# Economic Valuation of Mangrove Ecosystems: Potential and Limitations

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## Abstract

Mangrove ecosystems provide a range of non-market as well as marketed goods and services both on and off-site. Yet, the full value of mangrove products is not easily recognised, and is, therefore, often neglected in development planning. As a result it is often concluded that mangrove forests should be converted to uses which generate directly marketable products, such as aquaculture. Economic valuation methods offer a more comprehensive assessment of the many goods and services provided by mangrove ecosystems, and hence may contribute to more informed decision-making.

The objective of this paper is to review and analyse the scope and limitations of different valuation methods for assessing management alternatives for mangrove ecosystems. The paper compares a range of studies on mangroves with regard to the methodologies employed and the range of products and services valued. It includes a discussion of the benefits of valuation methods for assessing management alternatives, with particular reference to the goods and services of Pagbilao Bay in the Philippines - the study site of the project, Economic Valuation of Mangrove-Fishpond Interactions, for which this paper was written. The literature review and the discussion of the Pagbilao case study illustrate the potential of valuation methods for evaluating management alternatives, as well as the practical limitations to their application. In principle, methods are available but the lack of data and quantitative knowledge regarding some key ecological relationships affirm the need for further inquiry.

## Abrégé

Les écosystèmes de mangroves fournissent toute une gamme de produits et de services commercialisés et non- commercialisés tant sur place qu'hors du site. Cependant, la pleine valeur de la production des mangroves ne se laisse pas aisément cerner et se trouve donc fréquemment négligée dans la planification du développement. En conséquence, on aboutit souvent à la conclusion que les forêts de mangrove doivent être consacrées à des activités génératrices de produits directement commercialisables - l'aquaculture par exemple. Les méthodes d'évaluation économique offrent une estimation plus complète des nombreux biens et services fournis par les écosystèmes de mangrove et peuvent ainsi contribuer à des prises de décisions basées sur une meilleure information.

Ce texte a pour objectifs le passage en revue et l'analyse de la portée et des limites des différentes méthodes d'évaluation permettant d'apprécier les alternatives de gestion des écosystèmes de mangrove. On y compare une série d'études consacrées aux mangroves, prises du point du vue des méthodologies employées et de la gamme des produits et services évalués. Cela comprend la discussion des avantages comparés des différentes méthodes d'évaluation appliquées aux alternatives de gestion, référence étant particulièrement faite aux produits et services tirés de Pagbilao Bay, aux Philippines, site d'étude du projet "Évaluation économique des interactions mangroves-viviers", pour lequel fut rédigé ce document. La recension de la littérature en la matière et la discussion de l'étude de cas de Pagbilao révèlent le potentiel des méthodes d'évaluation pour l'appréciation des alternatives de gestion, ainsi que les limites pratiques de leurs application. Ces méthodes sont en principe disponibles mais l'absence de données et de connaissance quantifiées au sujet de certaines relations écologiques fondamentales renforcent le besoin d'un surcroît de recherche.

## Resumen

Los ecosistemas de manglares ofrecen una gama de bienes y servicios comercializables y no comercializables tanto en el terreno mismo como fuera de él. Sin embargo, la totalidad de valor de los productos provenientes de los manglares no ha sido reconocida debidamente y el ejercicio de

valoración con frecuencia se descuida en la planificación del desarrollo. Es por este motivo que a menudo se considera que los usos de los bosques de manglares deben dirigirse a actividades que generen productos directamente comercializables, como lo es la acuicultura. Al ofrecer una valoración más completa de la gran variedad de bienes y servicios disponibles en los ecosistemas de manglares, los métodos de evaluación económica pueden contribuir a enriquecer los procesos de toma de decisiones.

El objetivo de esta monografía es presentar una visión general y un análisis del alcance y las limitaciones de diversos métodos de evaluación en la consideración de alternativas para la gestión de los ecosistemas de manglares. Se comparan aquí algunos estudios sobre manglares desde el punto de vista de las metodologías empleadas y la gama de productos y servicios valorados. Se incluye también una discusión de las ventajas ofrecidas por los metodos de evaluación para valorar dichas alternativas de gestión, en particular los bienes y servicios en la Bahía de Pagbilao en Filipinas, lugar estudio del proyecto titulado "Evaluación económica de las interacciones entre manglares y estanques para peces" como parte el cual se escribió esta monografía. La revisión de la literatura y la discusión del caso de Pagbilao ilustran el potencial de los métodos de evaluación para valorar las alternativas de gestión, así como también las limitaciones prácticas de sus aplicaciones. En principio los métodos existen, pero la carencia de datos y de conocimiento cuantitativo referente a algunas relaciones ecológicas claves confirman la necesidad de estudiar el tema con mayor profundidad.

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# Introduction

Mangroves forests are located in the brackish water margin between land and sea in tropical and subtropical areas. These rich ecosystems provide a variety of economic and environmental services and products. In addition to their direct values, mangroves also support other ecosystems such as coastal fisheries, thereby indirectly sustaining a wide range of social and economic activities. In recent years modernisation and market integration has resulted in a dramatic reduction of mangrove forest for alternative uses (Kunstadter 1986) with negative consequences for the environment and economy.

The full value of mangrove ecosystems is often not recognised. This may be attributed to two factors (Hamilton *et al*, 1989): (i) many of the goods and services provided by these ecosystems are not traded on markets and thus do not have an observable value; and (ii) some of these goods and services occur off-site and are therefore not readily acknowledged as being related to mangrove ecosystems. As a result it is often concluded that mangroves should be developed for uses which generate directly marketable products, such as aquaculture. However, such decisions ignore the opportunity cost of development. Methods for valuing environmental goods and services offer a more comprehensive valuation of the many goods and services provided by mangrove ecosystems, and thereby contribute to more informed decision-making.

Pagbilao Bay mangrove forest is located in the southern part of the Province of Luzon, the Philippines. Today, what remains of the original Pagbilao Bay mangrove is the experimental forest , now under the jurisdiction of the Department of Environment and Natural Resources. Located in the intertidal zone between the Nahalinan and Palsabangan Rivers, it occupies approximately 114 hectares, and is almost completely surrounded by fishponds (Figure 1). The forest is second growth with an average age of 20 years. In the 1970s the mangroves were cut for commercial fuelwood and charcoal - the major cause of degradation. These activities have been prohibited since 1981 following the Presidential Proclamation 2151 which declared mangroves as wilderness areas and endowed them with Experimental Forest status. Since then, the only activity allowed in the forest is the collection of crabs and shell fish, although illegal cutting, primarily of pole-sized trees, is still evident (Carandang and Padilla, 1996).

The objective of this paper is to review and analyse the scope and limitations of valuation methods for evaluating management alternatives for mangrove ecosystems. Firstly, a selection of valuation studies of mangrove ecosystems will be briefly described and assessed. This is follow by an analysis of the benefits of valuation methods for assessing management alternatives for these ecosystems, with particular application to Pagbilao Bay - the study site of the project Economic Valuation of Mangrove-Fishpond Interactions, for which this paper was written. The paper is structured as follows: The first section reviews a range of studies of mangrove ecosystems. This is followed by a discussion of the concept of total economic value as it applies to mangrove ecosystems in general, and to the Pagbilao Bay mangrove ecosystem in particular. Next, the goods and services that were originally considered for valuation in the Pagbilao case study are outlined. This is followed by a discussion of the appropriateness of existing valuation methods to value these goods and services. The final section draws some conclusions from the review of the case studies and the Pagbilao study regarding the potential and limitations of valuation methods for assessing management alternatives for mangrove ecosystems.

**Figure 1 Pagbilao Bay**

# Review of Case Studies

Several studies have been conducted to estimate the economic value of mangrove ecosystems, all of which differ in a number of ways. First, the range of mangrove related products and functions which are analysed varies; secondly, the types of mangrove management alternatives considered, such as clear cutting for fishponds or woodchipping, differ for each study; finally, the underlying assumptions regarding ecological linkages between mangrove and other ecosystems, are inconsistent. These differences make it complicated to compare mangrove valuation studies. In this section several studies will be described. In order to understand the impact of a particular methodological approach on the outcome, several of these studies are evaluated in detail, as follows:

- *Mangrove Resources and their Management Utilisation for Forestry, Fishery and Agriculture near Khung, Chanthaburi Province, Thailand: A Case Study.* Christensen (1982). The main objective of this study is to describe quantitatively the various uses of mangrove resources in the area and thus provide comparative data for land-use planning.

- *Logging versus tourism in Palawan: an Environmental and Economic Analysis.* Hodgeson & Dixon (1988). This more recent study demonstrates that, for the Philippines, benefits from tourism coupled with fishery production substantially outweigh the short-term benefits which may accrue from increased logging in Palawan.

- *Conservation or Conversion of Mangroves in Fiji.* Lal (1990). This mangrove valuation study compares the net benefits of converting mangrove lands to rice and sugar cultivation by estimating the benefits of mangrove-related products that would be lost after conversion.

- *Mangrove Management: An Economic Analysis of Management Options with a Focus on Bintuni Bay, Irian Jaya.* Ruitenbeek (1992). This includes an extended C/B analysis with varying ecological linkages for different forestry (woodchip) scenarios.

- *The Value of a Mangrove Area in Sarawak.* Bennet and Reynolds (1993). This valuation study estimates the benefits to fisheries and tourism of mangroves in Malaysia.

- *Estimating the Total Economic Value of a Mangrove Ecosystem in El Salvador.* S. Gammage (1994). This explores the different commercial and community uses of mangrove ecosystems.

The studies are presented in chronological order in Tables 1 and 2. Table 1 presents the range of values incorporated in the mangrove studies. Values are converted into US$ to facilitate comparison. Table 2 summarises the valuation techniques and assumptions which underlie the studies.

**Table 1** **Range of values included in the studies**

| | direct use values | indirect use values & non-use values |
|---|---|---|
| **Christensen (1982)** | ♦ **local uses**: fruits, cigarette wrappers and nipa thatch for roofing. *US$230/ha/year.*<br>♦ **on-site fisheries**: commercial harvest by small, medium and large scale fishermen of fish, trash fish, prawns and shrimp, based on a weighted market price of US$.0.35/kg. *US$30/ha/year.*<br>♦ **forestry:** charcoal production is 1 $m^3$/ha/year (potential of 12 $m^3$/ha/year). *US$30/ha/year.*<br>♦ **aquaculture**: the current yield from shrimp farming is 184 kg/ha/year at a price US$.1.1/kg *(US$206/ha/year)*. The potential yield is 541 kg/ha/year of better species (US$3.9/kg) leading to a yield of *US$.2,106/ha/year.*<br>♦ **agriculture:** annual rice yield of 1,700 kg but fails every fourth year. *US$165/ha/year.* | ♦ **off-site fisheries**: Mangrove related shrimp (80kg/ha), and fish species such as mullet, snapper, whiting. *US$100/ha/year.* |
| **Lal (1990)** | ♦ **on-site fisheries**: total production of commercial (147 kg) and subsistence (184 kg) harvest in mangrove-ecosystem is 331 kg/hectare/year based on a weighted average market price by species of US$2.61/kg; *US$60-US$240/ha/year with average of US$100/ha/year.*<br>♦ **forestry**: net benefits are retrieved for commercial forestry from market prices and for subsistence consumption from next best alternative approach (buying from saw mill plus transport). *US$6/ha/year.*<br>♦ **agriculture & aquaculture**: opportunity costs development into sugarcane production and aquaculture were estimated to be negative. *US$52/ha/year.* | ♦ **off-site fisheries**: these values are Included in the category on-site fisheries.<br>♦ **nutrient (waste) filtering service**: derived from conventional treatment plant (alternative cost approach). *US$5,820/ha/year.* |
| **Bennet & Reynolds (1993)** | ♦ **on-site fisheries**: commercial harvest of prawns and fish based on 95% of total catch in Sarawak.<br>♦ **forestry:** commercial harvest of building poles, charcoal, semi-charcoal and cordwood of the whole West of Sarawak. | ♦ **tourist industry:** the revenues in and around the Mangrove Forest Reserve is assumed to disappear.<br>♦ **off-site fisheries:** deep-sea and coral reef fishing is incidental. |
| **Ruitenbeek (1992)** | ♦ **local uses**: traditional household production from hunting, fishing, gathering, and manufacturing are based on "shadow" prices. This conversion into shadow prices is based on transportation cost of Rp500/kg. *US$33/ha/year.*<br>♦ **on-site fisheries**: sustainable shrimp harvest based on real average export prices US$6.25/kg. Costs are based on investment and operation costs. Taxes, royalties and compensation payments are excluded. *US$94/ha/year.*<br>♦ **forestry:** cutting for export of woodchips based on real average export prices US$40 per cubic metre. Sago production is valued at constant local market prices Rp300/kg. Costs are based on investment and operation costs. *US$67/ha/year.* | ♦ **erosion control**: based on agricultural output from local production. *US$3/ha/year.*<br>♦ **off-site fisheries**: imputed (potential) value of Rp300/kg for by-catch which is 90% by weight of total shrimp catch (assumption of future commercial use). Costs are based on investment and operation costs. *US$23/ha/year.*<br>♦ **biodiversity**: ascribed as the "capturable biodiversity benefit". Maximum for ecosystems (rainforest) reaches US$3,000/$km^2$. For Bintuni Bay US$1,500/$km^2$. *US$15/ha/year.* |
| **Gammage (1994)** | ♦ **local uses**: The seeds of mangrove trees are used as fodder for the local cattle, yet this was not included. Also honey and fruits were used but not valued.<br>♦ **on-site fisheries**: the annual sustainable shrimp harvest based on local market prices are approximately 5.5 kg/ha priced at US$14/kg. Related costs were not mentioned.<br>♦ **forestry**: local fuelwood consumption is valued through shadow wage and input cost | ♦ **off-site fisheries**: a pseudo production function including mangrove coverage and effort was used to estimate artesenal and commercial fishery. Subsistence fishing is negligible. |

| | | |
|---|---|---|
| | methodology at approximately US$100 per $m^2$. Local timber consumption is valued at local market prices. Total annual sustainable wood consumption is determined at approximately 6 $m^2$ per hectare. | |

**Table 2** **Valuation techniques and key assumptions for the mangrove studies**

| Study | Valuation Techniques | Key-assumptions |
|---|---|---|
| **Christensen (1982)** | ♦ **market price**: both commercial and subsistence forest, fisheries and agricultural products are valued at market prices (costs are practically ignored). | ♦ **discount rate & time horizon**: future developments are ignored.<br>♦ **environmental linkage**: removal of mangroves results in total disappearance of mangrove-dependent fish species. |
| **Lal (1990)** | ♦ **market price**: the value of commercial forest and fisheries products is based on market prices corrected for actual costs incurred.<br>♦ **shadow price**: for subsistence fisheries products a shadow price is derived from the average price paid by commercial fishermen when they buy surplus fish from villagers.<br>♦ **surrogate or substitute price**: the alternative of subsistence forest products was valued to take the offcut timber from inland sawmills at on-site cost less costs of transportation. The value of the mangrove soils' filtering capacity is based on the costs of the treatment of comparable sewerage volume costs by a conventional treatment plant. | ♦ **discount rate**: 5 % which is the average real interest rate for 1983 to 1986.<br>♦ **time horizon**: 50 years (no rationalisation).<br>♦ **environmental linkages**: linkage scenarios varying from 20% to 100% decline in fish harvest if mangroves are destroyed. In main valuation it is assumed that 1 hectare of mangrove produces 331 kg of fish per annum.<br>♦ **economic assumptions**: marginal values of labour and capital in fishing and forestry industries are zero.<br>♦ **other assumptions**: 40 year forestry rotation cycle. |
| **Bennet and Reynolds (1993)** | ♦ **market price**: commercial forestry and fisheries are valued at market prices (costs ignored). | ♦ **discount rate & time horizon**: future developments mentioned but ignored in the actual valuation exercise.<br>♦ **environmental linkage**: removal of mangroves results in total disappearance of mangrove-dependent fish species which is 95% of total catch. |
| **Ruitenbeek (1992)** | ♦ **market price**: local farming products are not corrected for transportation costs because these are not traded outside the region.<br>♦ **shadow price**: livestock, fish and fuelwood are corrected for transportation costs at US$ 0.25 per kg.<br>♦ **other prices**: biodiversity benefit of mangrove ecosystems is based on International transfers for rainforests (50% of US$.3000 per kilometre); erosion is valued through valuing the benefits of local agricultural production. | ♦ **discount rate**: 7.5% reflects opportunity cost of risk-free investment.<br>♦ **time horizon**: costs and benefits are extended over a 90 year period to allow three full rotations in forestry evaluations, and to accommodate potential delays in environmental linkage effects.<br>♦ **environmental linkages**: scenarios depend upon impact intensity and impact delay parameters. Various ecosystems (ie. mangrove and fisheries) are linked.<br>♦ **other assumptions**: 30 year forestry rotation cycle. |
| **Gammage (1994)** | ♦ **market price**: timber is valued at local market prices net of input costs and extraction costs; the same is applied for salt, shrimp and fish. Fuelwood is valued at market prices for the traded wood, and at gathering costs of the non-traded wood. Opportunity costs of allocating labour time for fuelwood collection are zero.<br>♦ **other prices:** for comparison “the least alternative cost” of substitutes were reported but not applied to the actual C/B analysis. | ♦ **discount rate**: various rates were applied. 19.08% which is the foregone return on other investment projects, 8% which the costs of external borrowing, and 4.64% reflecting the social rate of time preference.<br>♦ **time horizon**: 56 years going till 2050.<br>♦ **environmental linkages**: a Maximum Sustainable Yield (MSY) of shrimp was based on a non-linear relationship between shrimp yield and intertidal vegetation. A linear relationship between mangrove area and artesenal fish production was estimated implying a decrease of 14 kg in annual fisheries yield for each hectare of mangrove cut.<br>♦ **economic assumptions**: fishery benefits are gross of costs. |

The overview illustrates the trend in mangrove valuations for both the *type of products* and *functions* taken into account, and the *type of prices* used. Typically, recent valuation studies include more intangible values: whereas Christensen limits the range of valued products and functions to absolute direct use values, Ruitenbeek includes non-use values such as biodiversity. Table 3 summarises the estimates made of the different types of value incorporated in the different studies. Negative prices indicate the opportunity costs of mangrove preservation. The study by Gammage is not included because no average net benefits were provided. Generally, more products and functions are mentioned in the studies than are actually incorporated in the C/B analyses. For example, Lal mentions an annual water purification value of mangroves at US$ 5,820 per hectare but does not apply this value to the analysis. If this value would be incorporated, it would clearly dominate the total economic value of mangrove ecosystems. Another tendency is the type of prices used in the analysis. While Christensen generally uses local market prices, Ruitenbeek converts most of the market prices into shadow prices.

**Table 3 Benefits and opportunity costs of mangrove preservation**

| | **Christensen** | **Bennet & Reynolds** | **Lal** | **Ruitenbeek** |
|---|---|---|---|---|
| | **in US$/ha.** | **in US$/ha.** | **in US$/ha.** | **in US$/ha.** |
| Forestry | 30 | 14 | 6 | – 67 |
| Fisheries | 130 | 2418 | 100 | 117 |
| Agriculture | – 165 | - | –52 | - |
| Aquaculture | – 2106 | - | - | - |
| Erosion | - | - | - | 3 |
| Biodiversity | - | - | - | 15 |
| Local uses | 230 | - | - | 33 |
| Tourism | - | 424 | - | - |
| Purification | - | - | 5820 | - |

Values are converted into US$

Another difference is the inclusion of the *discount rate* in economic valuation studies so that future effects of mangrove management can be taken into account. Lal, Ruitenbeek and Gammage base their recommendations on net present values (NPV); implying that future benefits and costs are included along with present returns. The studies by Christensen and Bennet *et al*. are limited to gross annual income per hectare which do not adequately account for dynamic effects. To conduct a sound comparison of NPVs, it is important to do this under identical assumptions. Ideally, both the time horizon and the discount rate should be equal across studies, although often this is not the case. For example, Ruitenbeek (1992) uses a time horizon of 90 years while Lal includes a 50 year period.

Another relevant issue in the review of mangrove valuation studies is the type of *management alternative* with which sustainable mangrove management is compared: Ruitenbeek considers the conversion of mangroves for woodchipping while Lal studies the potential for sugar cane or rice production. Obviously, the type of conversion will have an impact on the change in total economic value of the mangrove area. Both Lal and Ruitenbeek find that the management alternative, which is, respectively, agriculture and wood chipping, are less economically feasible than mangrove preservation. Yet, in the Thailand study by Christensen, aquaculture is clearly more economically beneficial. It may therefore be concluded that the management alternative being considered is integral to the question of mangrove preservation or conversion.

Finally, the underlying assumptions across the studies vary considerably with regard to the *dose-response relations*. Lal assumes that half of the fish stock are mangrove dependent. Thus, the mangrove area is linearly related with fishery benefits. Counteraction of the fishery sector to the decreasing fishstock through an increase in the catching effort is ignored. Gammage applies a "pseudo" production function which facilitates the substitution between catching effort in terms of labour and capital, and mangrove area. Ruitenbeek improves on the environmental linkages assumption by introducing an impact delay factor and the possibility of varying the linkage rate between mangroves and fisheries.

All these changes indicate that in the last decade valuation studies have become more comprehensive. Nevertheless it may be concluded that, given the large variations in applied ecological interdependency between mangrove area and fisheries, clear scientific evidence on this relationship is still imperfect (Gilbert and Janssen 1996).

# The Economic Value of Mangrove Ecosystems

In environmental economics, the Total Economic Value (TEV) of a natural resource such as a mangrove ecosystem is considered to comprise two main sources of value: use value and non-use value (sometimes referred to as passive use value). Often, option value is added as a third component. However, option value is best regarded not as a separate component of the TEV, but rather as reflecting the difference in valuation from an *ex ante* or an *ex post* valuation. Below we will discuss the components of the TEV as they relate to mangrove ecosystems.

**Use values and non-use values**

Mangroves are rich ecosystems, capable of providing a range of goods and services of use to human populations. The value of these goods and services represent *use values*. In his discussion of the TEV of tropical wetlands such as mangrove ecosystems, Barbier (1992) distinguishes between direct and indirect use values, the former relating to "the values derived from direct use or interaction with a wetland's resources and services" (*Ibid*; 2). Examples of such direct use values are plentiful and include, among others, wood from mangroves used as fuelwood and for building purposes, fish and crabs caught in the waterways running through mangroves, nipa leaves for construction (roofing and walling), other products derived from nipa palms such as alcohol and vinegar, and traditional medicines derived from plants and other species found in mangrove ecosystems.

Indirect use values stem from "the indirect support and protection provided to economic activity and property by the wetland's natural functions, or regulatory 'environmental' services" (*Ibid*; 156). The classic example of an indirect use value of mangrove ecosystems is the support provided to off-site fisheries through their nursery function. Another is the protection provided against weather-related damage to productive activities located in or just behind mangrove ecosystems (aquaculture, agriculture) and to assets such as housing and infrastructure located inland .

Non-use values, on the other hand, are derived "neither from current direct or indirect use of the wetland" (*Ibid*; 156). Non-use values may arise, for example, from the satisfaction an individual derives from knowing that mangroves continue to exist, but is not necessarily planning to use them (sometimes referred to as *existence value*). Another possible motive of non-use value is the desire to preserve mangrove ecosystems for future generations (*bequest value*). For a more extensive discussion of possible motivations underlying non-use value see Bishop and Heberlein (1984). Intuitively, it is very unlikely that non-use values for the Pagbilao Bay mangrove forest will be very important. Although the total area of mangrove cover is rapidly declining world-wide, the contribution of the 110 hectares of the Pagbilao Bay mangrove to the continued existence of mangrove ecosystems is limited. It is therefore unlikely that people will be willing to pay a substantial amount for its preservation, unless it was one of the last remaining mangrove areas. On the other hand, some unique characteristics of the area may mean that non-use values might be high. For example, the area is one of the most diverse in terms of the number of true mangrove species (Carandang and Padilla, 1996). It also serves as a crucial stepping stone in bird migration paths through the Philippines, eg. the Brahminy kite (*Haliastur indus*), and their loss could be expected to cause increased stress and thereby mortality in these populations (Ong, pers. comm.). Thus, if there is a non-use value attached to these populations, the Pagbilao Bay mangrove forest has a non-use value.

### Option value

Option value (OV) refers to an individual's Willingness To Pay (WTP) to preserve the *option* of using a good in the future. It is *not* equal to the total *ex ante* WTP for preserving the option of future use. This *ex ante* WTP is known as the option price (OP). OV is only a part of this WTP, and perhaps only a small part. To clarify this, consider the following example. Suppose an individual is interested in the WTP for preservation of a certain mangrove ecosystem, and the only benefit of preservation would be the use for tourism. Consider now the WTP of some (potential) tourist for preserving the area. Suppose his WTP for a visit to the area would be $100, while the cost of visiting would be $50. His *expected consumer surplus*, E(CS), would be $100-50 = $50. Thus, his maximum WTP for preserving the area for tourism would be $50. However, it might be that an individual is unsure about whether he will actually want to visit the area, or how often. If so, and the individual is risk averse, it is possible that he is willing to pay something just for preserving the option of using the area if he wants to. This WTP, say $10, is known as the OV of preserving the area. Thus, the total *ex ante* WTP for preservation, or OP, is $60 and consists of the E(CS) of preservation ($50) and the OV of preservation ($10).

Although it seems intuitively clear that OV would be positive for risk averse individuals, closer analysis has shown that this is not necessarily the case. OV can be either negative, zero or positive, depending on the particular combination of risk aversion and the source of uncertainty (uncertainty about future preferences, about future income, or about future availability of the good). See Pearce and Turner (1990) for a summary of the results of option value under different combinations of risk aversion and sources of uncertainty.

It seems unlikely that the option value for the Pagbilao Bay mangrove ecosystem will be substantial. Remember that the source of option value is uncertainty - either a (potential) mangrove user's uncertainty about future preferences or income, or uncertainty regarding the future availability of a good or service. Whether current users are uncertain with regards to their future preferences regarding mangrove products cannot, of course, be said beforehand, but does not seem very likely. Income uncertainty might play a role. In the absence of an elaborate social welfare system or other possibilities to compensate for a loss of income from, for example, unemployment, people might value the possibility to fall back on the mangrove ecosystem for the fulfilment of certain needs. At the same time, with the increased market integration of communities dependent on mangrove ecosystems, the dependence on the direct access to mangrove ecosystems is likely to decrease (Ruitenbeek, 1992), making any option values unlikely.

Potential users, such as tourists, might be uncertain whether they want to visit the area in the future. However, sufficient alternatives exists for tourists who want to visit mangrove ecosystems, so it seems unlikely that they would be willing to pay just for keeping open the option of visiting this particular area, unless it has unique characteristics.

The uncertainty regarding the effect of development on the nursery function could be interpreted as a case of uncertainty regarding the availability of a service. Thus, there might be an option value for the fishermen for conservation. If so, the option value would be positive because in such cases of uncertainty about future availability the option value is always positive.

As already mentioned, most authors agree that OV is not a separate category of value and they question the possibility and usefulness of estimating it separately (Freeman 1993; Randall 1992). OV rather reflects the difference between an *ex ante* and an *ex post* valuation. It can be shown that from an individual point of view, OP is the appropriate measure of the value of preservation, *ex ante*. However, it is less apparent which measure is preferred in the aggregate (see, for example, Johansson, 1987).

### Quasi-option value

As with option value, quasi-option value is not a separate component of the total economic value. Quasi-option value (Arrow and Fisher, 1974) relates to those planning decisions where the benefits of preservation are unknown, while at the same time development is irreversible, that is, the potential benefits of preservation will be lost forever. However, with the passage of time more information on the benefits of preservation may become available. Hence, there is some value in deferring the decision whether or not to develop the resource until such time as the uncertainty about the benefits of preservation is resolved. The expected value of the increase in total benefits that can be obtained by deferring the development decision to the period when the uncertainty will be resolved is the so-called quasi-option value. It is also known as the expected value of perfect information (Conrad, 1979).

Quasi-option value may be a useful concept in mangrove management. Given the state of current knowledge about the nursery function, it is still extremely uncertain how these will be affected by alternative management regimes. At the same time, many think that the value (damage) of any impairment of this function might be very high. By delaying a decision, more scientific information of the effects of a loss of this function might become available, and therefore may result in better understanding for more informed decision making. Given some prior expectation of the outcome of the delay (for example, there is a 50% probability that more information will show that there will be no damage if the function is impaired, and a 50% probability that damage will be some amount $x$) the expected value of the increase in total benefits that can be obtained by waiting until the information is available can be calculated. If this expected value of information is higher than the benefits forgone by not developing now, then it is optimal to wait for the decision until that moment. A problem here is that some development might be necessary in order to be able to resolve the uncertainty. In the literature on option value this is known as dependent learning, in contrast to the case of so-called independent learning where information will become available independently of any development. Incorporating learning in models of quasi-option value is possible, but makes the analysis considerably more difficult (see, for example, Fisher and Hanemann, 1987). Despite the potential benefits, the application of the concept of quasi-option value is extremely difficult and, to our knowledge, has never been tried for mangrove ecosystem management.

### An alternative classification

More recently, another classification of wetland values has been suggested by Gren *et al* (1994). In their approach, the total production output of a wetland is divided between three different uses: (i) for its own development and maintenance; (ii) for export to other ecosystems; and/or (iii) for export to human society. The first type of output refers to the build-up and organising capacity of a wetland ecosystem, and is called the *primary value*; the second and third type of outputs refer to the exported life-support values, and is called the *secondary value*. Since the secondary value is dependent on the well-functioning of the wetland ecosystem, the primary value is a prerequisite for the existence of secondary values (Gren *et al*, 1994).

Although it cannot be denied that the good functioning of a wetland ecosystem such as a mangrove ecosystem, is a prerequisite for it being able to provide the goods and services it does, we do not feel that the concept of primary and secondary values is, in principle, more complete than that of the TEV, and that both primary and secondary values are included in the TEV. Indeed, as the authors state themselves: "If human preferences and their valuation were consistent with perfect information on the functional properties of ecosystems as a basis for generating ecological services, both directly as exports to human society and indirectly through their exports to other ecosystems, then the measurement of value according to either of the two classification schemes ...... would coincide" (Gren *et al*, 1994; 59).

Hence, it is the lack of information on the properties of ecosystems which may lead to their undervaluation, but the same is of course true when an ecosystem is valued according to the classification of primary and secondary values. Further, the division between primary and secondary values may give rise to double counting.[1] In as much as the primary value of an ecosystem consists of it being a necessary prerequisite for generating secondary values, any change in the primary value is reflected in a change in these secondary values: if the well-functioning of a wetland is obstructed, that is, a loss of primary value, this will lead to a decrease in secondary value, that is, a decrease in goods and services provided to human society (and other ecosystems). Unless we value the well functioning of the wetland in itself, the loss in primary value is simply the resulting loss in secondary value. But this is exactly what is meant by indirect use values. And if the well-functioning of the wetland ecosystem is valued in itself, this is included in the non-use value. So, although the concept of primary and secondary values may be more explicit about the importance of the well-functioning of an ecosystem the idea of primary value is, in our view, implicit in the concept of indirect use value.

### Goods and services to be valued in the Pagbilao Bay case study

The objective of the project "Economic Valuation of Mangrove-Fishpond Interactions" for which this paper was written, is the valuation and evaluation of management alternatives for the Pagbilao Bay mangrove reserve. To this end a number of management alternatives were constructed, ranging from complete preservation without any extraction of resources allowed except fishing (essentially the current situation) to total development for fishponds. (See Janssen and Padilla (1996) for a detailed description of the management alternatives that were evaluated.) Table 4 identifies the goods and services that were included in the different management alternatives, classified by the types of value discussed above. Note that option value is not included; as explained in the previous section, option value is not a separate category of value but reflects the difference between an *ex ante* and an *ex post* perspective. Thus, depending on the perspective taken, some of the use values in Table 4 may comprise an option value component. If it is thought that option values may be

[1] Admittedly, when using the concept of direct and indirect use values, one also has to be alert to the danger of double counting, see Barbier (1994).

important and should be included in the valuation, contingent valuation is essentially the only method capable of measuring these values.

**Table 4. Products and services to be valued**

| Use values | Non-use values |
|---|---|
| forestry products (fuelwood, timber, poles, nipa shingles) | biodiversity conservation |
| on-site fisheries products (crabs, fish) | carbon sequestration |
| supporting off-site fisheries (fish, shrimps) | providing opportunities for research & education |
| protective services provided to property and production activities | other non-use related benefits |
| aquacultural products (fish, shrimp) | |
| carbon sequestration | |
| plants used in traditional medicine | |
| providing opportunities for research & education | |
| biodiversity conservation<br>- potentially medicinal plants<br>- ecotourism | |

Table 4 is certainly not complete; mangrove ecosystems are capable of providing many more products and services. (See Gilbert and Janssen (1996) or Hamilton *et al* (1989) for a more complete overview of products and services from mangrove ecosystems in general.) Since the purpose of this project is to evaluate possible management alternatives for the Pagbilao mangrove forest, only those (potential) uses and services that were considered most important were included. Furthermore, the valuation of these other goods would largely proceed along the lines of the products and services mentioned in Table 4. Since this paper is concerned with the application of valuation methods to mangrove ecosystems, not much would be gained by including them in the discussion.

Most of the products and services listed in Table 4 have a direct or indirect use value: mangrove trees provide fuelwood and timber; nipa palms provide nipa shingles for roofing and walls for houses; on-site fisheries include crabs, mudcrabs and mangrove resident fish species in the river mouth and creeks running through the mangroves; through their nursery function for certain species, mangroves also support the off-site (bay) fisheries that depend on these species. The value of the function "supporting off-site fisheries" thus represents an indirect use value which derives from the value of the off-site fisheries it supports.

Aquacultural fish cannot be considered a good derived from the mangrove ecosystem as such. It represents a product related to an alternative use of the space occupied by the mangrove ecosystem. Since aquaculture is such an important management alternative, aquacultural products are included in the list of products and services to be valued. Moreover, there may exist strong linkages between the remaining parts of the mangrove ecosystem and the fishponds after conversion. For example, through the regular flushing of the ponds with fresh water from the waterways running through the remaining mangrove ecosystem, mangrove litter enters the ponds, providing a source of food for its fish. Mangrove ecosystems probably also play an important role as a nursery area for the juveniles that are stocked into the ponds.

Mangrove ecosystems provide protection to human activities and property by stabilising shorelines. In addition, they provide protection against the effects of extreme weather events, such as tropical cyclones, by dispersing the energy of floodwaters as they spill out of water channels. In the case of the Pagbilao Bay mangrove ecosystem the protection offered is mainly of service to the fishponds. Protection to housing or other assets is probably not relevant to this particular study site, although a railway runs quite close to the forest.

Anthropogenic increases in the concentrations of "greenhouse gases" are believed to warm the earth's atmosphere - the so called (enhanced) greenhouse effect - potentially causing economic damage. Of these gases, the most significant contributor to global warming is carbon dioxide ($CO_2$). Carbon sequestration by mangrove ecosystems thus has an economic value since carbon trapped in the ecosystem does not contribute to atmospheric $CO_2$ concentrations, and thus does not contribute to expected future damages. The value of this function is thus related to the value of the avoided damages and may consist of both use and non-use values, depending on the nature of the avoided damages.

Plants found in mangrove ecosystems are often used in traditional medicine. (For an overview of medicinal uses of these plants see Anon. (1992)). Although no information was available on the use of medicinal plants from the Pagbilao Bay mangrove ecosystem, the widespread use of plants from mangroves implies that the Pagbilao Bay provides similar uses which should therefore, in principle, be included in the analysis.

A number of benefits have been identified for biodiversity conservation. Firstly, biodiversity conservation means that plants which may contain medicinal substances are preserved for possible future use. Further, biodiversity contributes to the diversity and "naturalness" of the mangrove forest landscape and thereby to its attractiveness. This is probably also an important determinant of the tourist value of an area. Ecotourism can therefore be seen as a use value related to biodiversity conservation. At present, however, ecotourism is non-existent at the study-site, despite the availability of facilities such as walkways in the past. The potential for ecotourism in the Pagbilao Bay mangroves thus seems limited. Conservation of biodiversity may also have a non-use value: people may value the preservation of mangrove-related species or the complete mangrove ecosystem without any use motives in mind.

Besides biodiversity conservation, a non-use value may be attributed to forest conservation for other reasons. For example, an "altruistic value" is derived from the knowledge that forest-based livelihoods will be sustained. In addition to altruism, other motives underlying non-use values have been cited in the literature. However, one cannot be sure that this list is exhaustive. This is because, essentially, the only thing that can be said about non-use value, is that it is that part of the total WTP that is unrelated to any use. Thus, one always has to allow for the existence of some other, non-use related motive that generates a non-use value.

Providing ecosystem resilience[2] is often mentioned as probably the most important function of biodiversity (Barbier *et al*, 1994; Perrings, 1995). Despite this, this function has not been included in Table 4. This is because the value of this function of biodiversity is ultimately reflected in the other products and benefits listed in the table. If loss of biodiversity reduces resilience and adversely affects ecosystem functioning this will affect the system's ability to provide goods and services of value to humans. The value of any change in this function of biodiversity is thus reflected in the change in the value of these products and services. Ultimately, all products and services in Table 4 may be regarded as biodiversity, either because they are biological resources (wood, fish etc.) or because they could indirectly be affected by changes in biodiversity of the mangrove ecosystem through impacts on ecosystem resilience and functioning.

A very specific function of the Pagbilao mangrove forest is the service it provides as a site for scientific research and education. Strictly speaking, this represents a use value since it concerns the actual use of the resource. However, the value of this function probably extends beyond providing opportunities for research and education, and may relate to: (i) the value of the application of the acquired knowledge; and (ii) the value of increased understanding of mangrove ecosystems in itself. Regarding the first, increased understanding of mangrove ecosystems acquired through research at Pagbilao Bay may lead to improved management at other sites, leading to higher use value se of mangrove ecosystems at these sites. Research thus has an indirect use value. Regarding the second, scientific research contributes to the fulfilment of people’s general desire to understand the world regardless of the direct application of acquired knowledge. This might be called a non-use value of scientific research.

[2] Ecosystem resilience refers to the ability of an ecosystem to resist disturbances and to return to an equilibrium state after such disturbances.

# Valuation

Table 5 links the products and services discussed in the foregoing section with the methods that may be used for their valuation. For those readers not familiar with these methods, appendix 1 provides a short description. Extensive descriptions and discussions of the micro-economic foundations of these methods and of the econometric issues involved in applying them may be found in Braden and Kolstad (1991) and in Freeman (1993). See Dixon et al. (1994) for a discussion of valuation methods in the context of the evaluation of projects in developing countries. James (1991) provides a very practical and detailed description of the steps involved in applying the various methods. The application of these valuation methods to the Pagbilao Bay case study will be discussed below.

For each product or service in Table 5, the available valuation methods have been listed roughly by descending degree of theoretical validity. For example, regarding forestry products, ideally one would like to value those products that are marketed by using demand and supply curves. In the absence of these methods, using market prices presents the next best approach. For those forestry products that are not marketed, neither of these methods is appropriate and prices of marketed substitutes would have to be used, if available.

**Table 5 Linking the products and services with valuation methods**

| product/service | applicable valuation methods |
|---|---|
| forestry products (fuelwood, timber, poles, nipa shingles) | demand/supply analysis<br>market prices<br>surrogate market prices |
| on-site fisheries products (crabs, fish) | production function approach |
| supporting off-site fisheries (fish, shrimps) | production function approach |
| protective services provided to property and production activities | hedonic prices method<br>averting behaviour<br>(cost of replacement)<br>(rehabilitation cost method)<br>(additional establishment cost)<br>(cost of relocation) |
| aquacultural products (fish, shrimps) | demand/supply analysis<br>market prices |
| carbon sequestration | reduction in expected future damage cost from climate change |
| plants used in traditional medicine | substitute price<br>contingent valuation |
| biodiversity conservation | |
| - potential medicinal plants | expected value of a plant as a source of medicinal substances |
| - ecotourism | travel cost method<br>contingent valuation |
| - non-use value | contingent valuation |
| other non-use related benefits | contingent valuation |

*Note:* The contingent valuation method is, in principle, applicable to all goods and services in the table. Thus, if none of the methods mentioned in the table can be used, contingent valuation may be attempted. Contingent valuation has been explicitly mentioned only in cases where it is the only method that can be used (non-use values), or where for some other reason it presents an appropriate method.
Methods between brackets denote less preferred methods.

### Forestry products

Some of the products under this heading are marketed, and therefore, ideally, they should be valued using demand/supply analysis. By this we mean that demand and supply are used to evaluate benefits (total WTP) and costs of this alternative. However, in the absence of any data on demand curves, these products were valued by simply multiplying the quantities under the different management alternatives by the appropriate market price (for nipa shingles) or substitute price (for timber and fuelwood) and the quantities under the different management alternatives (see Carandang and Padilla, 1996). Given that these quantities are relatively small compared to the total market, any price changes resulting from the project are probably absent or negligible. The substitutes chosen for timber and fuelwood from the mangroves are, respectively, coconut lumber and fuelwood from the upland forest.

A problem in using substitute prices is of course the extent to which any good may be substituted. For example, if the energy content of 1cu.m of wood from mangroves used for cooking is $b$ times the energy content of 1cu.m of upland fuelwood, then it is intuitively clear that the value of a unit of wood from the mangroves is $b*p_u$, where $p_u$ denotes the market price of 1cu.m of upland fuelwood.[3] The same applies to coconut lumber as a substitute for timber from mangrove trees. The quality of coconut lumber is inferior to that of timber from mangroves, resulting in a lower lifetime. The value of 1cu.m of coconut lumber is therefore lower than the value of 1cu.m of mangrove timber. Because of a lack of appropriate correction factors, no adjustment of the price of the substitutes was made to account for this difference in quality.

When using substitute prices the least cost alternative should be used. The least cost alternative for fuelwood for cooking is Liquefied Petroleum Gas (LPG) (see Anon., 1995). However, the use of LPG requires high initial investments in equipment, which is prohibitive for most households which depend on fuelwood. LPG cannot then be considered an appropriate substitute for fuelwood.

A second problem is the valuation of the costs. Collection of forest products is largely a subsistence activity and the factors of production (mainly labour) receive no compensation. To value the labour some measure for the opportunity cost of time is needed. (Other inputs are ignored because they are probably negligible compared to the labour.) Valuation by the local wage rate is one possibility, although it is doubtful whether this reflects the true opportunity costs of time for people who depend on the mangrove forests. Since these are usually members of the nearby coastal fishing communities, the approach taken in this study was to value the time spent gathering forest products by the income that could have been earned by spending this time fishing (see Janssen and Padilla, 1996).

A third approach to valuing the time spent in subsistence activities is to use a discrete choice framework (Gammage 1994). Adopting this approach, households are modelled as having to choose between two possible sources of a product: either to buy it on the market at a certain price, or to collect it themselves. The household is assumed to choose the alternative that will yield the highest utility. The observed choices are therefore assumed to be those which maximise the households utility (revealed preference). Using this framework it is possible to calculate the opportunity cost of time if data on the choice taken (gathering or buying), market price of the product and time spent gathering is available (see Gammage, 1994).[4]

### On-site fisheries

Again, in the absence of data on the demand curve, a valuation was performed using market prices. Projected catches under the different management alternatives were multiplied by market prices to obtain the total value of the catches under the different regimes. Ideally, the value of the change in catches resulting from the management alternatives should be valued using the production function approach. Since the procedure for valuing such changes in on-site fisheries is essentially the same as

[3] Using the household production function framework, interpreting upland fuelwood and wood from mangroves as two possible inputs in the production of energy for cooking, it can easily be shown formally that this is the right expression for the value, see Smith (1991), pages 44-45.

[4] Using the simple indirect utility function used by Gammage (indirect utility is a linear function of the market price of fuelwood and gathering time only), the opportunity cost of time for those households that choose to gather is simply the ratio of the market price and the time spent gathering.

that for off-site fisheries, this will be discussed in the next section together with the approach that was taken in this study.

### Off-site fisheries

Mangrove ecosystems are generally considered important for supporting the populations of certain species of fish which are caught off-site. Therefore, any disturbance to the mangrove ecosystem, such as cutting down for fishpond development, will result in smaller population sizes and hence smaller catches in the off-site fisheries. The production function approach (PFA) provides an appropriate method for valuing such changes in catches. In this paper, the term PFA is used in a generic way to denote techniques that value changes in environmental quality by their effects on the production of marketed goods. Some authors adopt a more limited use, for example, Freeman (1993) uses it to denote a technique that explicitly uses the production function. However, in order to obtain the values needed, it is not always necessary to use the production function itself.

Conceptually, the approach is fairly simple and is illustrated graphically in Figure 2. In this figure, $MC_0$ represents the marginal cost curve, or supply curve, of the fishing industry, and D represents the demand curve. Equilibrium price and quantity are $p_0$ and $q_0$, respectively. Suppose the mangrove area which supports the fish population essential to the fishery is partly logged over, inhibiting its nursery function and resulting in lower stocks. Total catches in the fishery are a function of the human effort (boats, nets, labour) and the stock of fish. Lower stocks thus means that more human effort is needed in order to catch the same quantity of fish. This can be represented as an upward shift in the marginal cost curve to $MC_1$. This results in a new equilibrium price and quantity of $p_1$ and $q_1$. The loss in consumer surplus is equal to the area $p^0ADp^1$., while producers lose area ABCF and gain area $p^0p^1DF$. The net result is a combined loss in producers' and consumers' surplus equal to area ABCD, that is, the area between the before and after change supply curves, bounded from above by the demand curve.[5]

The same approach can be used to value the impacts of a management alternative on on-site fisheries. Here, too, the impact of a management alternative on catches runs through the effect this alternative has on the mangrove ecosystem function of supporting the populations that are fished. (The precise mechanisms at work need not be the same, of course.)

[5] This analysis ignores two other effects that might occur. Firstly, not only supply, but also demand may shift. This could happen if, for example, the quality of the fish is affected. For example, average size of the fish caught might change. See McConnell and Strand (1989) for an analysis where both demand and supply are affected. Secondly, the changes in input demanded might affect the prices of these inputs, leading to changes in surpluses in these markets. If it is thought that such effects are present and might be substantial, a general equilibrium analysis, instead of the partial analysis presented here, would be more appropriate.

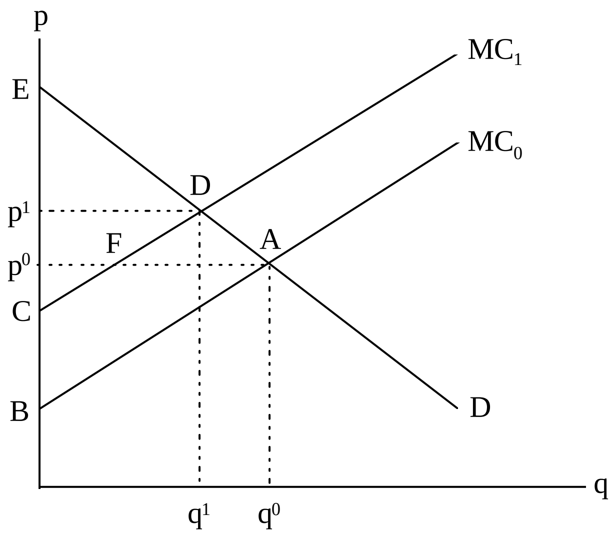


**Figure 2 The change in consumers' and producers' surplus from a loss of mangrove cover**

Applying the above approach to the fisheries in Pagbilao Bay requires knowledge about: (i) the relationship between the quality of the mangrove ecosystem and population size (the biological dose-response relationship); (ii) the catch function, ie, the function describing catches as a function of population sizes and human effort; (iii) the demand curve; and (iv) the supply curve and how it shifts under the influence of a change in stocks. With this information, the effect of a change in one or more of the mangrove attributes on consumers' and producers' surplus can be calculated. Two major obstacles, however, prohibit such an exercise: firstly, a lack of knowledge, certainly at a quantitative level, of the many complex interactions between mangrove ecosystems and fish populations; secondly, a lack of data to estimate or calibrate these relationships. These problems will be discussed in more detail below.

The two most important mechanisms that have been put forward to explain the link between mangrove ecosystems and fisheries are the nursery ground function and the contribution to offshore productivity through the export of detritus (see Ong and Padilla, 1996). The second mechanism is probably of very limited importance and no real evidence exists for it. The nursery ground function means that mangrove ecosystems provide food, shelter from predators and turbulence, or both. They further provide an important habitat for adult fish. The links between mangroves and fish populations are, however, very complicated and indirect. The nursery function is probably species specific, and there exists considerable interaction between mangroves and nearby seagrass beds, coral reefs and mud flats. This means that linking catch to such an obvious variable as eg, area of mangrove ecosystem, may be appropriate in some cases but highly inappropriate in others. For example, if stocks are related to food availability in the form of detritus, then area may serve as a good proxy variable for food availability. But even in such cases, statistical analysis of stocks and mangrove area might yield misleading results. For example, there may well be some other environmental factor, eg. water quality, that constrains stocks below levels where the area effect would become noticeable. Or some other, intermediate step in the detritus pathway may constrain stocks. Fish hardly ever feed on mangrove detritus directly. For some species, providing shelter from predators might be more important than the provision of food. This function is probably more related to the structure of the mangrove ecosystem; and area would probably only become important after some critical lower threshold level has been passed. Without properly accounting for such factors, simple regression analysis of catches and mangrove area might lead to erroneous conclusions.

Apart from basic data such as catch and area of mangroves, it is highly unlikely that data on other important variables are available, especially over a sufficiently long period to permit econometric analysis. In Pagbilao Bay, only some very aggregate data for catches for one month in 1992 were available, which is probably typical of many sites in the Philippines. Moreover, since it was declared a reserve, the Pagbilao Bay mangrove forest has not been disturbed, so there would probably be no, or little variation in the mangrove attributes, making it impossible to estimate their effects econometrically. In such a case one has to turn to cross-sectional data. This makes it even more crucial to identify all factors that may play a role. However, even with cross-sectional data, time series data are still necessary to provide variation in such factors as prices which is probably very limited across sites. The species specificity even further exacerbates the data problems since it means that the analysis should ideally be performed at the level of individual species. The price of inputs poses a particular problem: Fisheries in Pagbilao Bay are mostly of an artisanal nature, where the fishermen's own labour is the most important variable.

Stock is another variable for which data are scarce. In this case, an approach such as that used by Lynne *et al* (1981) could be adopted. The authors derive a reduced form equation from their model enabling them to substitute out stocks and linking catches directly to the environmental variable of interest (in this case marsh area) and human effort without having to estimate the underlying structural relationships. Lynne *et al* only estimate the reduced form production function and, except for the derivation of the marginal product of marsh area, do not go on to use the estimated function for valuing larger, discrete, changes in marsh area. This could be done by combining the estimated reduced form production function with a supply and demand curve. This is illustrated in Ellis and Fisher (1987).

However, the use of reduced form equations comes at a cost, namely the need to use a rather simple underlying structural model, which may not always be appropriate, and the loss of the opportunity for testing the appropriateness of the underlying structural relationships. If one wants to use the estimated reduced form equation for estimation purposes (far) outside the range of available data, the appropriateness of the underlying model is a prerequisite - good statistical performance of the reduced form equation is no guarantee. In fact, although the reduced form equation estimated by Lynne *et al* performed well on such criteria as $R^2$ and statistical significance, an ad hoc specification that was also estimated performed even better or just as well on these criteria.

Duality theory provides another possibility of circumventing the need to specify and estimate the intermediate relationships between mangrove ecosystems and fish populations. A dual cost function, or profit function, could be specified that includes the mangrove attributes that are thought to play a role in these relationships. An estimation of these functions would require data on catches, input and output prices, and the relevant mangrove attributes. A supply curve may then be derived easily by differentiating the estimated cost function with respect to output price. This supply curve includes the mangrove attributes and may thus be used to calculate, in conjunction with the estimated demand curve, the effect on supply, price and consumers' and producers' surplus of a change in one or more of these attributes. Although the data needs of this approach are somewhat less than that of a complete estimate of all relationships, they may still be prohibitive. Again, none of the required data was available for Pagbilao Bay.

Another problem with this approach is extrapolation to situations outside the range of available data. For example, we may want to estimate the effect of, say, cutting down 50 percent or more of a mangrove forest for fishpond development or another alternative use. Such changes are probably far beyond the range of data used to estimate the cost function. Ecological relationships are often thought to be highly non-linear and to exhibit threshold effects. For estimation purposes, usually simpler functional forms for the cost function are used that are not necessarily consistent with the underlying structural relationships. These might serve as a good local approximation to the true function, but using the estimated equation for evaluation far beyond the range of available data might be completely inappropriate. It is of course possible to derive the appropriate form of the cost function from the underlying structural relationships, but this will probably be possible for rather simple models only, and if the appropriate form of these structural relationships is known.

Another approach would be calibration as in Ellis and Fisher (1987), based on a production function for the Gulf Coast Blue Crab fishery estimated by Lynne *et al* (1981) already mentioned above. This production function includes marsh area as one of the explanatory variables, and by differentiating this production function with respect to marsh area one obtains the marginal product of marsh area. This estimate of the marginal product of marsh area is used by Ellis and Fisher to calibrate a simple model consisting of a Cobb-Douglas form cost function and a constant elasticity demand equation, which could then be used to calculate the changes in consumers' and producers' surplus from any changes in marsh area. Freeman (1991) extends the Ellis and Fisher analysis by demonstrating the effect of access conditions on the calculations.

Applying such an approach in this study would require an estimate of the marginal product of the relevant mangrove attributes, for which there is none available. The nearest to such an estimate of marginal product are the regressions by Paw and Chua (1991). The authors regress municipal total catch by species group for several coastal provinces on corresponding mangrove area. The problem with the regressions is that human effort is not included and hence, they cannot be considered a true production function. Further, the only explanatory variable is mangrove area, whereas other mangrove attributes may also play an important role. Besides an estimate of the marginal product of mangroves, estimates of other parameters needed to calibrate the model are missing, which eliminates the possibility of adopting this approach in the study. Appendix 2 provides some rough calculations of the value of the nursery function based on Paw and Chua's regressions. These calculations provide an alternative to the approach taken in this study, which will now be outlined briefly. For a more detailed description see Ong and Padilla (1996).

In the absence of any data on catches or stocks, a maximum allowable sustainable catch per year was determined as follows. First, an estimate of annual starting stock of 10 species groups (5 mangrove residents, 5 mangrove transients) was calculated based on the sampling of juveniles from the Sukol Creek by Bagarinao (1995). The juveniles were considered to represent one cohort. Using some simplifying assumptions, the annual number of adult individuals was calculated from the number of juveniles.[6] Assuming an optimal exploitation rate of 50%, as used in Ong and Padilla (1996), these were then translated into maximum sustainable catches. In the absence of data on catches, it cannot be assessed to what degree the reserve contributes to total catches. However, the contribution to the on-site fisheries is probably considerable whereas it makes only a limited contribution to the off-site fisheries.

To calculate the effect of the different management alternatives on catches, it was assumed that there was a direct relationship between nutrient productivity of the area and fish productivity. The reduction in area for a certain alternative was translated into a reduction in nutrient availability based on the analysis presented in Carandang and Padilla (1996). The percentage reduction in fish productivity was set equal to the calculated percentage reduction in nutrient productivity under each alternative (see Ong and Padilla 1996). For some alternatives an extra correction was applied to account for ecological effects other than reduced nutrient productivity, albeit in a rather heuristic way. Maximum sustainable catches under each alternative were again calculated assuming an optimal exploitation rate of 50%. Valuation of the catches was performed by simple multiplication, that is, catches were multiplied by the market price of the species or species group.

How does this approach compare to the "ideal" as illustrated in Figure 2? It obviously ignores any economic reactions; however, the assumption of a constant price may be appropriate since the catches in Pagbilao Bay represent only a limited amount of the total supplied to the market. More serious is the neglect of the production side, that is, how producers react to the change in terms of the level of inputs. The above approach effectively assumes that the amount of inputs used remains the same. For off-site fisheries this is not necessarily a bad assumptions since the contribution of the Pagbilao mangrove reserve to the catches in these fisheries is probably very limited. However, in the case of on-site fisheries this assumption is less justifiable. A justification for ignoring changes in inputs, both for the off-site and on-site fisheries, is that these fisheries might be characterised as open access. In that case, the supply does not equal the marginal cost curve but rather the average cost curve, and producers' surplus is equal to zero (Freeman, 1991).

[6] This approach is similar to that followed by Kahn and Kemp (1985). These authors also translated number of juveniles into number of adults. However, besides time-series on juvenile stocks, these authors also had available data on adult stocks for some years, making it possible to derive a relationship between juvenile and adult stocks based on observations of these variables. The approach used here has to rely on simplifying assumptions between these variables and limited data on juvenile stocks (two samples only).

**Protective services**

James (1991) describes a number of methods that may be used to value the protection provided to production activities and property by tropical wetlands. These are all based on some measure of the (expected) damages that would be incurred if the protective function is impaired, or the cost of moving an activity or asset to another location which provides an equal level of protection. A word of caution is required regarding the validity of these methods. The link with the preferred measure of the value of increased risk of a damaging event, WTP or WTA, is sometimes very tenuous. Using expected damages could, of course, be defended on the grounds that this would be the maximum amount of money an individual would be willing to pay to prevent the increased risk of damages, or, if a WTA measure is more appropriate, the minimum amount of compensation an individual would demand for accepting the increased risk of damages. However, this ignores the disutility of the increased risk it self. People are generally averse to increases in risk, and are therefore willing to pay more to prevent risks, or demand higher compensation for increased risk than simply the cost of expected damage. Using expected damage thus underestimates the real value of increased risk, or conversely, underestimates the true value of a loss of protection provided by a mangrove ecosystem.[7]

These methods also ignore the discomfort related to some damaging events which should also be included. Loss of protection may also lead to increased risk of injuries and loss of life - these too should, ideally, be included in the valuation. The valuation of increased mortality risk is, however, a difficult and ethically laden subject. Both the CVM and so-called hedonic wage analysis have been used to value such risks.

The Pagbilao Bay mangrove ecosystem does not directly provide protection to house owners. However, two approaches that could be used to give a more theoretically justifiable way of estimating the value of the protective services of mangrove ecosystems will be described briefly. The first is the hedonic prices method (HPM). Differences in house prices between areas with undisturbed and those with disturbed mangrove ecosystems could be linked to differences in the risk of flooding between these areas. However, the absence of a fully developed house market may pose a problem. Another problem concerns the extent to which the areas used for such an analysis can be seen as one market, or rather as segregated markets.

The second approach to valuing protective services is to use defensive expenditure. Expenditures on measures that compensate for a loss of protection provided by mangrove ecosystems (dikes, for example), give a measure of the WTP for the protection. Two problems arise here. Firstly, the extent to which these measures may substitute for the protection otherwise provided by mangroves is questionable. Secondly, observed defensive expenditure generally underestimates the true value, even in the case of perfect substitutes (Smith, 1991).

The Pagbilao Bay mangrove forest does, however, provide protection to production activities, namely the fishponds located in the forest. However, this function has not been valued separately

[7] Freeman (1989; cited in Freeman 1993) has computed how large this underestimate can be for a number of utility functions differing in the degree of risk aversion. For small losses (ca. 1 percent of income) the underestimate is negligible, but for catastrophic losses (50 percent of income) the difference can be very large, ranging from a factor of 2.5 to a factor of 100 for the most risk-averse utility functions.

because this would lead to double counting. In all management alternatives involving aquaculture, the legally required buffer zone of 50 metres was observed. The value of the protection provided by the buffer zone is the value of the lost production in case the buffer zone was not observed. For example, loss of the buffer zone would lead to one extra loss of harvest every five year. (This is not necessarily the correct value, see below.) Adding this value to the value of the aquacultural products would simply be double counting since this one harvest is counted both as part of aquacultural production and under protective services.

Below, possible approaches to valuing the loss of this function in case one is interested in a separate estimate, will be indicated briefly. The expected damage from a complete loss of the protective function would be relatively easy to estimate. Statistics on the frequency of extreme weather events are readily available. Furthermore, the damage is easy to calculate since it generally results in a complete loss of the crop and seaward dikes. Thus expected damage over a certain period of time may be calculated and could serve as a measure of the value of a complete loss of the protective functions. Damage resulting from a partial impairment of the protective functions would be more difficult to estimate. However, in both cases, this approach again suffers from the weakness that it does not account for risk aversion.

Again, hedonic methods and defensive expenditures could be used to derive a better measure of the true value of the protective services. Differences in degree of protection provided by disturbed and relatively undisturbed mangrove ecosystems are possibly reflected in differences in the price paid for land in these areas. An hedonic land price study would use these differences in price to derive a measure of the value of the protective functions.[8] An obvious problem here is that many other factors influence land price, many of which are probably more important than the local level of protection. This makes the specification of the hedonic price function of crucial importance. Another problem is that a market for land for fishpond development is hardly developed. Moreover, the land on which fishponds are developed is often not owned by the fishpond owner, but leased from the government. There exists no (official) markets for such leases and the price paid for them is uniform and extremely low. Thus, they do not reflect any differences in land quality. The underlying causes of these institutional failures however have not been addressed in this study and the implications for policy making are beyond the scope of this paper. Institutional aspects of mangrove forests in the Philippines are addressed in Janssen and Padilla (1996).

The second approach is again defensive expenditures. Expenditure on measures that compensate for the protective functions otherwise performed by mangrove ecosystems (for example, reinforcing fishpond dikes), provide a measure of the WTP for protection. The problem is the substitutability (to what extent do such measures compensate for the loss of protection), as well as the fact that observed defensive expenditures generally underestimate the true value of the lost function.

**Aquacultural products**

[8] See Palmquist (1991) for a general discussion of hedonic land price models. Gammage (1994) provides an extensive discussion of the problems involved in using land prices to value protective functions of mangrove ecosystems.

The valuation of aquaculture poses no special problems. Surveys of aquaculture farms have been carried out (Padilla and Tanael, 1996). From these surveys, yields and use of inputs have been determined for different aquaculture technologies that were considered in this project (intensive and semi-intensive aquaculture and combined aquaculture and silviculture). The valuations are carried out by straightforward multiplying by market prices. The establishment of fishponds at the study site may be seen as a marginal project, justifying this approach.

**Carbon sequestration**

The value of carbon sequestration by mangrove ecosystems is related to the avoided damage from future global warming by the fixing of carbon in the system. Valuation of a loss of this function thus requires two parameters: an estimate of the future damage from global warming and the net release of carbon to the atmosphere from conversion of a mangrove ecosystem to an alternative use (Pearce and Moran, 1994). To start with the second, Brown and Pearce (1994, cited in Pearce and Moran, 1994) report net changes in carbon content of 36 to 220 tonnes of carbon per hectare, depending on the original state of the forest and the alternative land use. Some estimates are now available for the future damage costs of climate change. A much cited figure is that calculated by Fankhauser (1994) of US$20 per tonne of carbon. This figure represents the capitalised marginal damage costs of a tonne of $CO_2$ for the so-called $2\times CO_2$ scenario (a doubling of $CO_2$ concentrations compared to pre-industrial concentrations), that is, the discounted value of the future damage from one extra tonne of carbon emitted today. This figure explicitly takes account of the delay time between emission and the occurrence of damages, and of the lifetime of $CO_2$ in the atmosphere. Using these figures, the expected damage costs of converting tropical forests to other uses range from approximately US$ 600 to US$ 4400 per hectare. Note that these represent the present value of future damage, not annual damage.

The above figures relate to tropical forests and also to land use alternatives that are not relevant to mangrove management (shifting agriculture, permanent agriculture and pasture). To do such an analysis for the study site would require an estimate of the net release of carbon to the atmosphere for the alternative uses considered relevant for mangrove ecosystems. We do not know of such estimates. Below we will roughly assess the relative net release of carbon under the different management alternatives.

The first alternative involves complete preservation with no harvesting of forestry products. Under this alternative it may be expected that the forest will further recover, that is, the carbon content will actually increase. This alternative thus has a positive value in terms of carbon sequestration. To value this, the maximum biomass of the mangrove forest relative to the current state would have to be known as well as the carbon content of this biomass. Note that the further regeneration of the forest might contribute to higher productivity elsewhere, leading to further carbon sequestration.

The second and the third alternatives are subsistence forestry and commercial forestry, the difference between the two being the type of products which are harvested (mainly timber or fuelwood). For both alternatives a maximum sustainable cut, where annual harvest equals annual growth, was determined. Although this means that the carbon content of the forest remains the same, there is still a net fixation of carbon. Even if all wood is eventually burned, some carbon will remain stored in the ashes. To determine which of the two alternatives leads to the highest net fixation is not possible without further information on the "life cycle" of the wood harvested under the alternatives. For example, how much is used for timber and how much for fuelwood, and how much of the timber is eventually burned and at what time. Note that this means that, although the carbon content of the forest itself is higher under the preservation alternative than under the forestry alternatives, without further information it cannot be said whether preservation leads to higher carbon fixation. What may be said with certainty, however, is that the aquaculture alternative is the least desirable in terms of carbon fixation. Under this alternative the forest is cleared and not replanted and will thus inevitably lead to a net release of carbon.

**Ecotourism**

As already mentioned, no ecotourism was observed in the area. The valuation of this service represents a potential value of preservation rather than an observed value.[9] Since we cannot rely on actual tourist visits to value this function, the valuation has to rely on either benefit transfer using existing studies of mangrove ecotourism, or on contingent valuation since this is the only method that can value hypothetical goods. Benefit transfer refers to the use of value estimates derived at another site to the site of interest. See Bergland *et al* (1995) for an overview of approaches to benefit transfer.

Applying benefit transfer in this case would require the availability of the estimates of the mean unit value of a tourist visit to mangrove ecosystems from a travel cost study, for example. Multiplication by the expected number of tourists then gives the expected value of ecotourism. To our knowledge, travel cost studies of mangrove ecotourism do not exist. However, even if they do, directly transferring such unit values to Pagbilao Bay is a precarious procedure. Travel cost studies are site specific (area of the site, specific species of wildlife living in the area, the presence and quality of tourist facilities such as hotels and traffic infrastructure, etc). Strictly speaking, transferring mean unit values would be valid only if the characteristics of the study site and Pagbilao Bay are equivalent. If this is not the case, corrections for the different characteristics would have to be made: this requires knowledge about how these characteristics influence the value. Travel cost models have been developed for determining the contribution of certain characteristic to the value of a site, but these are not without their drawbacks (see Freeman, 1993). However, travel cost models based on random utility models provide a promising approach to the valuation of site characteristics, but these have their own disadvantages (see Bockstael *et al*, 1991).

Another approach would be to use contingent valuation (CVM). Using CVM, the value of tourist visits would be determined by directly asking people's WTP for a visit in the form of an entrance fee, for example. However, the fact that at present no tourism has been observed at Pagbilao Bay raises the question of the relevant population. That is, who may be considered potential visitors and how many visits may be expected. (Benefit transfer suffers from the same problem, of course.)

**Traditional medicine**

It was not possible to value the use of medicinal plants from the Pagbilao Bay mangrove ecosystem for traditional medicine due to a lack of data. Had data been available, however, the most

[9] Given that the provision of facilities, such as walkways, have not led to the development of tourism in the area, the potential for ecotourism is probably very limited.

straightforward valuation would have been by market price for those plants or plant-derived substances that are traded, or by substitute prices for those that have commercial, "western" substitutes. However, such an approach would ignore the more intangible attributes of traditional medicinal practices that might have a value in themselves. The only way to capture the value of such attributes would be to determine peoples WTP for traditional medicines through the use of CVM. To our knowledge, a satisfactory method for valuing traditional medicinal uses has still to be developed. As Pearce and Moran (1994) note, most work has been applied to the valuation of conserving plants for possible future use in pharmaceutical research. These methods are briefly discussed below.

**Conservation of potential medicinal plants**

One of the benefits of biodiversity conservation is the contribution of plants to pharmaceutical research. Approaches to the valuation of such benefits usually multiply some estimate of the probability of discovering a commercially valuable substance by the value of such a discovery. The extremely high degree of uncertainty in valuing such benefits is illustrated by the fact that the values obtained in such studies range from $44 per untested species to $23.7 million (Simpson *et al*, 1995).

Valuation may be based on several measures of the value of medicinal plants (Pearce and Moran, 1994): (i) the market value of traded plant material; (ii) the market value of drugs based on some plant; and (iii) the value of a plant based drug in terms of life-saving capacity and using the Value of a Statistical Life. If it does not concern a life saving-drug one could of course use the value of curing the specific health state the drug is intended for. Although (iii) is probably the most relevant measure of value from society's point of view, valuation is usually based on (i), on the argument that using the first two would give an overestimate of the actual value that can be captured by the source country.

As already mentioned, several estimates of the value of species conservation for pharmaceutical research exist. Pearce and Moran (1994) derive a value of a "representative" hectare of land for medicinal plants in the range of $0.01 to $21 per hectare of tropical forest based on an estimate of the probability of any plant species giving rise to a successful drug ranging from 1/10,000 to 1/1,000. The capitalised value of the upper end of this range equals $420 at a 5 percent discount rate.

Another approach to valuing biodiversity protection for medicinal uses is that proposed by Simpson *et al* (1995). They calculate an upper bound on the "value of a marginal species", ie the value of a species based on its incremental contribution to the probability of making a commercial discovery and the net revenues from a new product. This would give the maximum WTP of pharmaceutical companies for the conservation of one species at the margin. They come to a maximum possible estimate of the value of a marginal species of slightly less than $10,000 under, what they term, fairly optimistic assumptions regarding the parameters of their model. This value is extremely sensitive to these assumptions and falls off rapidly under less optimistic assumptions.
Applying such a value to the species found in the Pagbilao Bay mangrove reserve would certainly result in a considerable biodiversity benefit and would provide a strong incentive for conservation of the area in its current state. However, none of the species found there can truly be regarded as marginal species, since none of them is endemic; if a species is lost at this particular site, there are

still samples available from other sites. Therefore, there are no incentives for the pharmaceutical industry to invest in conserving biodiversity at Pagbilao Bay. Equally, there is no incentive for society to conserve biodiversity at Pagbilao Bay for the purpose of pharmaceutical research. Thus, it may be concluded that the value of the area for biodiversity conservation may safely be set at zero, as far as it concerns conservation for pharmaceutical research.

**Non-use values of biodiversity conservation**

Besides use values, conservation of biodiversity can have a non-use value. However, the question of non-use value cannot be stated a priori; it may only be answered through empirical research. The only method capable of measuring non-use values is the Contingent Valuation Method (CVM) which asks people directly for their WTP to conserve biodiversity at the site. To do so, one would have to develop scenarios describing the current state of the area and the state of biodiversity under alternative management systems. Then, by asking people for their WTP for preserving the forest in its current state, one would obtain the value of biodiversity conservation compared to alternative management regimes.

A problem of using this approach is that WTP would probably be very sensitive to the level of information in the questionnaire. Hanley *et al* (1995) demonstrate that the WTP for biodiversity conservation increases with the level of information provided. Similarly, in their study of the WTP to restore the Wadden Sea wetland to its 'natural state, Spaninks *et al* (1996) demonstrate the significant influence of information about the present and "natural state" of the area. These, and other studies, thus raise the question of the appropriate level of information to be provided, eg, should information be limited to an absolute minimum by referring to, eg, "conserving biodiversity at the site" or should information be provided on individual species found at the site? should information be limited to unique species and/or threatened species only, should information be provided on the function of a species in the entire ecosystem, etc,?

Also the context in which the valuation problem is placed might be very important. For example, the most important motivation underlying the WTP for conservation of the Pagbilao mangrove forest would probably be the wish to preserve mangrove ecosystems in general, or maybe a certain species that depends on the mangroves. To illustrate the effect information could have on WTP if this is indeed the underlying motivation, imagine how WTP could be affected by simply mentioning the size of the Pagbilao mangrove forest (110 ha) relative to the total remaining area of mangrove forest in the Philippines (123,400 ha) and that there now exists a ban on cutting mangrove forests in the Philippines; or the effect of mentioning that a certain species lives in the forest, but would not be threatened with extinction if the Pagbilao mangrove forest would disappear.

If one is interested in the non-use value of biodiversity conservation only, care should be taken that respondents indeed only express their non-use value and not any other value. For example, some individuals may be aware of the importance of biodiversity for the development of pharmaceuticals, and part of their WTP may reflect their valuation of this use of biodiversity. In order to isolate the non-use value of biodiversity conservation, questions should either: (i) ask respondents to indicate what part of their WTP is unrelated to any such use motives; or (ii) explicitly instruct them to disregard these motives when giving their WTP. The second option is probably the preferred strategy, since it is questionable whether respondents are able to separate out non-use values from total WTP.

Another problem concerns determining the relevant population. It would probably include people in other parts of the world as well as the Philippines. The problem with extending the population beyond the national boundaries is that the capturability of this WTP for the national government is limited and therefore might not be considered by national decision-makers.

A CVM survey was not undertaken in this project, mainly due to budgetary reasons. Certainly if the relevant population were to be extended to include people outside the Philippines, the number of respondents needed to obtain a reliable estimate of WTP would be substantial.

**Other non-use related benefits**

As already mentioned, other motives for non-use values might exist. In order to value these, one would first have to investigate them; for example, it might be found that respondents value the possibility of maintaining support to those livelihoods that depend on the forest. If so, it is important to include information on this in the questionnaire because it influences WTP.

**Providing research opportunities**

The Pagbilao mangrove forest is extensively used by scientists and students for field work. The value of this research function can be divided into two components: (i) the value of providing a site for scientific research; and (ii) the value of the results of this research. The value of the first function could be approximated by looking at the extra expenditures that would be necessary if this particular site were not available and one would have to use another, comparable site for research. An alternative would be to assess the WTP of the organisations using the Pagbilao mangrove forest for research for preserving the area for research purposes.

The second component is probably more important, but at the same time more difficult to value. Firstly, there is the non-use value of the research. That is, the value of scientific research without any direct application of the acquired knowledge. To value this function one would have to resort to CVM. Secondly, there is the indirect use value of research, being the value of improved management of other mangrove forests hat might be based on the results of research carried out at Pagbilao Bay. Note that this value is not necessarily higher for an undisturbed mangrove ecosystem than for a degraded one. In fact, the deliberate disturbance of a mangrove ecosystem in order to study its effects may be of more value than leaving it undisturbed. For example, by developing the area for fishponds, one can study the effect of this form of management on off-site fisheries, thus reducing the uncertainty still surrounding these effects and contributing to improved management at other sites. However, without some prior expectation regarding the outcome of research as well as the value of improved management based on the possible outcomes, one cannot value this function properly. Note the analogy with the concept of quasi-option value. Essentially what is described here is a case of dependent learning: only by allowing some development to take place, is it possible to reduce the uncertainties regarding the effects of development, and thus improve management.

# Conclusion and Discussion

The literature review points to a growing recognition of the numerous products and services provided by mangrove ecosystems. Yet most studies still limit valuation to use values: the availability of market prices or market prices for substitutes means that the valuation of use values is relatively easy. With the exception of Ruitenbeek (1992) who includes 'capturable biodiversity benefits', none of the above studies estimate non-use values. However, this capturable biodiversity benefit of Ruitenbeek refers not only to the value of preserving biodiversity, but also to use values such as the use for pharmaceutical research.

Most studies limit indirect use values to the nursery function. In all the studies reviewed, the (off-site) fisheries constituted a substantial part of the total value, ie, more than 90%. The value of this function in various mangrove studies such as Lal (1990) and Gammage (1994) depends heavily on the ecological linkages between mangrove area and fish stocks. However, in most cases, valuation of the impacts of a management alternative on catches in off-site fisheries is based on somewhat arbitrary assumptions, rather than on detailed scientific information. This is probably due to inadequate knowledge regarding the ecological linkages between mangrove ecosystem and fish populations. The studies also ignore price changes and other economic reactions, and use simple multiplication by market price to value catches. Although Ruitenbeek (1992) designs different scenarios to account for the uncertainty regarding the ecological linkages between mangrove ecosystems and off-site fisheries, he nevertheless disregards any economic reactions.

Similar arguments apply to the Pagbilao case study. Valuation is generally limited to use values of fuelwood, timber and nipa products, which is not problematic. Applying the production function approach to measure the indirect use value of the nursery function is appropriate, theoretically. However, many assumptions have to be made about the ecological relationships involved. The complexity and species specificity of these relationships makes it very unlikely that in the foreseeable future much progress will be made here without considerable investments in ecological research in this area. Until that time the valuation of this function will remain rather speculative.

A valuation of the forest's protective services was not undertaken but, given the definition of the alternatives this was believed to be unnecessary. Possible approaches to the valuation (hedonic prices and averting behaviour) of these services were indicated, but their appropriateness is probably limited because the conditions necessary for their application will not always be fulfilled.

Non-use values for biodiversity were not assessed, mainly because of budgetary reasons. In addition to the expense of good CVM research, other problems such as the appropriate level of information and relevant population make the valuation of biodiversity very difficult.

The value of biodiversity conservation for pharmaceutical research was set at zero. There are no endemic species in the area, hence there is little incentive for either pharmaceutical companies or society to invest in biodiversity conservation at Pagbilao Bay for this purpose. However, if the situation did arise whereby it would be necessary to value this function, there would be numerous problems. The valuation of biodiversity for pharmaceutical research remains a highly speculative business.

It was not possible to value the use of the forest for traditional medicine because of a lack of data. However, if these data would have been available there would still have been problems in finding appropriate values for these medicines.

It was also not possible to value ecotourism. No ecotourism is currently observed in the area and studies of ecotourism in other mangrove forests, which could have been used for benefits transfer, are lacking.

It was not feasible to value carbon sequestration due to a lack of data on the carbon content of mangrove forests and the use of the products derived from them. An additional problem is that the valuation of this function can only be as good as the valuation of possible future climate change, which is still highly uncertain. Lastly, the research value of the area was recognised but was also impossible to value.

**Future research**

The literature review and the discussion of the Pagbilao case study illustrate the potential of valuation methods for evaluating management alternatives. At the same time they also indicate the practical limitations to their application. In principle, methods are available for the valuation of the full range of products and services provided by mangrove ecosystems; but the lack of data and quantitative knowledge regarding some key ecological relationships present major constraints. That all mangrove valuation studies produce very high values for the nursery function, even based on ad hoc assumptions and with limited knowledge regarding the ecological relationships, affirms the need for further inquiry. The values for this function currently dominate the total value of mangrove valuation studies and need to be substantiated by more research.

This paper has argued that the Pagbilao Bay mangrove forest had no real value for pharmaceutical research. The arguments for this conclusion are, however, site specific and not necessarily valid for other mangrove areas. Another research priority therefore, would include extensive data gathering to value this function properly where appropriate.

It was also recognised that the under-valuation of the mangrove ecosystem in Pagbilao was the result of institutional failures. The lease price for the fishponds is still rather low. The underlying causes of these failures also present an opportunity for future research.

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## Appendix 1 Brief overview of valuation methods

***Demand/supply analysis and market (shadow) prices***

Since a demand curve can be interpreted as a marginal WTP curve, the total WTP for a certain amount of a good is equal to the area under the demand curve for that good. Thus, for those mangrove related goods and services for which demand curves are available, the value can be calculated as areas under the demand curve. Costs can be calculated as the area under the supply curve as the supply curve equals the marginal cost curve. This approach to calculating the net value of a good or service has been termed demand/supply analysis in Table 5 in the main text This approach is, in principle, applicable to all those goods and services from mangrove ecosystems which are traded on markets.

***Market prices***

If demand and supply curves are not available, but the good in question is traded on markets, the WTP can be determined from the market price of the good, which gives the marginal WTP for a good. This approach gives an underestimate of the true WTP since consumer surplus is ignored. How serious this underestimate is depends on the elasticity of the demand: the more elastic (flat demand curve) the smaller consumer surplus, and thus the smaller the error. For relatively small projects, such as the one considered in this study, any effects on prices are probably absent or negligible and consumer surplus may be safely ignored. If, due to certain distortions, market prices do not reflect the true scarcity value, the market price should be corrected in order to reflect the true scarcity price or shadow price. When using demand and supply curves these should also be corrected for any distortions.

***Surrogate market prices***

In the absence of market prices surrogate price methods can be used. These methods value a mangrove related good using the price of a marketed substitute, or the value of the resources used to produce the mangrove related good or its substitute. Of these methods, the *substitute price method* is the most direct and widest applied. It values a mangrove ecosystem related good by the price of a marketed substitute. In the absence of such a marketed substitute, two other methods could be used. The *indirect substitute price approach* values a mangrove related good by the opportunity costs of using a particular good as a substitute for a mangrove related good instead of for its original purpose. Another approach is to value a mangrove related good by the opportunity costs of the inputs used to produce or collect it. This is known as the *indirect opportunity costs approach*. Several authors warn that the last two methods should be used with care.

### *Travel cost method*[10]

The Travel Cost Method (TCM) has been used extensively to value the recreational services of natural areas. In the absence of an admission fee the costs incurred in travelling to a site (including the opportunity cost of the time spent travelling) can be seen as an indication of the WTP for a visit to a site. Using data on travelling costs and number of trips taken to an area, a demand curve can be derived giving number of trips taken as a function of travelling costs which can be used to value the recreational services of the area.

### *Averting behaviour/defensive expenditures*

When using this method the value of some service provided by a mangrove ecosystem is measured by expenditures on goods and services that substitute for this service, or by expenditures on goods and services that mitigate against the effects of a loss of this function.

### *Hedonic prices method*

The basic idea behind the hedonic prices method (HPM) is that the price of a good is a function of its characteristics, including environmental characteristics. The HPM has been used mainly to analyse house prices. In these HPM studies, the price of a house is regressed on characteristics of the house itself (number of rooms etc.), neighbourhood characteristics and on some environmental characteristics such as air quality or noise levels. Differentiating this so-called hedonic price function with respect to the environmental characteristic of interest gives the marginal implicit price function, giving the value of a marginal change in the environmental characteristic of interest.[11]

### *Contingent valuation method*

The contingent valuation method (CVM) elicits an individual's WTP simply by direct questioning through a questionnaires. In the questionnaire a respondent is confronted with a well-defined, hypothetical change in the quantity and/or quality of an environmental good and then asked what he or she is willing to pay for this change. The great advantage of the CVM over the above methods is that it is the only method capable of estimating option and non-use values. The hypothetical nature of the CVM has led many to question the validity of its results. However, much research has been devoted to better understanding the validity and reliability of CVM, and strict guidelines have been developed for conducting proper CVM studies (see Arrow *et al*, 1993).

### *Production function approach*

[10] Both the travel cost method and averting behaviour are sometimes referred to as household production function methods. In the theory of the household production function (HPF), households are viewed as combining their time and marketed and non-marketed environmental goods and services to "produce" some good that then enters the utility function. Under certain assumptions regarding the complementarity and substitutability relationships between these marketed and non-marketed goods in the production of the good, an implicit demand curve for the non-marketed goods can be derived (see Smith, 1991). For example, in the case of the travel cost method, travelling time and transportation can be seen as a complement to a recreation site to produce a good "recreation"

[11] Under the restrictive assumption that all individuals have identical incomes and utility functions, the marginal implicit price function can be interpreted as an inverse (compensated) demand function for the environmental characteristic, and used to value non-marginal changes in this characteristic. When these assumptions are relaxed, valuing non-marginal changes using the hedonic price function becomes much more difficult (see Palmquist, 1991, or Freeman, 1993).

This production function approach (PFA) to valuing environmental functions is applicable whenever an environmental resource serves as an input in the production of some marketed good. The value of a change in the quantity and/or quality of the resource is equal to the value of the resulting change in production of the marketed good, as measured by the change in the consumers' and producers' surplus.

## Appendix 2 Some alternative calculations of the value of the nursery function

Paw and Chua (1991) have regressed municipal catches on mangrove area for several coastal provinces in the Philippines. Results are shown in Table A2.1. Since only mangrove area is included as the explanatory variable, while other production factors are excluded (notably, human effort), these equations cannot be considered a production function. However, as an alternative to the approach to valuing the nursery function taken in this study (see section 5, or Ong and Padilla, 1996), below some calculations based on these regressions are presented and compared the calculations by Ong and Padilla.

**Table A2.1 Regression values of municipal catch (metric tons) and corresponding mangrove area (hectares) from several coastal provinces in the Philippines.**

Model: $^{10}\log(\text{catch}) = a + b \times {}^{10}\log(\text{mangrove area})$

| Species group | a | b | n | r |
|---|---|---|---|---|
| Cavalla | 0.9896 | 0.8082 | 18 | 0.73** |
| Mullets | -0.4091 | 0.7361 | 20 | 0.63** |
| Siganids | 1.1462 | 0.9505 | 12 | 0.81** |
| Groupers | 1.1530 | 0.4734 | 18 | 0.63** |
| Snappers | 0.7972 | 0.5337 | 15 | 0.58* |
| White shrimp[1] | 1.2263 | 0.7623 | 18 | 0.81** |
| Total shrimp[2] | -0.0575 | 0.8706 | 18 | 0.78** |
| Total catch[3] | 2.5482 | 0.4304 | 34 | 0.63** |
| Total catch[4] | 1.8045 | 0.5948 | 39 | 0.67** |

** highly significant ($p<0.01$) * significant ($p<0.05$)

[1] Catch was predominantly Penaeus indicus (municipal and commercial)

[2] Catch included all shrimp species caught by municipal fisheries and penaeid commercial catch

[3] Data from SPOT inventory; did not include fishponds and low-density logged-over areas (SSC 1988).

[4] Data from SPOT inventory, included fishponds derived from mangrove conversion (SSC 1988).

Note: Species group catch represented the maximum catch for any one-year period from 1976 to 1977 while total catch represented the average catch for nine years from 1976 to 1984. Data are from BFAR (1976), (1984) and (1986). Data on mangrove areas are from Gomez (1980b).

Source: Paw and Chua (1991), Table 5.

Two approaches could be taken to calculate the effect of a loss of mangrove area using the equations in Table 5. The first would be to estimate catches under the current and the projected area of mangroves using these equations and to calculate the difference. The second makes use of the fact that because of the log-log specification of the equation, the b coefficient gives the elasticity of catches with regard to changes in mangrove area. Thus: percentage change in catches = b $\times$ percentage change in mangrove area. The disadvantage of the second approach is that to translate percentage changes in catch into changes in absolute numbers data on the current catches are required. Only some aggregate data are available for a single month in 1992 (Fortes, 1993). These are presented in Table A2.2 and will be used to illustrate the approach.

**Table A2.2 Total fishery catch of the 8 motorised fishing boats in Pagbilao Bay for one month (23 July to 22 August, 1992)**

| | volume of catch (kg) | % total catch |
|---|---|---|
| Fish | 2,716 | 20.2 |
| Invertebrates (crabs, shrimps, mollusks) | 10,724 | 79.8 |
| Total | 13,440 | |

Source: Fortes (1993), Table 14.

As the estimates of the b coefficients in Table A2.1 show, the elasticity of catches with respect to mangrove area varies considerably over the species groups: from a 0.95% decrease in catches for siganids, to an 0.47% decrease in catches for groupers for a 1 percent decrease in mangrove area. This illustrates the species specificity of mangrove dependence. Therefore, ideally one would want to estimate changes in catches per species group. The aggregated data in Table A2.2 do not allow this. Therefore, the estimate of the elasticity of total catch (0.43) was used to illustrate the approach for one of the management alternatives that was considered in the project. This alternative (combined aquaculture and forestry) would result in a 46 percent decrease in mangrove area. This would result in a $46 \times 0.43 = 19.8$ percent decrease in catches, or a decrease of 2,661 kg per month using the estimate for total catch of 13,440 per month from Table A2.2. This monthly loss is equivalent to a yearly loss of 31,933 kg.

Total catch includes fish and shrimp. An estimate for the lost catch of fish separately can be obtained by calculating an average elasticity from the estimates of the b coefficients for the fish species groups in Table A2.2. The unweighted average of the elasticity for these groups is 0.70. Using the estimate of fish catch of 2,716 kg per month, a 46 percent decrease in mangrove area would then result in an annual loss of 10,495 kg. A better estimate could be obtained by calculating a weighted average elasticity, using as weights the ratio of the catch of a species group to the total catch. Unfortunately, estimates of the elasticity are only available for three of the nine fish species groups thought to be the most important in Pagbilao Bay from Paw and Chua's analysis, namely mullet, groupers and snappers. These are also all mangrove transients whereas the mangrove resident species are probably more important for the total catch in Pagbilao Bay. Therefore, the above estimates of catch loss are probably not adequate for the Pagbilao Bay site.

However, it might be interesting to compare these estimates with that calculated using the other approach. The projected catch calculated by Ong and Padilla (1996) are 167,877 and 41,789 kg for the preservation alternative and the alternative resulting in a 46 percent reduction in mangrove area, respectively. This is equivalent to a 75% loss, compared to the 45% loss calculated above. In absolute terms, the loss calculated by Ong and Padilla is 12 times as large: 126,087 kg versus 10,495 kg calculated above.

What could explain these huge differences? First of all, the calculations using the regressions are based on the catch as reported by Fortes for one month in 1992. Since then the catch might have increased. Further, simple multiplication by 12 was used in order to obtain the annual catch; this may have resulted in underestimation if the particular month used for the calculations was not representative of the average monthly catch. Secondly, in their calculations Ong and Padilla had to assume an exploitation rate. The assumption of a 50% exploitation rate might have been to high. Thirdly, most of the species groups included in Paw and Chua's calculations are mangrove transients whose dependence on mangrove ecosystems is not as strong as for mangrove residents. In Pagbilao Bay, mangrove residents constitute the bulk of the catch thus resulting in a higher percentage loss. Fourth, Paw and Chua's regressions only include mangrove area. Their explanatory power is therefore limited since many more factors determine catch. At least human effort should have been taken into account. Fifth, their regressions relate to a larger geographical scale, namely catch per province. The extrapolation to a smaller scale such as Pagbilao Bay might not be warranted.

Many more possible reasons could be identified, but will not be pursued here since this would require a more detailed description of the assumptions made and the procedures followed by Ong and Padilla. The comparison of the two approaches illustrates how the application of simplified approaches to this very complex issue leads to completely different results. Without more detailed data and knowledge about the ecological and economic relationships involved, the estimation of damage to catch from mangrove conversion will probably remain rather arbitrary.

## Appendix 3 Literature review

In the CREED project "Economic Valuation of Mangrove-fishpond Interactions" a large number of publications were gathered which relate to mangrove management and valuation. An overview is provided in the following list, which is not all encompassing. A short remark is added to indicate the relevance of the publication.


Anderson, R. and M. Rockel (1991).
Economic Valuation of Wetlands. Discussion Paper 065. American Petroleum Institute, Washington, DC.
* Overview and (rather extensive) discussion of various US wetland valuation studies.

Baines, G.B.K. (1979).
Mangroves for National Development: a Report on the Mangrove Resources of Fiji. Report to the Government of Fiji. Suva, Fiji.
* Uses the incomes or products and services approach to estimate the gross annual value of mangroves in Fiji. Referred to in Lal and Dixon (1990).

Bacongius, S.R. (1993).
Aquasilviculture Technology: Key to Mangrove Swamp Rehabilitation and Sustainable Coastal Zone Development in the Philippines. In Canopy International, vol.17, no.6.
* Aquasilviculture (fish/mangrove intercropping system) is described as multiple-use system that promotes a harmonious co-existence between fishery species and mangrove tree species in a semi-enclosed system while providing coastal protection and maintenance to the ecosystem. At the same time it is a compromise to solve conflicting interests between the forestry/fishery sectors and the local communities.

Barbier, E.B. (1989).
Economic Evaluation of Tropical Wetland Resources: Application in Central America. LEEC Working Paper. University College London, London.
* An application of tropical wetland valuation. Referred to in R.K. Turner (1992).

Barbier, E.B. (1989).
The Economic Value of Ecosystems: 1 Tropical Wetlands. LEEC Gatekeeper 89-02, London Environmental Economics Centre, London.
* Referred to in Barbier and Arntzen (1992) as a useful guide for the initial choice of valuation method for the different environmental functions of wetlands.

Barbier, E., W. Adams and K. Kimmage (1991).
Economic Valuation of Wetland Benefits: the Hadejia Jama'are Floodplain, Nigeria. LEEC Paper DP 91-02, London Environmental Economics Centre, London.

Barbier, E., J. Burgess, A. Markandya, J. Arntzen, A. Gilbert, O. Kuik and H. Verbruggen (1991).
Environmentally Sensitive Project Appraisal. LEEC Report No. 91-03, London Environmental Economics Centre, London.
* Discusses the use of economic methods to appraise environmentally sensitive projects. Includes a table from Barbier (1989) on the use of various valuation methods for different wetlands functions.

Barbier, E.B. (1993).

Sustainable Use of Wetlands. Valuing Tropical Wetland Benefits: Economic Methodologies and Applications. In The Geographical Journal, Vol.159, No.1, March 1993, p.22-32.
* Total economic values of wetlands, as well as the partial versus total valuation methodologies are explained. These are illustrated with case studies.

Batie, S.S. and J.R. Wilson (1978).
Economic Values Attributable to Virginia's Coastal Wetlands as Inputs in Oyster Production. Southern Journal of Agricultural Economics, vol. 10, pp. 111-118.
* The authors estimate the economic value of Virginia's coastal wetlands for oyster production. Their approach is discussed in Anderson and Rockel (1991).

Batie, S.S. and L. Shabman (1982).
Estimating the Economic Value of Wetlands: Principles, Methods and Limitations. Coastal Zone Management, vol. 10, pp. 255-278.
* Probably an overview and discussion of wetland valuation issues. Referred to in R.K. Turner (1992).

Batie, S.S. and C.C. Mabbs-Zeno (1985).
Opportunity Costs of Preserving Coastal Wetlands: a Case Study of a Recreational Housing Development. Land Economics, vol. 61, pp. 1-9.
* The authors compute the opportunity cost of not developing a specific wetland in Virginia by using a property value model. Their approach and results are discussed in Anderson and Rockel (1991).

Bell, F. (1989).
Application Of Wetland Valuation Theory To Florida Fisheries. Sea Grant Publication No. SGR-95. Florida State University, Tallahassee, Florida.
* Assesses the contribution of estuarine wetlands acreage in Florida to marine fisheries. The results are discussed in Anderson and Rockel (1991).

Bergstrom, J.C., J.R. Stoll, J.P. Titre and V.L. Wright (1990).
Economic Value Of Wetlands-based Recreation. Ecological Economics, vol. 2, pp. 129-147.
* The authors quantify the outdoor recreational value of Louisiana coastal wetlands. The gross economic value (consumer's surplus plus expenditures) per ha is $110.

Bertelsen, M.K. and L.A. Shabmanh (1979).
The Use Of Development Value Estimates For Coastal Wetland Permit Decisions. Land Economics, vol. 55, pp. 214-223.
* The authors provide a model to measure the foregone opportunity cost of the residential development of wetlands. The results are discussed in Anderson and Rockel (1991).

Bojö, J., Mäler, K.-G., and L. Umeno (1990).
Environment and Development: An Economic Approach. Stockholm School of Economics, Sweden. Kluwer Academic Publishers, Dordrecht, Boston, London.
* The book aims to discuss the causes of environmental degradation from an economic perspective, to create an informational framework to enhance environmental decision-making, to create an overview of valuation methods, and to give examples of applications of the theoretical methods described.

Bowers, J.K. (1983).
Cost-Benefit Analysis Of Wetland Drainage. Environment and Planning, vol. 15.

* Probably an overview article. Referred to in R.K. Turner (1992) in Table 1.2 on page 18.

Brown, W.H. and A.F. Fischer (1918).
Philippine Mangrove Swamps. Department of Agriculture and Natural Resources, Bulletin No.17.
* State of the art of mangroves in the beginning of this century.

Brown, G.M. and H.O. Pollakowski (1977).
Economic Valuation Of Shoreline. Review of Economics and Statistics, vol. 59, pp. 272-278.
* Type of benefits measured: foregone development output value. Referred to in R.K. Turner (1992) in Table 1.2 on page 18.

Burgess, J.C. (1993).
Timber production, Timber Trade And Tropical Deforestation. In Ambio Vol.22, No.2-3, May 1993.
* The author explains how the impact of international trade in timber on deforestation is highly overrated. Other factors, in particular conversion of forest land for agricultural use and harvesting of trees and fuelwood, are considered to be much more important in the process of tropical deforestation. Could be interesting to compare with mangrove forest.

Cabahung, D.M. (1987).
Community-based Small-scale Utilization And Management Of Mangroves Areas In the Philippines. National Mangrove Research Program. Laguna, Philippines.
* Two studies of government agencies are summarized: 1. Central Visayas Regional Project Office and 2. Philippine National Mangrove Committee.

Christensen, B. (1982).
Management and Utilization Of Mangroves in Asia and the Pacific. FAO Environment Paper No. 3. FAO, Rome.
* A study on the value of mangroves in Thailand. Referred to in Lal and Dixon (1990).

Christensen, B. (1983).
Mangroves - What Are They Worth? Unasylvia, No.35.
* A qualitative overview of the various functions of mangroves.

Clough, B.F. (eds) (1993).
The Economic And Environmental Values Of Mangrove Forests And Their Present State Of Conservation In the South-East Asia/Pacific Region. Mangrove ecosystem technical reports, Volume 1, October 1993.
* This voluminous assessment aims to provide a more up-to-date and quantitative evaluation of the status, use and value of mangrove ecosystems in Indonesia, Malaysia, and Thailand (also Fiji). It is based primarily on information provided by each of these countries in their Country Reports. Finally, a mangrove resource information database is developed.

Common, M.S. and T.W. Norton (1994).
Biodiversity, Natural Resource Accounting and Ecological Monitoring. In Environment and Resource Economics, Vol.4, No.1, February 1994, p.29-53.
* The availability of biologically-adjusted national income figures will not, for itself, contribute significantly to the protection of biological resources. Therefore, ecological monitoring should take priority over the generation of economic data.

Constanza, R. and S. Farber (1985).
Theories And Methods Of Valuation Of Natural Systems: A Comparison Of Willingness-To-Pay And Energy Based Approaches. Man, Environment, Space and Time, vol. 4, pp. 1-38.
* Probably the same kind of article as Farber and Constanza (1987) but with more emphasis on theory. Referred to in Constanze et al. (1989).

Constanza, R. and S. Farber (1986).
The Economic Value Of Coastal Wetlands In Louisiana. Louisiana State University, Baton Rouge, Louisiana. See title.
* Probably they use the same data-set as in Farber and Constanza (1987).

Constanza, R., S. Farber and J. Maxwell (1989).
Valuation and Management Of Wetland Ecosystems. Ecological Economics, vol. 1, pp. 335-361.
* Their estimate of the total present value of an average acre of natural wetlands in Louisiana is $2429-6400 per acre (assuming an 8% discount rate).

Dixon, J.A. (1989).
Valuation of Mangroves. In Tropical Coastal Area Management. Vol.4, No.3, Metro Manila, December 1989, p.1-6.
* Many mangroves yield greater social net benefits as natural ecosystems. In cases where conversion is clearly necessary or justified, sound physical-social-economic analysis can help to plan conversions that reduce to a minimum loss of mangroves forest benefits.

Dixon, J.A. and P.N. Lal (1994).
The Management Of Coastal Wetlands: Economic Analysis Of Combined Ecological-Economic Systems. From The Environment and Emerging Development Issues, Partha Dasgupta and Karl-Goran Maler, Oxford: Clarendon Press.
* very comprehensive overview study in which methodologies are discussed as well as several case studies on mangrove. An interesting conclusion is that because of market failure in mangrove exploitation, government intervention is essential to create a social optimum.

Durante, L. (1992).
Malaysia's `Sleeping Giant' Could Wake Up on the Wrong Side. Bay of Bengal News (BOBP), Issue No. 48, December 1992, p.19-21.
* Malaysia's commitment to develop shrimp aquaculture is criticised. Oversupply of shrimp on the Asian market and loss of the marketed and nonmarketed functions of mangroves are the main threat of shrimp aquaculture.

Farber, S. (1987).
The Value Of Coastal Wetlands For Protection Of Property Against Hurricane Wind Damage. Journal of Environmental Economics and Management, vol. 14, pp. 143-151.
* Placing a value on wetlands for their role in reducing wind damage to property because of diminished storm intensities. Results are discussed in Anderson and Rockel (1991).

FAO (Food and Agricultural Organization of the United Nations) (1992).
Mangrove For Charcoal; A Vanishing Sustainable Woodfuel Resource System (the case of Yeesarn, Upper Gulf of Thailand), Bangkok. GCP/RAS/131NET Field Document No.30.

Farber, S. and R. Constanza (1987).
The Economic Value Of Wetlands Systems. Journal of Environmental Management, vol. 24, pp. 41-51.

* Applies energy analysis and CVM to the wetlands systems of South Louisiana. Results are discussed in Anderson and Rockel (1991).

Farber, S. (1988).
The Value Of Coastal Wetlands For Recreation: An Application Of Travel Costs And Contingent Valuation Methodologies. Journal of Environmental Management, vol. 26, pp. 299-312.
* The study reports on a survey of Louisiana coastal wetlands recreational users administrated for the purpose of estimating wetlands recreational value. Depending on the time cost value, the average capitalised value ranged from $36 to $111 per acre.

Finney, C.E. and S. Western (1986).
An Economic Analysis Of Environmental Protection And Management: An Example From The Philippines. The Environmentalist, vol.6, pp. 45-61.
* See title.

Fiselier, J.L. (1991).
Living of The Tides: Strategies For The Integration Of Conservation And Sustainable Resource Utilization Along Mangrove Coasts. A report of the environmental database on wetlands interventions, Leiden.
* Referred to in Barbier and Arntzen (1992).

Fisher, A.C., M. Hanemann, J.Harte, A. Horne, G. Ellis and D. von Hippel (1986).
Economic Valuation Of Aquatic Ecosystems. Final Report to the U.S.E.P.A., Cooperative Agreement No. 811847, Washington, DC.
* These authors use the empirical results of Lynne et al. (1981) to arrive at a theoretically correct measure of welfare to value the contribution of marsh inputs to the production of Florida Gulf Coast blue crabs.

Folke, C. and N. Kautsky (1992).
Aquaculture With Its Environment: Prospects For Sustainability. Beijer Reprint Series No.5. Stockholm, Sweden.
* The characteristics of one-species aquaculture are compared with those from the Chinese integrated systems. The authors conclude that the more a cultivation system recognises and mimics natural ecosystem functions the less resource inputs are required and the less environmental effects can be expected. A successful aquaculture system does not have wastes, only by-products, to be used as positive contributors to the surrounding ecosystems and the economy.

Fortes, M.C. (1991).
Seagrass-Mangrove Ecosystems Management: A Key To Marine Coastal Conservation in the ASEAN Region. In: Marine Pollution Bulletin, Vol.23, pp.113-116, 1991.

Foster, J.H. (1978).
Measuring the Social Value Of Wetland Benefits. In: Wetland Functions And Values; The State Of Our Understanding. America Water Association.
* Unclear. Probably an overview article.

Gammage, S. (1994).
Estimating The Total Economic Value Of A Mangrove Ecosystem In El Salvador. Report to the Overseas Development Administration of the British Government.

* The purpose of this project is to estimate the “total economic value” of a mangrove ecosystem in the Gulf of Fonseca, El Salvador, and to develop a cost-benefit framework to compare sustainable management of the forest with alternative use scenarios. A variety of different valuation techniques are used to assess the contribution of different products and services of the mangrove ecosystem.

Giesen, W. (1993).
Indonesia's Mangroves: An Update On Remaining Area & Main Management Issues. Asian Wetland Bureau, Presented at the International Seminar on "Coastal Zone Management of Small Island Ecosystems", Ambon 7-10 April 1993.
* Wastelands are created as a result of failure in the development of mangroves. Lack of forestry regulations, unclear land allocation procedures and administration, and lack of viability assessment prior to fishpond development, underlie these failed conversion attempts.

Gren, I.-M., C. Folke, K. Turner and I. Batemen (1994).
Primary and Secondary Values Of Wetland Ecosystems. In Environment and Resource Economics, Vol.4, No.1, February 1994, p.55-74.
* In an attempts to improve the understanding of the importance of the multi-functionality of the mangrove forest, an alternative classification of values is suggested: primary values refer to the development and maintenance of the ecosystem, secondary values to the outputs, life-support functions and services, generated by the wetland.

Gren, I.-M. and T. Soderqvist (1994).
Economic Valuation of Wetlands: a Survey. Beijer Discussion Paper Series No. 54.
* This brief survey of wetland studies reveals that a variety of methods have been used to study different environmental services. The most common wetland services to be valued are recreation and input resources. This is valid for all regions. Estimation of recreational valus has been most common in US wetland valuation studies, and input resources have been frequently valued in Asia and in Europe. Several European studies have also included the valuation of wetlands as sinks of pollutants.

Groombridge, B. (eds.) (199?).
Global Biodiversity: Status of the Earth's Living Resources. World Conservation Monitoring Centre.Chapman & Hall, London.
* Biodiversity is valued; also pharmaceutical value is mentioned.

Hamilton, L.S. and S.C. Snedaker (eds) (1984).
Handbook for Mangrove Area Management, writing team of the UNESCO, IUCNNR, and EPIEWC.
* This handbook summarises the most up-to-date information on the range of products, benefits, and services provided by the world's mangrove resources. Guidelines are provided throughout the handbook for sustainable, multiple-use management of mangrove ecosystem.

Hamilton, L.S., J.A. Dixon and G.O. Miller (1989).
Mangrove Forests: An Undervalued Resource of the Land and of the Sea. In Ocean Yearbook 8, E. Borgese, N. Ginsburg, and J.R. Morgan (eds.), The University of Chicago Press, Chicago and London.
* Mangroves yield greater social net benefits as natural ecosystems, etc.

Hirsch, D. and A. Mauser (1992).

The Economic Value Of Mangroves. Two Case Studies: Mida Creek and Funzi Bay. Report from a twinning project between the School of Environmental Studies, Eldoret, and the University of Amsterdam.
* The authors report on two sites with different types of mangrove management. Economic characteristics are given on these two sites. Tourism is highlighted as a potential future threat.

Hodgon, G. and J.A. Dixon (1988).
Logging versus Tourism in Palawan: an Environmental and Economic Analysis. East-West Environment and Policy Institute, Honolulu.
* The authors demonstrate that, for the Philippines, tourism benefits coupled with fishery production benefits substantially outweigh the short-term benefits which might accrue from increased logging in Palawan.

Hyde, W.F., R. Mendelsohn and R.A. Sedjo (1991).
Applied Economics of Tropical Deforestation. In AERE Newsletter, Vol.11, No.1., May 1991.
* This paper argues for three policy responses that would decrease the rate of global deforestation: 1. permit temporally more reliable timber concessions, 2. encourage multi-product forest management and secure long-term property rights for local indigenous and immigrant populations, 3. remove deleterious spillovers on the forest from macroeconomic policies and policies designed to develop other sectors.

James, R.F. (1991a).
Wetland Valuation; Guidelines and Techniques. PHPA/AWB Sumatra Wetland Project Report No.31, Asian Wetland Bureau - Indonesia, Bogor.
* The document is a guide for wetland valuation. A number of key issues of concern are discussed, many of practical value.

James, R.F. (1991b).
The Valuation of Wetlands: Approaches, Methods and Issues. PHPA/AWB Sumatra Wetland Project Report No. 29, Asian Wetland Bureau - Indonesia, Bogor.
* This report examines approaches and methods for use in the valuation of wetlands. It focuses primarily on the theoretical issues and aspects of valuation of the benefits and costs associated with wetlands. Relevant economic quantification techniques are identified and guidance provided regarding their application.

Jagtap, T.G., V.S. Chavan and A.G. Untawale (1993).
Mangrove Ecosystems of India: a Need for Protection. In: Ambio Vol.22, No.4, June 1993. p.252-254.
* see title. Estimates of mangrove aquaculture have reported the production of fish and prawns to be 23,000 kg/ha/year.

Janssen, R. (1991).
Multi-objective Decision Support for Environmental Problems. Institute for Environmental Studies, Free University, Amsterdam.
* The aim of this dissertation is to develop an instrument that makes complex environmental problems manageable by coupling the intellectual resources of individuals with the capabilities of the computer. Thereby, the complexity of the environment, the time scale and the diversity of environmental effects can be coped with. The MODSS provides assistance in interpreting and communicating results and in using the results to invent new ideas and creative solutions.

Janssen, R. and M van Herwijnen (1994).
Definite: A System to Support Decisions on a Finite Set of Alternatives, User Manual. Institute for Environmental Studies, Free University, Amsterdam. Kluwer Academic Press, Dordrecht, Boston, London.
* A computer program for analysing and valuing environmental problems. CBA and MCA, as well as sensitivity analysis on discount rate and time horizon, can be executed.

Kapetsky, J.M. (1985)
Mangroves, Fisheries, and Aquaculture. Advisory Committee on Marine Resources Information Paper No.13. 11th session, 21-24 May 1985, Rome.
* World-wide figures are given on average productivity of fisheries. Based on the fact that intensive aquaculture requires less (mangrove) space than extensive aquaculture, the former is promoted. The need for technical assistance is recognised.

Kuik, O.J., F.H. Oosterhuis, H.M.A. Jansen, K. Holm and H.J. Ewers (1992).
Assessment of Benefits of Environmental Measures. European Communities Environmental Measures, Graham & Trotman, London.

Lal, P.N. (1990).
Conservation or Conversion of Mangroves in Fiji. Occasional Papers of the East-West Environment and Policy Institute, paper No. 11.
* A CBA is used for answering the questions: under what circumstances should mangroves be maintained for *in situ* uses, such as dependent fisheries and forestry uses. With a 50 year planning horizon, the net benefits of "on-site" mangrove resources is US$200 and the "off-site" value is US$2,700.

Lal, P.N. and J.A. Dixon (1990).
The Management of Coastal Wetlands: Economic Analysis of Combined Ecologic-Economic Systems. 23-8-90
* see Dixon and Lal

Lal, P.N. (1991)
Mangrove Management Issues: Strategies Adopted in the Pacific Islands. Islands/Australia Working Papers No. 91/3. National Centre for Development Studies, The Australian National University, Canberra, Australia.
* The mangrove management of three Pacific countries (Fiji, Vanuatu and Korsae) is studied: In Fiji and Vanuatu management is less successful because of the neglect of cross-sectoral effects. The necessity for an integrated approach involving land, forestry, and fisheries sectors, proved to present in Korsae. A more macro-environmental standard approach is followed.

Larsson, J., Folke, C. and Kautsky, N. (1993)
Ecological Limitations and Appropriation of Ecosystem Support by Shrimp Farming in Colombia. Beijer Discussion Paper Series, No.29.
* Study on semi-intensive shrimp culture as practised on the Caribbean coast of Colombia. Results: the semi-intensive shrimp farm needs a spatial ecosystem support-ecological footprint 35-190 times the surface area of the farm. This indicates that shrimp farming ranks as one of the most resource-intensive food production systems, characterising it as an ecologically unsustainable throughput system.

Lesaca, R.M. (1972)
Coastal Aquaculture and Environment in the Philippines. IDFC proceedings 15th session, October 1972.
* The impact of industrial pollution of the major rivers on coastal aquaculture is described. Diminished availability of milkfish fry, abandonment of fish pond areas, damage to oyster beds and the increased parasitic infections transmitted to man from infected shell-fish are stressed.

Ong, J.E. (1982)
Mangroves and Aquaculture in Malaysia. In Ambio Vol.11, No.5, p.252-257.
* Stresses the socio-economic and environmental value of mangroves and the related fisheries versus forestry. Author states that ecological impact is not considered sufficiently in the selection of aquaculture sites.

Opschoor, J.B. (1987)
Monetary Valuation of Environmental Changes: a Review of Dutch Case Studies and Proposals for Methodological Research, Conference on Env. Pol. in a Market Economy, 8-11 September 1987, Wageningen.
* User and non-user values, and completeness and comprehensiveness are defined.

Parks, P. and Bonifaz, M. (1994)
Nonsustainable Use of Renewable Resources: Mangrove Deforestation and Mariculture in Ecuador. In Marine Resource Economics, Volume 9, p.1-18.
* The paper provides a conceptual model that examines (i) open access exploitation and (ii) mangrove deforestation as two potential causes for the scarcity of post-larval shrimp inputs to shrimp mariculture in Ecuador. Results indicate that conversion of mangrove ecosystems to shrimp ponds may have obtained short-term profit at the expense of long-term productivity. Open-access collection of post-larval shrimp may also have contributed to dwindling stock levels. Specific policy recommendations are presented, and future empirical studies are proposed.

Perrings, C., Folke, C. and Maler, K.-G. (1992)
The Ecology and Economics of Biodiversity Loss: the Research Agenda. In Ambio Vol.21, No.3, May 1992.
* Identifies four issues: 1. consequences of change in biological diversity, 2. economic valuation of ecological services, 3. the driving forces behind the biodiversity loss, 4. the scope of changing human behaviour. The nature of the linkage between ecological and economic systems is discussed in the context of informational, institutional, ethical and cultural conditions. The interdisciplinary approach is emphasised.

Pendleton, L.H. (1993)
Adding it All Up: The Economic Valuation of a Tropical Marine Park, Harvard Institute for International Development, Cambridge.
* This case demonstrates the incorporation of environmental valuation techniques into the project appraisal process.

Primavera, J.H. (1992)
Prawn/Shrimp Culture Industry in the Philippines, In: Fast, A.W., Lester, L.J. (eds.), Marine Shrimp Culture; Principles and Practices, Chapter 34, pp. 701-728

Populus, J. and Lantieri, D. (1991)
Use of High Resolution Satellite Data for Coastal Fisheries: 1 - Pilot study in the Philippines, and 2 - General review. Remote Sensing Centre of the FAO RSC Series No. 58. Rome.
* The crucial lack of baseline information about the physiographic environment prevents efficient management. This study shows how this information can be obtained.

Quarto, A. (1993)
Life and Death in the Mangrove. Mangrove Action Project. In ??. p.18-20
* The author discusses the impact that commercial prawn farming is having on the world's mangrove forest.

Ruitenbeek, H.J. (1992).
Mangrove Management: an Economic Analysis of Management Options with a Focus on Bintuni Bay, Irian Jaya. Environmental Management Development in Indonesia Project (EMDI) Environmental Reports, 8. (ISSN 1181-6457;8) Jakarta and Halifax.
* Forest management options, ranging from clear cutting to a cutting ban, are evaluated in a CBA incorporating environmental and economic linkages.

Thorhaug, A. (1986)
Restoration of Mangroves and Seagrasses and Attendant Economic Benefits for Fisheries and Mariculture: Management, Policy and Planning. FAO\IDFC Thailand, June 1986.
* This paper seeks to review mangrove and seagrass restoration as a means to benefit fisheries and aquaculture, both ecologically and economically. Both ecosystems function as accumulators of fish as well as providing surfaces for the growth of epizonts which are also grazed by fish.

Turner, R.K. (1992)
Policy Failures in Managing Wetlands. In Market and Government Failures in Environmental Management. OECD, Paris.
* Social inefficiency exists in the management of mangroves. Several failures are identified: 1. Natural land use conflicts, 2. information failures, 3. market failures, intervention failures. Sustainable wetland management will have to be based on data indicating the value of different classes of wetland. Different "wetland contexts" should be recognised.

Umali, R., P.M. Zamora, R.R. Gotera, R. Jara, A.S. Camacho and M. Vannuci (eds.) (1987).
Mangroves of Asia and the Pacific: Status and Management. Technical report of the UNDP/UNESCO research and training pilot programme on mangrove ecosystems in Asia nad the Pacific. Manila: Natural Resources Management Center and National Mangrove Committee, Ministry of Natural Resources.
* Proceedings of a congress on mangrove management. Seems extremely useful given the various references made to this book.

Villacorta, L. and Wetten, van J.C.J. (1992)
Wise Use and Restoration of Mangrove and Marine Resources in the Central Visayas. Regional Project, Philippines. IESAM, Philippines, and CML, Leiden, the Netherlands. 18-2-1992
* A state of the art of mangrove and aquaculture. "Tragedy of the commons" of the local populations is described. Wise Use, the project, aims at identifying the objectives of the various actors involved in resource management. These targets exist on several levels: actual users, legislative, governmental and society levels.

Zamora, P.M. (1988)

Impact of Fishpondification on the Mangrove Ecosystem of the Philippines. Paper read during the BIOTROP Tropical Forest Biology Program Symposium on Mangrove Management: Its Ecological and Economic Considerations, 9-11 August 1988, Bogor, Indonesia.
* State of the art of fishpondification in the Philippines. Both ecological and economic data. Also distinction in efficiency is made between type of ownership (government versus private). Measures are proposed (prohibition of conversion within mangrove swamp, banning of timber cutting in mangroves, if unproductive fishponds should be returned into mangroves).

Zamora, P.M. (1990)
Ecosystems of the Philippines, Proceedings of Symposium on Mangrove Management: State of the Art of Species in the Philippines.