggs. During the early 1990s the absence of coordinated sustainable agriculture and aquaculture programs led to Rekawa's designation as a Special Area Management (SAM) pilot-study site under the aegis of Sri Lanka's Coast Conservation Department. Such SAM projects were established with the aim of promoting community-led coastal resource management and stimulated studies into the physical characteristics of the lagoon, socioeconomic profiling, along with a feasibility study into the potential role of aquaculture projects (Lowry and others 1999).

Of particular concern for this study is a proposal to develop a relatively large 42-ha shrimp aquaculture project in the Medilla area on the western shore zone

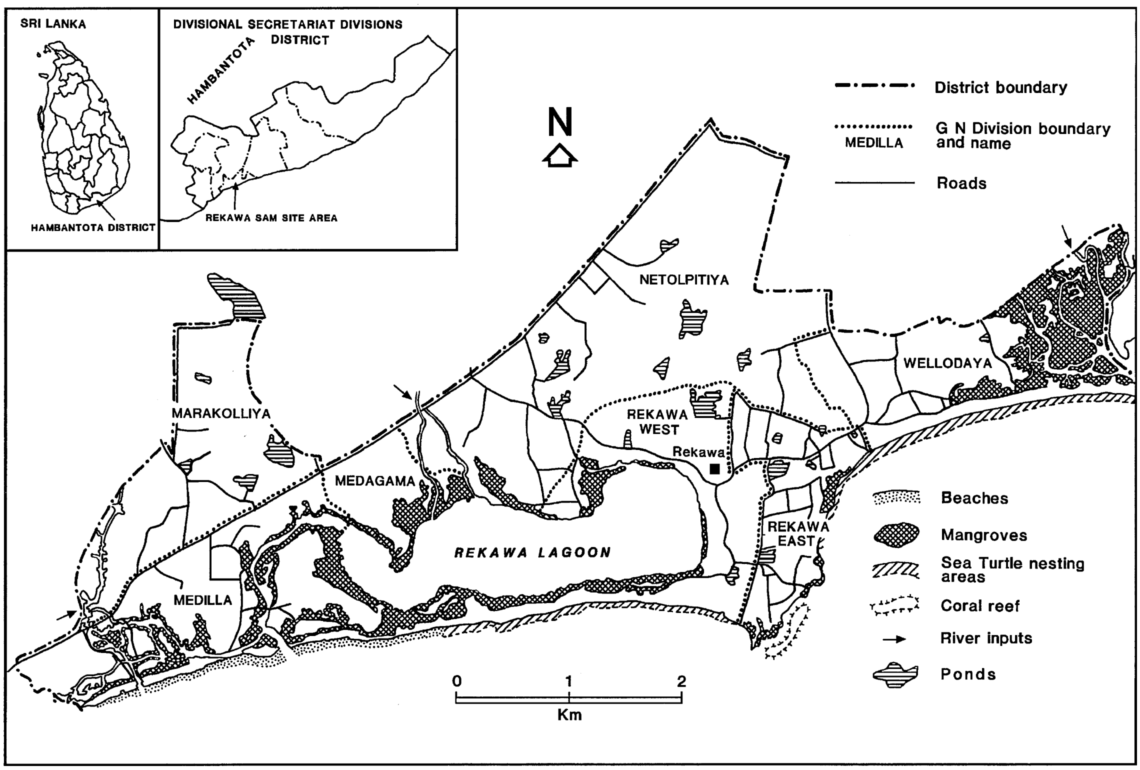

Figure 1. Location and physical characteristics of the study site.

of Rekawa Lagoon (Figure 1). Thirty-two hectares will be developed for shrimp aquaculture and 10 ha will be reserved without development as a buffer zone. The proposal involved the following components: (1) 48 shrimp culture ponds; (2) inlet feeder canals bringing in fresh seawater to the ponds; (3) effluent canals that will transfer the effluent to the settlement tanks; (4) settlement tanks; (5) pump house and standby generator; (6) an intake structure located at the sea coast nearest to the projec, which will extract water from the sea and transfer it via a pipe laid below ground level to the feeder canals, which, in turn, will distribute the water to individual ponds through control structures; (7) a pipe carrying the treated effluent will be laid below ground level through which the effluent will be pumped out into the sea; (8) storm water disposal canals that will divert excess storm water from the project area; and (9) administrative buildings, stores, and residential areas (EIAR 1993). Approximately half the local population live off products sourced form the lagoon and sea fishing; the other half is engaged in various agriculture-related activities (RSAMMC 1996). It was proposed that around 50 jobs would be created on a regular basis and around 250 during the main construction period.

Field Methods and Analytical Approach

Conceptual Framework and Background Data Availability

A scoping analysis was first undertaken to identify the key environmental and socioeconomic impacts likely to arise from the proposed shrimp culture project at Rekawa. Standard EIA approaches (cf. Glasson and others 1994) were adopted, supported by discussions held with government officials, consultants, and members from local communities and set out as an ECBA framework (Figure 2). The TEV of the Rekawa mangrove ecosystem was then calculated by estimating the monetary values for (1) the total direct use value, (2) the total indirect use value, and (3) the option value along with the existence and bequest values. TEV is given by

$$\begin{aligned}\text{TEV} = {} & \text{Direct use value} \\ & + \text{Indirect use value} + \text{Option value} \\ & + \text{Existence and bequest values}\end{aligned}$$

(cf. Pearce and Turner 1990). In the TEV assessment, essentially five use categories of the environmental resource are recognized, with different degrees of tractability. Direct use values for mangroves include

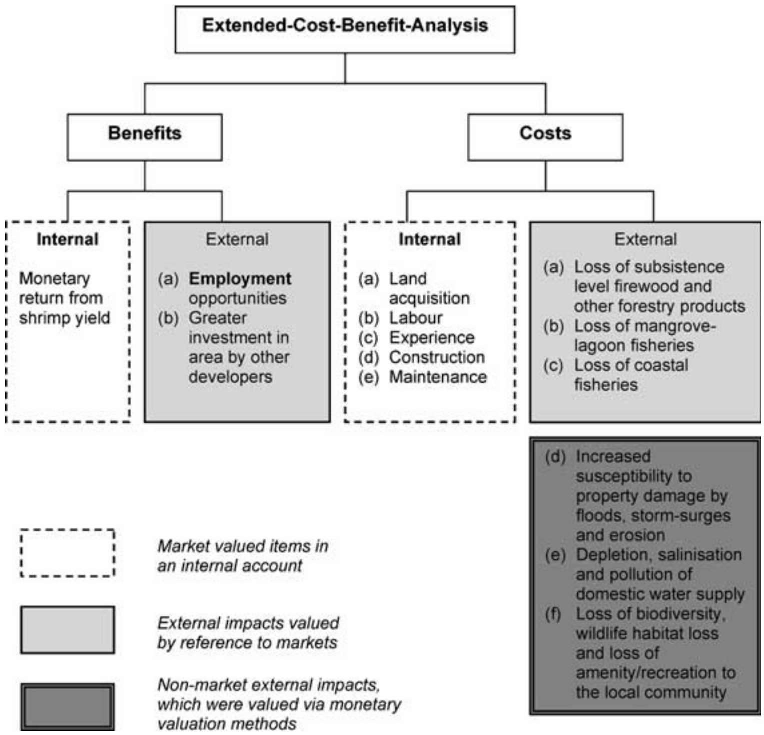

Figure 2. Extended cost–benefit analysis framework to appraise a proposed shrimp culture project in Sri Lanka.

forestry and fishery products harvested. Indirect use values or functional values relate to the ecological functions performed by the environmental resource (Adger and others 1995). The option value has been defined as a Willingness-To-Pay (WTP) for the preservation of an environment or resource against some probability that the individual will make use of it at a later date (Winpenny 1991). Existence and bequest values relate to the fact that even if the individual does not consume the environmental services, he/she might still be concerned about the quality or the existence of the asset and derive satisfaction from the simple fact that the asset is available for other people living now or in the future (Johansson 1990).

The different methods used to quantify the TEV of the mangrove ecosystem are outlined in Table 1. The data collection was initiated in June 1998. The first phase of the data collection process involved a pilot survey comprising visits to government agencies along with reconnaissance surveys to the Rekawa site and existing aquaculture projects elsewhere in the region. The aim of the pilot survey was to collect all available information relevant to calculating the TEV components of the Rekawa mangroves. The agencies visited included the Coast Conservation Department, the Ministry of Fisheries and Aquatic Resources, the Department of Fisheries, the National Aquaculture Development Agency, the Tangalle Fisheries Extension Office, and local authorities within the Rekawa area.

The pilot survey established that there was adequate government fisheries catch data for both the Rekawa lagoon and coastal fisheries. Fisheries data collated included production figures, species harvested, the number of fishing boats and fishermen, and the costs in terms of fuel, bait, fishing gear, and boats. An important caveat to consider is that official figures consistently undervalue noncommercial catches and nonmarketed species (Rönnbäck1999); thus, the value of the lagoon and coastal fisheries reported in this study should be considered as minimum estimates of the total resource.

The Rekawa case study deals with a single aquaculture development project that will extend over a fifth (21%) of the mangrove area, although land clearance for ponds will be restricted to approximately 16 % of the total area in the first instance. Clearly, there are scaling issues involved in quantifying the effects of partial losses to selected components of the ecosystem. For example, Pauly and Ingles (1986) observed that the relationship between the yield of penaeid shrimp fisheries and intertidal mangrove area was nonlinear (logarithmic), indicating that the impact intensified as the proportion of land conversion increased. Elucidating the complex and dynamic linkages between the mangrove ecosystem and the lagoon and coastal fish-

Table 1. Approaches adopted for TEV assessment

Environmental goods and services	Approach	Data derivation
Firewood collection—at a subsistence level	Marketed substitutes/alternative supplies (after Winpenny 1991)	Data collected from a random sample of households
Lagoon fisheries—at a subsistence level	Valuing the marginal productivity of the resource net of any human effort (after Turner 1993).	Based on available government catch data for the Rekawa lagoon fisheries
Coastal fisheries—at subsistence and commercial levels	Valuing the marginal productivity of the resource net of any human effort (after Turner 1993).	Based on available government catch data for the Rekawa coastal fisheries
Shoreline stabilization, erosion control, and control of storm surges	Preventive expenditures or damage costs avoided (after Turner 1993).	Based on available government data on the costs to implement erosion control structures
Existence, bequest, and option values	Contingent valuation method (after Bateman and Turner 1993)	Based on data collected from a random sample of households

eries was beyond the scope of the present study (Gunawardena 2001). Consequently, a linear response between habitat loss and ecological impact was assumed (cf. Nickerson 1999); thus, the empirical results and conclusions are heavily dependent on this assumption.

Questionnaire Survey

The second phase of the data collection process extended over a period of 1 month and principally involved in-depth interviews and questionnaire surveys as the means to collect other relevant data necessary to complete the TEV. Survey respondents were asked about the nature of mangrove products harvested and about their dependence on lagoon and coastal fisheries. These data enabled the proportion of mangrove users and nonusers to be defined and was used as the basis for establishing the existence, bequest, and option values of the mangroves for the local community. One of the researchers (MG) lived among the local community for the duration of the study, enabling a research diary to be maintained and providing valuable qualitative insights into lifestyles, local economic practices, and cultural attitudes to resource management.

To represent the population of Rekawa, a systematic random sample was drawn from a complete list of households held by the relevant local authorities. The household list revealed that there were a total of 1184 households in the Rekawa area. From this list, a random sample of 205 households was drawn. The sample interviewed was assumed to be representative of the entire Rekawa community. The questionnaire design followed accepted conventions (Joliffe 1983), and interviews were conducted on a house-to-house basis and conducted in the local language, Sanskrit. A total of 205 persons were interviewed. Beyond basic demographic data, including age, education, gender, income, the number of occupants per household, and number of children per household, the questionnaire sought to establish the proportion of the local population directly benefiting from mangrove goods and services (i.e., forestry and fisheries) as opposed to those not directly benefiting from mangroves (i.e., mangrove nonusers). This was needed to avoid double-counting effects when calculating the individual TEV components.

The questionnaire sought information about the range of mangrove products harvested, along with quantities and frequency of collection. These data were used as the basis for quantifying the value of traditional forestry uses in Rekawa. Survey respondents were also asked about their dependence on lagoon and coastal fisheries. However, most of the data needed to calculate the mangrove fisheries value were based on existing government fisheries catch data.

The contingent valuation method (CVM) using an open-ended approach (after Bateman and Turner 1993) was adopted to measure the worth of preserving the Rekawa mangrove–lagoon ecosystem from shrimp development. The CVM was designed to measure WTP to preserve the Rekawa mangroves, estimated in the form of voluntary contributions to a hypothetical mangrove protection fund (cf. Hutchinson and others 1995). The contingent market section of the questionnaire described the various functions and benefits of mangroves and presented information on the scale and nature of the proposed shrimp farm. Respondents were then asked a series of structured questions regarding maximum WTP to preserve and conserve the existing mangrove system without further development.

NPV of the Proposed Shrimp Development

The internal costs and benefits of the proposed shrimp farm were estimated from the financial statement of the project proposal, as were the external benefits. The external costs of the proposed shrimp development were estimated from the TEV assessment of the mangrove ecosystem. These data were used in an NPV formulation for the project where:

$$NPV = \sum_{t=1}^{n} (B_d - B_e - C_d - C_e)/(1+r)^t$$

NPV = net present value; B_d = direct or internal project benefits; B_e = external project benefits, C_d = direct or internal project costs, C_e = external project costs; r = discount rate; t = year in which costs or benefits occurred; and n = number of years in economic time horizon or project lifetime

(Source: Carpenter and Maragos 1989).

A key variable in determining NPV is the expected useful life of the project. Shrimp pond productivity has been observed to decline at a rates between 3%–8% per production cycle (cf. Funge-Smith and Briggs, 1994). When intensive aquaculture is practiced, the life span of ponds typically does not exceed 5 to 10 years because of attendant problems of self-pollution, disease, and acid–sulphate conditions (Gujja and Finger-Stich 1996). In Thailand, 70% of previously productive ponds get abandoned (Stevenson 1997), while in Sri Lanka, even after a few years of operation the abandonment rate can be even higher c. 90% (Siriwardena 2000). In view of the findings in the literature, the present analyses assumed that the working life span of the proposed shrimp farm to be 10 years and benefits were calculated accordingly. However, the costs of the project will occur during and well after the expected useful life of the project. Therefore, the NPV was calculated over a more realistic time frame of 20 years.

Discounting the costs and benefits in CBA is based on the fact that future costs and benefits usually weigh less in the decision-making process, rather than those occurring nearer the present time. This is because governments and people tend to prefer present values over future ones. The project's NPV was calculated over a range of discount rates spanning from 0% to 15% to explore the sensitivity of the results. Discount rates should partially reflect the cost of borrowing money as set in the marketplace by financial institutions such as banks, which for Sri Lanka at the time of the study ranged between 10% and15%. They should also partially reflect the social rate of time preference, which indicates society's willingness to sacrifice present consumption for the future (Bateman 1995). This rate will normally be lower than that of the money market, so social discount rates of 2% and 5% were used. Using low discount rates such as 2% or 0 % favors projects with long-term benefits, whereas using high discount rates (i.e., greater than 10%) favours projects with short-term benefits.

Results of the Rekewa Lagoon TEV

The TEV required utilitarian (direct and indirect values), option, existence, and bequest values to be quantified and these will be reported in turn.

Direct Value: Forest Goods and Services

The household survey results revealed that 24% of the population harvested the mangroves for firewood, 10% for fish or prawn traps, 8% for construction material, and a small proportion for other miscellaneous products (e.g., medicinal extracts, honey and other food items, tannins for dyes, and manure). The rates of extraction of forestry products in Rekawa are currently low, and most harvesting is conducted at subsistence levels. Patterns of dependency were highly variable, with some households in the local villages heavily dependent on mangrove wood and timber products for domestic uses, and others not at all.

The survey revealed that those households dependent on forestry products (24% of the 205 households surveyed) harvested an average of 20.5 kg of firewood each week, equivalent to 982 kg/year. Assuming that the random sample is representative of the total 1184 households in the area (Ranaweera and others 1994), it can be extrapolated that the annual harvest equates to 279 tons/year, which from a 200-ha mangrove forest represents 1.4 tons/ha/year.

The value of mangrove firewood was estimated using the actual amount of firewood harvested multiplied by the "shadow value" in the form of the price for firewood obtained inland and sold by local licensed concessionaries. Minor products such as honey or those used for medicinal purposes were not valued due to the absence of markets for these products and the difficulty in establishing quantities harvested. At local markets, equivalent firewood sold for 1.2 Rs/kg, giving an annual value to the harvest of 334,800 Rs (US$ 4783), equivalent to 24 US$/ha/year. This figure provides a minimum gross preservation value for firewood, but does not include an estimate of the opportunity costs associated with the time spent foraging for timber. Such costs can be approximated using shadow wage rate techniques, but have not been undertaken here because wood harvesting is conducted at subsistence levels. It must be acknowledged that the simple replacement-cost approach only partially captures the social welfare aspects of forest losses imposing a market

Table 2. Calculation of the value of the Rekawa mangrove–lagoon and near-shore coastal fisheries

Lagoon fisheries

Total number of lagoon fishermen[1] = 250, total annual production[2] = 36 tons

Crustaceans (30% of total lagoon fisheries catch)[2]

Main species harvested: *Penaeus indicus, Penaeus monodon*, and *Metapenaeus monoceros*[1]

Mean catch per person = 2.96 kg/day

Total annual catch = 10.8 tons/year @ 300 Rs/kg = 3.24×10^6 Rs/year

Fish (70% of total lagoon fisheries catch)[2]

Main species harvested: *Mugil cephalas, Oreochromis niloticus, O. mossambicus, Anabus testudini, Ophiocephalus punctuates*[3]

Mean catch[3] = 1.0 kg/day

Annual catch[2] = 25.2 tons @ 40 Rs/kg = 1.01×10^6 Rs/year

I. Total value of mangrove dependent lagoon fishery = 4.25×10^6 Rs year

II. Harvesting costs

Harvesting costs per fisherman (fishing gear, bait, and other minor costs)[c] = Rs 2000/year

Total harvesting costs = $2000 \times 250 = 0.5 \times 10^6$ Rs/year

III. Net Value of the lagoon fisheries (I–II) = 3.75×10^6 Rs/year

Net Value based on 200-ha mangrove = 18,750 Rs/ha/year (US$ 268/ha/year)

Coastal fisheries value

Number of fishermen[4] = 276, number of boats[2]= 60, mean catch per boat[2] = 23.5 kg, mean number of fishing trips per month[5] = 22, number of fishing months per year[5] = 9, fishing households[4] = 228, population of fishing households[4] = 972, mean boat to fishermen ratio[4] = 1:4

Catch data and gross value

Sardine fishery (family Clupeidae): Total annual catch[4,6] = 75 tons @ 85 Rs/kg = 6.4×10^6 Rs

Mullet fishery (family Mugilidae): Total annual catch[4,6] = 12 tons @ 160 Rs/kg = 1.9×10^6 Rs

Prawn fishery (family Penaidae): Total annual catch[4,6] = 5 tons @ 300 Rs/kg = 1.5×10^6 Rs

I. Total value of mangrove dependent coastal fishery = 9.8×10^6 Rs/year

Harvesting costs

Total variable cost per boat per year[5] = 44,748 Rs

Average cost per boat for boat, fishing nets and other gear[4,6] = 4150 Rs

II. Annual harvesting costs for 60 boats ($60 \times 48{,}898$) = 2.9×10^6 Rs/year

III. Net value (I–II) = 6.9×10^6 Rs/year

Net Value based on 200-ha mangrove = 34,500 Rs/ha/year (US$ 493/ha/year)

Data sources: [1]RSAMCC (1996), [2]Jayakody and Jayasinghe (1992), [3]DFAR, personal communication (1998), [4]DFAR (1998), [5]Ediriweera (2000), [6]DFAR, personal communication (2000).

economy onto local people who previously have drawn uncosted goods from the forest (cf. Nickerson 1999).

Indirect Value: Fisheries

Mangroves are characterized by a high abundance of fish, crustaceans, and molluscs and capture fisheries constitute a major value of marketed products from an unexploited mangrove forest (Barbier 2003). Fish standing stock is much higher in mangrove habitat compared to adjacent coastal habitats. This is because many species of fish and invertebrates use mangroves during at least one stage of their life cycle, which, in turn, is related to food abundance, shelter from predation, and the hydrodynamic ability of mangroves to retain immigrating larvae and juveniles (Rönnbäck 1999).

The role of mangroves in the production of leaf litter and nutrients, which support the rich aquatic and benthic plankton food supply for fisheries, is well documented (Moberg and Rönnbäck 2003). Because of the high primary productivity in mangrove ecosystems (Robertson and Blaber 1992), it has been suggested that fish and invertebrates occupying mangrove habitats do so mainly to utilize the food resource (Singh and others 1994). Primary production in mangroves can be attributed to several sources such as the trees themselves, the associated epiphytes, phytoplankton, and benthic microalgae (Rönnbäck 1999). The proportion of commercially important marine fisheries dependent on mangroves for key stages of their lifer-acycle varies from 60% to 90 % (Nickerson 1999).

Mangrove ecosystems provide a range of services that are important for the recruitment success of many species of fish, crustaceans, and molluscs. Mangroves serve as refuges from predation for larvae and juveniles of many fish and invertebrates by virtue of the shallow water and highly turbid conditions, as well as the structural complexity resulting from mangrove roots, debris, and other vegetation (Singh and others 1994). In addition, mangroves help increase the residence time of water and thus facilitate settling of immigrant

Table 3. Environmental protection provided by mangroves

Environmental protection function	Examples of problems resulting from mangrove clearance
Protection against erosion	Indonesia and Philippines: loss of inland agricultural land through sedimentation and coastal erosion (Bennett and Reynolds 1993)
Protection against storm damage and flooding	The destruction of mangroves along the Philippines coastline accounts in part for the great losses to life and property inflicted by typhoons and tsunamis each year (e.g., 7000 deaths in Ormoc and other towns in 1991) (Primavera 1991).
	The clearing of mangroves in the Chakaria Sundarban area of Bangladesh resulted in the increased vulnerability of the area to cyclones and tidal waves (Choudry and others, 1994).
	On the east coast of India, shrimp ponds impeded water flow that resulted in floods (Alagarswami 1995).
Protection against salt intrusion	Salt-water intrusion due to shrimp ponds has been observed in coastal areas of Vietnam (Thuoc 1995) and 6 km upstream from shrimp ponds in Sri Lanka (Jayasinghe 1995).
	Salinization of groundwater supplies and agricultural land reported widely, including Sri Lanka (Foell and Harrison 1999).
Protection of nearby beaches and coral reefs	Indonesia and Philippines: mangrove destruction for aquaculture ponds led to mud deposition on nearby beaches and degradation of coral reefs (de la Cruz 1979).

larvae spawned from offshore areas into mangrove habitat, where they find refuge and food during their juvenile stages. Mangrove ecosystems are also important in trapping sediment and organic material from land resources and interact with sea grass and coral reef ecosystems by maintaining water quality, nutrient balances, and hydraulic characteristics (Nickerson 1999). Although mangroves, sea grass beds, and coral reefs can exist in isolation from each other, they commonly form integrated ecosystems of high productivity and provide a myriad of ecological services (Moberg and Rönnbäck 2003).

In the present analysis, it was assumed in that the Rekewa mangrove forest represents the main source of detritus and nutrients and provides essential habitat protection for fishery nursery grounds in the local area. The two main types of fishery identified were the mangrove–lagoon and the near shore–coastal systems respectively (RSAMCC 1996). Both fundamentally operate at subsistence levels. Government survey data indicate that the key crustaceans and fish harvested from Rekawa waters belong to the families Penaidae, Mugilidae, and Clupeidae (RSAMCC 1996; DFAR, personal communication 1998, 2000). These families not only spawn in the Rekewa lagoon areas, with the exception of the penaeid shrimp (Davenport and others 1999), but their fry and larvae also spend critical periods of their life cycles in the mangrove–lagoon habitat (Matthes and Kapetsky 1988). Indirect impacts from pollution resulting from waste effluents from the aquaculture ponds (McKinnon and others 2002) are also a potential concern, although in this case, this issue was well mitigated in the project design.

The annual net value of the Rekawa mangrove–lagoon fisheries per hectare of mangroves was estimated at US$ 268/ha/year and that of the Rekawa coastal fisheries at US$ 493/ha/year (Table 2). The lagoon fishery, which engages up to 250 local people, is very traditional in nature. Nonmarket labor is effectively universal and fishing gear is mainly derived from products of the mangrove forest (e.g., for making wooden traps and boats), and polychaetes and other organisms from the mangrove system provide bait (Ediriweera 2000). The use of motors in the mangrove–lagoon system boats is prohibited (thus, engines and fuel costs are taken as zero).

To determine the total value of the coastal fishery, the catch of each mangrove-dependent family was calculated and then these were combined to determine the aggregate yield. The key species were *Clupeidae, Mugulidae,* and penaeid shrimp, which registered a combined net value (including variable costs, but excluding the opportunity costs of subsistence labor) of 9.6 million Rs, equating to a mean annual value for the Rekawa fisheries of US$ 754/ha/year. This figure is at the bottom of the range of valuations US$ 750/ha/year to 11,280/ha/year reported by Rönnbäck (1999), who criticized valuations using only official statistics because of their overreliance on one or a few species of economic importance and so overlook the potentially significant value of nonmarketed species (in terms of protein sources and damage to the ecosystem) or their failure to acknowledge the value of noncommercial catches. Acknowledging these concerns, the reported value of the Rekawa fisheries should thus be regarded as a minimum figure.

Indirect Value: Shore Zone Stability

The ecological services provided by mangrove ecosystems depend on, and, in turn, influence through complex feedback mechanisms, the operation of natural physical processes in the coastal zone. Throughout much of the tropics, mangroves forests are important features of the coastline, with roles in stabilizing shorelines, preventing flooding, and protecting beaches and corals from siltation. Table 3 provides examples of the environmental services provided by mangroves, along with some of the problems that result when the mangroves are cleared for shrimp farming.

Primavera (1991) reported that the incident of life and property damage has increased significantly along the coastline of the Philippines as a result of mangrove clearance. Increased vulnerability of coastal communities to tropical storms in the aftermath of extensive mangrove clearance was also demonstrated in Bangladesh (Choudry and others 1994). The introduction of shrimp ponds affects the hydrology of local systems by raising water tables, leading to impeded water flow and flooding (Alagarswami 1995). The construction of dikes and embankments for shrimp ponds can also induce extensive salinization; for example, Jayasinghe (1995) reported saltwater intrusion to occur up to 6 km upstream of wetland areas in the northwestern province of Sri Lanka. Sediment budgets are also frequently disrupted; for example, de la Cruz (1979) connected aquaculture-driven mangrove conversions to accelerated rates of sedimentation on beaches and associated degradation of coral reefs within both Indonesia and the Philippines.

In areas where mangrove conversions have impacted physical environmental processes, the management response has often been to undertake expensive engineering works to counteract the problems. A simple approach to value the protective roles of natural systems is to use replacement-cost analysis (RCA). According to this method, the value of the mangrove system is estimated in relation to the costs incurred to construct coastal defenses such as seawalls, revetments, and groins. Constanza and others (1997) estimated the disturbance regulation function of mangroves at US$ 1800/ha/year, and Chan and others (1993) estimated the cost of replacing Malaysian mangroves at US$ 3 million per kilometer of coastline.

The RCA approach requires the size, complexity, and life span of any engineering response to be specified. For example, the size and style of a coastal defense system to guard against coastal erosion or storm surges will determine the initial construction costs, but the design-life of such structures will control long-term financial commitments. The Sri Lankan Coastal Zone Management Plan (CCD 1997) uses a general estimate of 14 million Rs (US$ 20,000/km) to install erosion and storm control structures in this area. It further reports that such structures require replacement within a 10-year maintenance cycle.

Based on the scale ofthe proposed shrimp farm, it might be conservatively estimated that the shrimp proposal for the Rekewa Lagoon will compromise approximately 3 km of the natural coastal defense function of the coastline through direct structural damage to the mangrove forest and disruptive engineering activity within the coastal barrier between the lagoon and the ocean. The costs to emplace such a program can thus be estimated at 42 million Rs, which annualized over a 10-year cycle equates to 4.2 million Rs/year. The value of the mangrove buffer can also be expressed on a unit area basis as 21,000 Rs/ha/year or US$ 300/ha/year.

Option, Existence, and Bequest Values

Mangrove ecosystems represent a rare and declining habitat in Sri Lanka. The Rekawa ecosystem represents a relatively intact mangrove site, where the full range of flora and fauna can be conserved. The site supports 17 species of mangrove and associated mangrove flora. In addition, the mangroves provide a habitat for a variety of wildlife species, including: 66 species of resident birds, 15 species of migratory birds, 37 species of lagoon fish, 9 species of mangrove crustaceans, 6 species of mammals, and 6 species of reptiles (RSAMCC 1996). In addition, the mangrove–lagoon system acts as a buffer and offers protection to the 10-km-long strip of beach, which is an important nesting ground for several species of rare sea turtles. It has been estimated that 1900 turtles nest in the Rekawa area, including Green, Loggerhead, Leatherback, Hawksbill, and the Olive Ridley turtle, all of which are in the World Conservation Union (IUCN) Red List of globally threatened species. As such, the wildlife resources in the Rekawa area are a potentially significant source of tourist revenue, although this potential remains unrealized in much of Sri Lanka beyond the perimeters of the country's National Parks (Bandaratillake 1995).

The contingent valuation method with an open-ended approach was used to quantify the option, existence, and bequest values of the Rekawa system. The questionnaire survey established that 49% of the households in the area directly used mangroves for forestry and fisheries products; the remainder were non-users. WTP values were thus estimated from the 105

Table 4. Results of TEV assessment for Rekawa mangrove ecosystem

Mangrove benefits	Methods	Value (Rs/ha/year)	Value (US$/ha/year)
Forestry net benefits (at a subsistence level)	Estimated using the actual amount of wood harvested multiplied by the "shadow value" in the form of the price for inland wood sold by licensed concessionaires.	1,500	24
Lagoon fishery net benefits (at a subsistence level)	Estimated using actual data on amount of fish obtained and their market value.	18,750	268
Coastal fishery net benefits	Estimated using actual data on amount of fish obtained and their market value, net of any human effort.	34,500	493
Erosion control and buffer against damage from storms	Estimated using replacement-cost analysis. This involved estimating the costs incurred to have erosion control and/or storm-control structures such as sea walls, revetments, or groins.	21,000	300
Existence, bequest and option values to local community	Estimated using the contingent valuation method with an open-ended approach. This involved estimating WTP values in the form of voluntary contributions to a hypothetical mangrove protection fund.	181.2	2.6
Total value		75,931	1,088

Table 5. Projected external costs of the proposed shrimp culture project

External costs	Magnitude/significance of impacts	Equivalent costs (Rs/year)	Equivalent costs (US$/year)
Loss of forestry products (replacement costs)	Loss of at least 32 ha of mangrove forestry products, 42 ha if locals excluded from project's perimeter "buffer zone".	48,000	768
Loss of lagoon fisheries (loss of sales revenue)	Proposed project will cause the direct loss of 32 ha (or 16%) of the mangrove habitat for shrimp ponds.	600,000	8,571
Loss of coastal fisheries (loss of sales revenue)	It was assumed that this loss will result in a proportionate decline in the lagoon and coastal fisheries	1.1×10^6	15,776
Loss of natural coastal defense services leading to increased coastal erosion and greater vulnerability of coastal community	Again, assumed that relationship between loss of mangrove habitat and erosion is linear and that 16% of the coastal defense services of the mangrove forest would be lost.	672,000	9,600
Loss of option, existence and bequest values	WTP values in the form of voluntary contributions to a hypothetical mangrove protection fund were estimated.	5,798	83
Total		2.43×10^6	34,798

mangrove nonuser households surveyed in the form of voluntary contributions to a hypothetical mangrove protection fund. Aggregating the option, existence, and bequest values, it was determined that the mean contribution proposed by each household was 60 Rs/year. This sum extrapolated across the estimated 600 households in the area having little or no direct use of mangroves generates a value of 36,240 Rs/year, equivalent to a unit-area value of US$ 2.6/ha/year. The mean WTP measure from the open-ended sample is considered the most conservative estimate of WTP for conservation of natural resources. In part, the apparently low WTP returned from the survey can be explained by the fact that many of the households operate at subsistence levels; for example, within the Hambantota District, 31% of the population face "consumption poverty," 80% of whom live in rural areas like Rekawa (Gunetilleke 2000). This formulation of WTP does not explicitly address the fact that

Table 6. Total benefits and costs, and the NPV of proposed shrimp culture project

Discount factor	0%	2%	5%	10%	15%
Total internal benefits (millions of Rs)	393	360	318	264	224
Total external benefits (millions of Rs)	4.5	4.3	4.0	3.5	3.2
Total internal costs (millions of Rs)	269.2	246	217	180	153
Total external costs (millions of Rs)	51	42.2	32.7	23.1	17.6
NVP over a 20-year planning horizon (millions of Rs)	+ 77.7	+76.3	+72.3	+ 64.7	+56.8
NVP over a 20-year planning horizon (millions of US$)	+1.11	+1.09	+1.03	+0.92	+0.81

wider conservation issues such as the conservation of turtle habitats, migratory birds, and biodiversity in general have value far beyond community boundaries. WTP estimates of value are also generally below those produced by "Willingness to Accept" methods, which measure what people are willing to accept as compensation for a cost (Daly and Farley 2003). Both considerations suggest that the existence value presented will underestimate the "true" existence value and should be considered as a minimum.

A summary of the results of the TEV assessment for the Rekawa mangrove–lagoon ecosystem is presented in Table 4. The TEV assessment of the Rekawa mangrove–lagoon ecosystem indicated that the annual value per hectare was in the order of US$ 1088/ha/year. Clearly, the greatest component of the value is obtained from the fisheries, which collectively equate to 70% of the TEV of the system. All of these estimates are subject to considerable uncertainties, not least of which is quantifying the consequences of the partial loss of the Rekewa mangrove forest (Table 5), along with complex indirect effects resulting from the generation of waste outputs, potential propagation of diseases into wild shrimp populations, and long-term issues such as resistance to antibiotics within the farm stock (cf. Corea and others 1995).

NPV of the Proposed Shrimp Development

The proposed shrimp project is to be developed in 3 stages over a 3-year period (i.e., in year 1, 16 ponds to be developed; in year 2, another 15 ponds to be developed; and in year 3, a further 17 will be commissioned, to a total of 48 ponds). In calculating the total internal benefits and costs of the proposal, the anticipated life span of the scheme was assumed to be 10 years. Data used to calculate internal costs and benefits and external benefits were obtained from the financial statement of the project. External benefits included employment opportunities during the construction, operational, and restoration phases of the project.

Table 6 presents the total internal costs and benefits, the total external costs and benefits, and the NPV of the proposed shrimp project over a 20-year planning horizon using discount rates ranging between 0% and 15%. Selection of the appropriate discount rate is critical to the projected value of a project. The use of a standard discount rate reflects returns on investment, but is insensitive to the degradation of the wider ecosystem services, which should exhibit higher marginal values in the future (Daly and Farley 2003). Notwithstanding this concern, the results still demonstrate that the total internal benefits of the shrimp proposal are much higher than the total internal costs. The developer will make a profit ranging from US$ 1 million to 1.7 million (Rs 224 million to 393 million), depending on the discount rate during the estimated 10-year lifetime of the project. The ECBA for the shrimp proposal revealed that the project gives a positive net present value (+NPV) over a 20-year planning horizon, for all discount rates. The envelope of +NPV ranged from US$ 1.1 million with 0% discounting to US$ 0.81 million with 15% discounting.

In spite of the +NPV suggesting a commercially viable future, the key finding of the research was to demonstrate that the total external benefits of the proposed aquaculture project were much lower than the total external costs; that is, the total costs to society in developing the aquaculture project are much higher than the total benefits. The net cost to society over a 20-year planning horizon was estimated to be between US$ 0.64 million (with 0% discounting) and US$ 0.24 million (with 15% discounting). The economic analysis for the proposed aquaculture project shows that although the internal benefit to internal cost ratio for the project was 1.5:1, the external benefit to external cost ratio for the project lies between 1:11 and 1:6, depending on the rate of discount used.

Discussion

There are two broad reasons for engaging in valuation exercises: first, to show that environmental issues are important for planning at the macroeconomic level (i.e., in the consideration of the damage and depreciation of natural resource stocks in national accounts) and second, for making efficient allocation decisions at the microeconomic level; that is, understanding the full costs and benefits of a project is essential to making investment decisions and for the decision-making process (Winpenny 1991).

The evaluation of the importance of mangroves to society requires insight into the flow of products and services within coastal communities and how they are linked and influenced by domestic and international markets and organizations. It also requires insight into the biophysical links within and between mangroves and other ecosystems for the generation of natural products and services, many of which are harvested or enjoyed outside the mangrove system (Rönnbäck 1999). Failure to consider all of the relevant issues has resulted in the economic value of mangroves being generally underestimated. Although it will not be possible to place a monetary value on all relevant factors, these must be recognized and incorporated at least qualitatively in the cost–benefit analysis.

In its entirety, the Rekawa mangroves, the lagoon, the fisheries and other wildlife, the agricultural land, the dynamic beach environment, and the local people who depend on and coexist with these resources comprise a large and complex ecosystem. The area and its components are all interconnected and each component is important to the other's well-being. The conversion of mangroves to shrimp ponds will have several important consequences to the people of the local community. Of key significance will be loss of traditional livelihood practices. The Rekawa mangroves provide a source of income and, in addition, nonmonetary sources of welfare to people, many of who live at the poverty level. Nickerson (1999) discusses that although shrimp culture is not a mangrove-area-dependent use (i.e., shrimp developers have alternative sites for ponds), traditional sectors have no alternative sites for fishery nursery grounds and forestry products provided by mangroves. Furthermore, levels of extraction of mangrove products at Rekawa might be sustainable indefinitely due to relatively low extraction rates. However, if the proposed aquaculture project is developed, the area of mangroves will decline and the growing rural population will be forced to concentrate their collection activities in a smaller forest area, which could lead to severe degradation of the ecosystem through overuse.

It is estimated that the intact mangrove ecosystem supports at least 1512 people from the local community through fisheries alone (Ranaweera and others 1994). The livelihood of all these people will be threatened by the aquaculture development. The proposed 42-ha shrimp farm is likely to employ only about 50 people on a regular basis and around 250 people during the construction period. Employment of the local people in shrimp farms is often limited to low-paying, unskilled jobs such as laborers and guards, whereas the technical and managerial positions are reserved for outsiders. Furthermore, because the funds invested in the aquaculture development are generated from the outside, all of the project profits will leave the local community.

The present economic analysis shows that the internal benefits of the project are about 1.5 times greater than the internal costs, whereas the external costs, or the costs to society, are between 11 add 6 times more than the benefits. Even though mangrove conversion to shrimp ponds in the Rekawa area would give a positive return, the net benefits from shrimp culture are obtained entirely by the aquaculturist; that is, shrimp aquaculture would negatively impact on the indices of equity and offer limited scope to share the benefits among the local and wider community. ECBA can therefore be a useful tool for decision-makers in considering the nature of the costs and benefits, the number of individuals affected, and the user groups to which the costs and benefits accrue (Nickerson 1999). These considerations are important in ensuring sustainable resource use and improvements in social welfare.

The environmental statement that accompanied the planning application for the Rekawa shrimp projectmshowed only a financial breakdown of the project's internal benefits and costs. This can be misleading to the decision-makers because internal benefits and costs deal only with the profits and losses made by the private company and not the benefits and costs accrued directly to society. It is important to include the external costs and benefits of a project into the economic analysis, if an accurate estimate of a project's total costs and benefits is to be obtained. As seen from the present study, economic analysis (provided it integrates environmental, economic, and social issues) is a valuable tool to more fully elucidate the likely consequences of development projects, programs, or, indeed, policies.

Conclusions

It is now widely recognized that development of mangrove systems for shrimp aquaculture degrades ecosystems, providing a range of environmental services into unsustainable monocultures (cf. Hein 2002; Senarath and Visnanathan 2001). Because of the foreign exchange earning potential of shrimp development projects, such as that proposed at Rekewa, governments have placed relatively few constraints on mangrove conversions, and aquaculture developments continue to be authorized at the expense of common property resource systems (cf. Armitage 2002). However, the evidence clearly indicates that intensive industrial-scale production is rarely sustainable.

Abandonment and progressive encroachment in increasingly marginal areas has been a common experience in many mangrove ecosystems. Clearly, new approaches and mitigation strategies are needed (cf. Paez-Olsuna 2001; Lebel and others 2002). At Rekewa, this might involve smaller ponds and situating ponds at the inner margin of the mangrove along the mangrove–dryland gradient. Alternatively, it might be more desirable to boost the output of traditional fisheries by supplementing the natural stocks within the lagoon. Davenport and others (1999) released *Penaeus monodon* postlarvae into the Rekawa Lagooon and reported a 33% increase in the annual catch within 2 years of the experiment commencement. The use of such culture-based fisheries is, therefore, a potentially important means of spreading benefits across rural communities and counteracting the most damaging aspects of the conventional aquaculture industry (De Silva 2003).

This study began an ongoing process to more fully articulate and value the full range of environmental and social services provided by mangrove–lagoon ecosystems such as Rekawa. The analysis demonstrated that an ecologically rich ecosystem supporting low-intensity, but sustainable, harvesting is far more valuable to the local and wider community—engaging several hundred local residents—than a large shrimp culture project, which is associated with significant socioeconomic impact and loss of traditional livelihoods. The issue of wealth distribution is crucial to the social and economic development of any country. By highlighting the nature of the benefits and costs accruing to each group, more information can be made available to decision-makers concerned with the promotion of equity amont the populace. Typically, aquaculture is favored because individual developers can capture all of the benefits, whereas the benefits of intact mangroves accrue to the entire community. Although the focus of this investigation has been on the costs and benefits to the local community, it is clear that the ecological and cultural dimensions of the proposal have consequences for regional, national, and international stakeholders (e.g., eco-tourism).

Economic valuation can be used to estimate a monetary equivalent for environmental goods and services that might otherwise be treated as free. Such analysis is naturally constrained by the assumptions made because most valuation studies ultimately rely on some element of subjectivity. ECBA is a valuable framework for interpreting the biophysical findings of EIA in economic welfare terms, and presenting the results in a language familiar to decision-makers. The aspiration of this study was to undertake a total economic valuation, but it is recognized that the analysis remains selective, and considerable uncertainty remains regarding the full range of environmental services provided by mangrove ecosystems and how these interact with other ecosystems that also produce services of value to humans. Accepting such qualifications, the conclusion remains that ECBA should be promoted to enable decision-makers to be more fully cognizant of a project's environmental and socioeconomic implications.

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