FINAL REPORT

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Mangroves or Fishponds? Valuation and Evaluation of Alternative Uses of a Mangrove Forest in the Philippines

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PREFACE

This report is divided in two sections. Section 1 includes three contributions that summarize and integrate the results. Section 2 includes technical documents that provide all data used to produce these results. The report includes the following contributions:

Section 1. Summary of results

1. Valuation and evaluation of management alternatives for the Pagbilao mangrove forest by Ron Janssen and Jose E Padilla.
2. The use of environmental functions to evaluate management strategies for the Pagbilao mangrove forest by Alison J.Gilbert and Ron Janssen.
3. Economic valuation of mangroves: a review of techniques and case studies with special attention to the production function approach by Frank Spaninks and Pieter van Beukering.

Section 2 Technical documents

4. Assessment of forest resources of the Pagbilao mangrove forest by Antonio P. Carandang and Jose E. Padilla
5. Assessment of fisheries-related functions of the Pagbilao experimental mangrove forest by Perry S. Ong and Jose E. Padilla.
6. Assessment of milkfish and prawn culture in brackish water ponds by Jose E. Padilla and Michael A. Tanael.

PART ONE
SUMMARY OF RESULTS

1. VALUATION AND EVALUATION OF MANAGEMENT ALTERNATIVES FOR THE PAGBILAO MANGROVE FOREST

Ron Janssen and Jose E. Padilla

1.1. Introduction

Mangrove forests can be found in the brackish water margin between land and sea in tropical and subtropical areas. Mangroves are part of rich ecosystems providing a variety of economic and environmental functions and products. In traditional subsistence economies, the exploitation of mangrove resources is usually not intensive and settlement is quite sparse. In South East Asia this was attributed to the scarcity of freshwater for domestic use and the unsuitability of mangrove soils for long-term agricultural exploitation. However, in recent years, exploitation and settlement of mangrove forests have intensified, as traditional economies become increasingly market-integrated and modernised. The building of access roads, provision of amenities in these areas, and the improvements in technology have provided the impetus. The transition in utilisation of mangrove forests described above is observed in the Philippines. Through the years, mangroves in the Philippines were reduced from approximate 288,035 ha. in 1970 to 123,400 ha. in 1993.

One of the major threats to mangroves in the Philippines is the rapidly increasing aquaculture industry. In 1993 261,402 ha of mangrove area were used for brackish water fishponds (Table 1.1). Although in the Philippines a moratorium is placed on harvesting of mangroves for timber, the process of conversion is still taking place. To understand the importance of mangroves insight into the total economic value of mangroves is important. Comparisons can be made with the total value generated by alternative uses such as aquaculture and forestry. Several studies in which the environmental functions of mangroves have been analysed and valued indicate the necessity to internalise these externalities in environmental management (Opschoor 1987, Ruitenbeek 1992, Barbier 1991, Dixon and Lal 1994, Gren et al. 1994).

Besides estimating the total value of mangrove forests, it is important to focus on the decision makers who will decide on the management of mangrove forests. Such decision makers exist at different levels, ranging from the local level, for example the fishpond owner, to the international level, for example the Global Environmental Facility. Each decision maker has specific objectives which are not always included in the economic values of the management alternatives. Such objectives can be improvement of local employment and income and other equity objectives and the conservation of intrinsic qualities of the environment (sustainability objectives).

The objective of this chapter is to demonstrate the use of results from valuation to support evaluation of management alternatives for the Pagbilao mangrove forest.

Table 1.1. Area of mangroves and brackish water fishponds (ha).

year	mangroves	brackish water fishponds
1970	288,035	168,118
1971	286,650	171,446
1972	284,211	174,101
1973	258,895	176,184
1974	256,156	176,032
1975	254,016	176,032
1976	251,577	176,231
1977	249,138	176,231
1978	246,699	176,231
1979	245,000	176,231
1980	241,801	176,231
1981	239,382	195,832
1982	239,382	195,832
1983	234,504	196,269
1984	232,065	206,525
1985	226,673	205,001
1986	221,280	210,319
1987	143,522	210,458
1988	139,100	210,681
1989	135,700	210,681
1990	132,500	210,681
1991	129,200	225,002
1992	126,300	239,323
1993	123,400	261,402

Source: Forest management bureau, Bureau of fisheries and aquatic resources.

The structure of the chapter is as follows: the study site is introduced in the next section. Section 1.3 includes the management alternatives for the Pagbilao mangrove forest. Values of the goods and services linked to these management alternatives are presented in Section 1.4. The decision problem is formulated in section 1.5. In Section 1.6 and 1.7 the information collected is used to support the selection of the preferred management alternative. Section 1.6 uses the results of valuation in cost-benefit analysis. In Section 1.7 results from valuation are combined with other types of information in a multi-criteria approach. Conclusions and recommendations can be found in Section 1.8.

1.2. The Pagbilao experimental mangrove forest

The municipality of Pagbilao is situated in the foothills of Mount Banahaw in the southern part of Quezon Province in Luzon Island. It is bounded on the north-west by the municipality of Tayabas, north-east by Atimonan, south-east by Padre Burgos and south-west by the City of Lucena (Figure 1.1). It has a total land area of 15,820 ha. covering 27 barangays[1] of which 21 are rural and the other 6 are urban. Pagbilao has 9 coastal barangays of which 6 are fringed with mangroves. Pagbilao has a volcanic terrain with slope of up to 15%.

The population of Pagbilao stood at 41,635 in 1990 (National Statistics Office) with an annual growth rate of 2.77% from 1980-1990. Total number of households in 8,450. It is estimated that by the year 2000 municipal population and the number of households will reach 56,730 and 11,818, respectively. Over 50% of the population of Pagbilao is in the working age group and about 97% is literate. Half of Pagbilao's population depends on agriculture for livelihood as 77% of its land area is devoted to it. Coconut and palay are the dominant crops with 65% and 12% of the total land area planted with these crops, respectively. Copra is the top agricultural product in Pagbilao. Coffee, corn, bananas, root crops, citrus fruits and vegetables are also grown. Agro-livestock and cottage industry also provide considerable employment. Pagbilao is a fourth class municipality[2] in terms of municipal income. As such income is derived from municipal taxes which, in turn is a function of the income of households and business establishments, it can inferred that the municipality is relatively poor. Information of the average household income is not available but observations on the type of dwellings in the coastal villages show that these are similar to the rest of the Philippines. Poverty is quite pervasive and there is large emigration in search for more stable sources of income. Education is pursued as it may be the key to finding employment elsewhere.

Pagbilao has a total of 1,440 ha of forest lands scattered in several barangays. The northern and western sides are parts of the Quezon National Forest Park with 983 ha of old-growth tropical dipterocarp forest. Surrounded by mangrove forest and coral reefs, Pagbilao Bay is one of the richest natural marine areas in Southern Luzon. There are about 2,048 fishermen with 247 motorised and 282 non-motorised bancas. There are 56 fishpond operators covering 1,146 has. The collection of tropical aquarium fishes is an important alternative to capture fishing. This activity involves about 300 collectors.

Coral reef diversity is average with 33 genera recorded. There are 60 species belonging to 18 families of coral reef fishes. With live coral cover ranging from only 27% - 73%, the

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1 The barangay is the smallest political unit in the Philippines.

2 Municipalities are classified based on the following income ranges during the last three years (1990-1992): First class (P15 million or more), second class (P10 M or more but less than P15 M), third class (P7 M or more but less than P10 M), fourth class (P4 M or more but less than P7 M), fifth class (P2 M or more but less than P4 M) and sixth class (below P2 M). (Source: Department of Finance Order No. 35-95).

coral resources are categorised poor to good. There are 10 species of seaweeds and 4 species of seagrasses but these resources are disturbed (Fortes 1993). In the mangroves, there are 128 fishes belonging to 54 families (Pinto 1987). Ambassis kopsi (Ambassidae) was the most abundant species. Gobies (Glossoqobius sp.), mullets (Mugil sp.), snappers (Lutjanus sp.), Milk fish (chanos), scads (Scathophagus sp.) and groupers (Serranids) were also found in the area. Crustaceans such as shrimps (Peneaus sp), macrobrachium sp. and crabs (Grapsidae) also dwell in the mangroves.

Some rare and endangered species can be found in the Quezon National Forest Park. Endangered species include the Rufous hornbill, the Philippine deer (Cervus rusa philippinensis) and the Philippine monkey (Table A1). Classified as rare birds are the Philippine forest kingfisher, spotted wood kingfisher and Luzon little crow. Rare mammals in the park include the Philippine rind rat. In the mangroves, shore birds are the most apparent wildlife species. There are 20 species observed in drained or disused fishponds and inter tidal areas at low tide. Common species include the wood sandpiper, red-necked stint, common sandpiper and wimbrel. Also observed in Tayabas Bay are herons, egrets and bitterns. Nankeen night herons breed in the seaward mangrove fringe and hunted by the local community. Cattle egrets can be found in the rice fields and some portions of the landward parts of the fishponds and coastal area. An endangered species, the Chinese egret was found foraging in the inter tidal areas of Pagbilao. Terns (Laridae) were also observed wherein the most common is the whiskered tern and an endemic duck, Philippine mallard. Bats are identified as locally important through the collection of guano (bat manure) as a source of income.

A recent estimate (Bina 1988) of remaining mangrove areas in the Philippines shows that of the original 400,000 - 500,000 hectares thought to have existed in 1918 (Brown and Fischer 1920), about 139,725 has. remain. The distribution of this area is as follows: 16% Luzon, 30% in Palawan, 27% in the Visayas and also 27% in Mindanao (excluding Sulu and Tawi-Tawi). The figure should be smaller now, considering the continued clearing of mangroves for aqua-culture and the decimation brought about by pollution. Of the remaining mangroves stands, only 10,000 hectares are old growth and the rest are mainly second growth. While around 68% of the denuded mangrove areas are now devoted to brackish water aquaculture (Zamora 1990), mangrove areas are not usually directly converted to fishponds. Conversion to fishponds follows construction of dikes in unproductive mangal areas. The latter results from unsustainable harvesting of mangrove forest resources. Table 1.1 suggests that most of the mangrove areas lost were converted to fishponds.

The original area of mangroves in Pagbilao is not known but can be deduced from the existing area of mangroves and brackish water fishponds. In 1984 the total area of Pagbilao mangrove forest is around 693 ha. Of this, 396 ha are within public forest lands while 297 ha are owned privately (RP-German FRI Project, 1987). Today, what remains of the public forest land is the experimental forest under the jurisdiction of the Department of Environment and Natural Resources. The legal basis of the experimental forest is

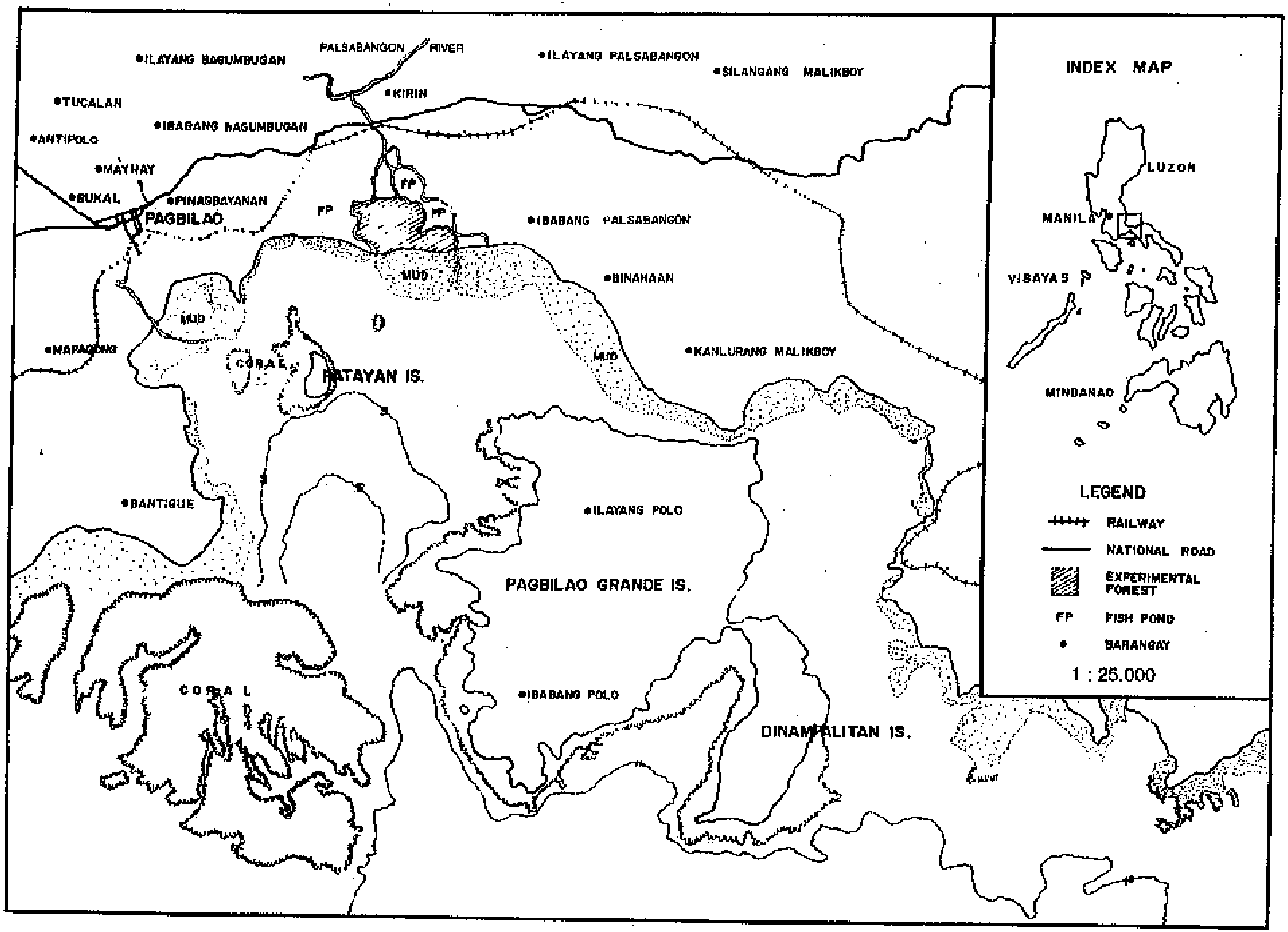

Figure 1.1. Map of the municipality of Pagbilao.

Presidential proclamations 2151 and 2152 which declared certain islands and/or parts of the country as wilderness areas in 1981. These laws withdrew from entry, sale, settlement and other forms of disposition a large portion of mangrove areas in the country. The primary purpose of these proclamations is to preserve whatever is left of the mangrove forest in the country for various reasons.

The second growth mangrove forest in Pagbilao was further designated as a Genetic Resource Area and National Training Centre for Mangroves. The specific objectives of a genetic resource area include: a) conservation of the genetic diversity of the mangrove ecosystem; b) demonstration of practical management for perpetuating mangrove species; c) establishment of sources of documented seeds and seedlings for mangrove reforestation; d) provision of livelihood and recreational amenities to communities and visitors; and e) serve as a laboratory for students, scientists, environmentalists, researchers, and other interested parties. Since its declaration, the mangrove area has generated scientific interest and has attracted numerous scientists, both local and foreign.

Forest Zones and Mangrove Tree Species

The experimental forest has three evident zones. The landward portion borders towards the ecotone[3]. Among the landward tree species are nilad, buta-buta, api-api, pi-api, tinduk-tindukan, etc. (Table A2). Except for api-api and pi-api, most species in this portion are small in diameter with plenty of thickets underneath. Vines such as bagnit and gatasan also abound. The middleward portion is the part immediately after the landward and constitute the central portion of the forest. This portion has big trees of api-api and pi-api together with busain, pototan, tangal, and malatangal. It has relatively clear underneath (forest floor) with vines such as bagnit and gatasan occurring sparsely. The seaward portion begins from the shore towards the middleward portion (Figure 1.2). Tree species in this portion are bakawan lalaki, bakawan babae, bagatpat, etc. Trees are stunted in this portion due to heavy exploitation in the past. Regeneration underneath is also observed. In the riverine portions, tabigi, pagatpat, nipa, lagolo, pedada, bagnit, and galivario (thorny vine) exist in association with the species as observed in the previously described zones wherever the riverine portion is located.

Compared to other mangrove areas in the Philippines, Pagbilao Bay has the highest number (19) of true mangrove species. This comprises 56% of the total true mangrove species. It also appears to be the most botanically diverse in terms of number of tree species, associates and variations in the nature of topography and substrate (NRMC 1980). The most important of the true mangrove families observed in Pagbilao are the Rhizophoraceae and Aviceniaceae where the bakawans and api-api species belong, respectively.

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[3] An ecotone is a transition area between two adjacent ecological communities usually exhibiting competition between organisms common to both.

Mangrove Fishery Resources

Several studies on the fishery resources of the Pagbilao mangrove forest have been conducted. The fisheries surveys for this project were conducted to extend and verify

Figure 1.2. Seaward section of the Pagbilao mangrove forest.

results of previous studies. The most abundant species were the glass fishes Ambassis kopsi and A. urotaenia, the halfbeak Zenarchopterus buffonis and the juveniles of the ponyfishes Leiognathus spp (Table A3). Several species appear to be residents of Sukol creek and the waterways of Pagbilao Bay based on: (1) high abundance in the pocket seine catches; (2) wide size range including adult sizes; and (3) low abundance or non-occurrence outside the mangroves. Such residents include Ambassis kopsi, A. urotaenia, Zenarchopterus buffonis, Butis butis, Prosposodasys gogorzae, Gullaphalus mirabilis, Yongeichthys criniger, Oxyurichthys opthamonema, Acentrogobius spp, Leiognathus spp., and Valamugil cunnesius. The other gobies in the catch were probably also residents but not in high population densities. The Ambassis and Leiognathus spp. are found all over Pagbilao Bay, even outside the mangrove areas. Snakes are common in the mangroves and in Pagbilao Bay in general. Two colubrid snakes were caught during the study: the dog-faced Cerberus rhychops and sea snake Acrochordous granulatus. Both species are known to feed on fish (Table A4). The coastal villages of Pagbilao are dependent on the mangrove fishery resources, the most important of which are the mud crabs and marine crabs. Mostly local artisanal fishers based in the coastal villages of Pagbilao exploit the mangrove fishery resources in Pagbilao Bay (Figure 1.3). The fisheries of Tayabas Bay, to which Pabilao Bay opens, is exploited by both local municipal and commercial fishers. Commercial fishers based elsewhere may also exploit Tayabas Bay fisheries.

1.3. Mangrove Resource Management Alternatives

Past and Current Uses

Through the years the mangroves provided livelihood for Pagbilao coastal residents such as the gathering of minor mangrove products like vines for handicraft, shells and crabs for food, nipa leaves for home construction, and bark for tannins, etc. Wide scale conversion into fishponds contributed to the loss of mangrove areas while excessive harvesting of timber for charcoal and fuel wood degraded the quality of the forest. It is estimated that the total area of fishponds in Pagbilao town with legitimate fishpond lease agreements (FLAs) is 604.57 ha. This area excludes the area in private lands and those which were illegally established.

Figure 1.3. Pagbilao fishing harbour.

Although extraction of mangrove forest resources is now prohibited, harvesting still persists on a limited scale. Field visits and interviews verified the cutting of mangrove branches for fuel wood and poles (but not for timber) and nipa fronds for shingles even after

Proclamation 2151 and 2152. These low-impact forms of extraction are tolerated but not the widescale cutting or clearing of a mangrove patch. An illegal attempt to convert part of the area into fishpond is now under court litigation. Trapping of resident fish species is not prohibited and is done by local fishers.

The continuing exploitation of mangrove resources may be attributed to its accessibility. The experimental forest is very close to inhabited areas and is very accessible by boat, by land transport and on foot. From the nearest village of Palsabangon, access time on foot is about 30 minutes. Tricycles can negotiate the same route in about 10 minutes. Work animals such as carabaos and horses may be used more effectively to transport forest resources such as poles and timber. Boats are more commonly used in gathering nipa products. Because the Pagbilao mangrove forest is the only remaining intact forest of its kind close to Manila, it has been frequently the site of mangrove-related studies conducted by the government, university and other researchers community, both local and foreign. This is evident in studies cited in the fisheries and forestry reports. During the course of the study, several students gathered specimens from the mangroves as part of their academic research work.

Management Alternatives

In this study eight management alternatives are considered which are described below. The allocation of the area in each management alternative is shown in Table 1.2. The likely institutional arrangement for each management alternative is also described as this is an important consideration in resource valuation. Sustainability is the overriding consideration in the exploitation of mangrove fishery and forestry resources as well as in aquaculture alternatives. This consideration is imbedded in the specification of the recommended silvicultural and aquaculture technologies. Therefore all alternatives listed below can be considered sustainable.

1. **Preservation (PR).** Extraction of forest products is not allowed but the gathering of fish and shellfishes such as molluscs and crabs is permitted. The current institutional arrangement for the exploitation of fishery resources is open access although a community-based management of mangrove and bay fishery resources may be arranged. Most dependent on mangrove fishery resources are the poor artisanal fishers from the coastal villages of Pagbilao.

2. **Subsistence forestry (SF).** Coastal communities are allowed to obtain wholly or partly their forest products needs from the forest. The communities themselves manage the forest in consonance with existing policies on community-based forest management. To sustain the benefits, a maximum allowable harvest not to exceed the capacity of the forest to regenerate and develop naturally, is imposed. This implies that some sort of limited entry into the forest resources will be instituted. Mangrove stewardship agreements may be signed between the government and the communities in alternatives involving extraction of forest products. Thus, the benefits from this alternative would accrue to the local residents who are generally poor.

3. **Commercial forestry (CF).** A specified commercial volume of forest products is to be harvested. The required silvicultural system for this is the seed tree method with planting; seed trees (mother trees) are selected to be left to provide propagules for the harvested areas. Similarly, a mangrove stewardship agreement between the government and communities may be put in place for this management alternative. Thus, revenues from commercial mangrove forestry may accrue to the local community acting as a co-operative.

Table 1.2. Area allocation by management alternative.

Management alternative	Fishponds		Forest				Total
			Production Forest		Buffer		
	ha	%	ha	%	ha	%	ha
Preservation	0	0	110.7	100	0	0	110.7
Subsistence forestry	0	0	110.7	100	0	0	110.7
Commercial forestry	0	0	110.7	100	0	0	110.7
Aqua-silviculture	28.6	26	66.6	60	15.5	14	110.7
Semi-intensive aquaculture	95.2	86	0	0	15.5	14	110.7
Intensive aquaculture	95.2	86	0	0	15.5	14	110.7
Commercial forestry and intensive aquaculture	35	32	60.2	54	15.5	14	110.7
Subsistence forestry and intensive aquaculture	35	32	60.2	54	15.5	14	110.7

4. **Aqua-silviculture (AS).** Portions of the mangrove area are converted to fishponds while some portions will remain forested. Buffer zones are allocated based on legal requirements of 50 meters for areas facing the sea and 20 meters along river channels. The remaining area is devoted to aqua-silviculture assuming a 30 to 70 ratio for fishpond and forest. This is a combined use alternative whereby silviculture and aquaculture are simultaneously practised in one pond compartment. Considering the high investment costs in the construction of pond compartments, coastal dwellers may not be able to participate in this management alternative. The most likely beneficiaries are those who are able to shoulder the investment costs which are the rich, either from Pagbilao but more likely from elsewhere.

5. **Semi-intensive aquaculture (SI).** The mangrove forest is converted to fishponds for semi-intensive aquaculture while observing the required buffer zone. The remaining area will be covered by a system of ponds and water distribution systems. The recommended semi-intensive aquaculture technology is an average four crops of milk fish per year with stocking density of about 0.3 fingerling per m^2. The low stocking density and the limited use of chemicals in semi-intensive pond culture are likely to contribute to sustainability. For the management alternatives involving aquaculture, fishpond lease agreements may be auctioned off. Such will likely go to the wealthy who are able to put up the high costs of pond development.

6. **Intensive aquaculture (IA).** This alternative is similar to semi-intensive aquaculture in terms of allocation of area between the required buffer zone and fishponds. The same tenure structure as in semi-intensive aquaculture may emerge with this management alternative. The only difference is that the aquaculture technology employed is intensive. The intensive part of the recommended aquaculture technology applies to the one crop of prawn per year whereby relatively high rates of stocking (up to 15 fry per m2) and artificial feeding are practised. A second crop of milk fish is immediately grown with zero input to feed on the remaining fish food in the pond. The rotation of prawn and milk fish is considered sustainable given high mortalities experienced when growing two prawn crops in one year in some parts of the Philippines (Padilla and Tanael 1996).

7. **Commercial forestry and intensive aquaculture (CF/IA).** This alternative divides the area into commercial forestry and fishponds for intensive aquaculture. It is intended to satisfy competing demands on the mangroves. Mangrove stewardship agreements may be signed with the communities for the commercial forestry alternative while fishpond lease may be auctioned. The silvicultural practice in commercial forestry and the intensive aquaculture technology are as described above.

8. **Subsistence forestry and intensive aquaculture (SF/IA).** This is similar to the previous alternative except that the remaining forest is used for subsistence purposes. Tenure arrangements would be similar to the subsistence forestry alternative and the aquaculture alternatives. The silvicultural practice in commercial forestry and the intensive aquaculture technology are as described above.

The institutional arrangement for each management alternative is briefly described above. Alternatives including subsistence forestry or commercial forestry require mechanisms for controlling access and to limit cutting rates at sustainable levels. The costs of enforcement of such mechanisms are assumed to be lowest in community-based management. Regulations may become self-enforcing if these are formulated and enforced by the community itself.

1.4. Quantification and Valuation of Goods and Services from the Mangrove Forest

The alternatives range from preservation to alternatives which allow for combined uses of mangroves in Pagbilao. Some alternatives permit the use of the entire mangrove forest by an interest group (community or fishpond operators) while the combined use alternatives involve shared use by competing users. Environmental considerations are satisfied in all alternatives, for instance, the rate of timber harvesting is limited to the sustainable levels. The prescribed technology for aquaculture allows for long-term use of the fishponds and can therefore be considered sustainable.

Forest Products

The quantification and valuation of goods and services proceeded from field surveys of the mangrove reserve in 1995. For the forest resources, the results are summarised in

Carandang and Padilla (1996). The mangroves of Pagbilao are all second growth with an average age of 20 years. Three zones or ecotones were identified, i.e., landward, middleward and seaward. Sample plots were established in each ecotone and tree density, tree dimensions and subsequently of wood volume were measured or computed. Projected timber yield was estimated over time using an empirical equation for the Philippines with stand age and site index as explanatory variables. For 1995, the average timber yield in m^3 per ha ranges from 2.18 to 3.08 for the various zones. Over 100 years, the computed mean annual increments in m3 per ha are respectively, 1.18, 1.67 and 1.49 for the seaward, middleward and landward zones. Litter traps were also set within the same plots to estimate litter fall which were then dried in an oven to determine nutrient content.

Fuel wood, timber and nipa shingles are the primary forest products that may be derived from the Pagbilao mangrove reserve. In estimating the quantity of forest products, a sustainable cutting regime is recommended based on sound silvicultural practices. The specified breakdown of forest products, particularly timber, takes into account the forest management regime which is either subsistence or commercial exploitation. In subsistence forestry the breakdown of forest products follows the requirements of the coastal communities which are mostly fuel wood, charcoal and poles (timber) for fences and posts. In commercial forestry, high value products are to be produced primarily timber with incidental fuel wood from tree branches (Table A5). In subsistence forestry about 262 m^3 of wood products may be harvested compared to 272 m^3 per year in commercial forestry.

Valuation for subsistence uses is different from valuation for commercial uses. Computations are described in Table A6. In subsistence forestry, the use value of the forest products derived from the mangroves should be net of the gathering cost. When households are denied access to mangrove forest resources, the value attached to the forest products is equivalent to the cost they incur in obtaining alternative products. Such cost is equal to the market price of the alternative product plus the transport cost from the market to the point of use. Thus, the shadow price of forest products is the market price of the alternative product plus the transport cost less gathering costs. In a commercial forestry regime, it is assumed that the co-operative's objective is to maximise the value of net benefits to be derived from the forest. Net benefit is the stumpage value which is equal to the market price of the good less the costs of transport, extraction and related costs incurred in managing the forest. Thus, in forest product valuation, shadow prices were computed for non-traded products. For simplicity, the alternative product is the same regardless of whether it is used for subsistence or commercial purposes. For traded forest products such as nipa, actual market price is used which is then adjusted by transport and gathering costs.

For the five alternatives which permit harvesting of forest products, the highest value for such products may be derived in commercial forestry at over 400,000 pesos/year followed by subsistence forestry at about 350,000 pesos/year. On the other hand, the combination of subsistence forestry with intensive aquaculture yields only 187,000 pesos/year. In terms production value per unit area, i.e., economic efficiency, commercial forestry is superior to subsistence forestry.

Capture Fisheries

Taxonomic identification of resident and transient fish species was conducted to assess fisheries productivity of the mangrove reserve. The fisheries component of this study (Ong and Padilla 1996) updated some information generated in more thorough studies in previous years (e.g., de la Paz and Aragones 1985; Pinto 1985 and 1988; Fortes 1984). The experimental forest supports both on-site (resident species) and off-site (transient species) fisheries. Only the top six resident and 6 transient species groups are presented in the paper although about 45 species in 25 families were identified in the fisheries component of this study. The most abundant resident species are glass fishes and crabs while mullets and juvenile shrimps are the major transient species.

The estimation of sustainable harvest of fishery resources presents difficulties as the fisheries surveys for this study, as well as in previous studies, did not cover stock assessment. Simplifying assumptions were made to arrive at some measure of abundance based on the number of each species caught by the sampling gears. Moreover, the results of the survey of one creek were raised to arrive at an estimate for the entire mangrove forest. Sustainable harvests are then estimated for each species group using simple rule-of-thumb such as Gulland's 50% exploitation rate, which sets fishing mortality equal to natural mortality.

Most fishes are found in the mangrove reserve as juveniles, hence, the equivalent weight in terms of adult fish is first estimated. It is computed by multiplying sustainable harvest by the percentage deviation from market sizes of the fishes found in the creek. This is assumed to account for losses from natural mortality and predation as the fishes grow to market sizes. The results show that the experimental forest supports a small on-site fishery and contributes minimally to off-site fisheries (upper part of Table A7). The estimates of sustainable yields would be a very small fraction of Pagbilao Bay fisheries even in the absence of data on total catches for the entire Bay. For the other management alternatives, fisheries productivity is linked primarily to nutrient production. The ratio between the quantity of nutrient production in each management alternative and in the preservation alternative is used to adjust fisheries production. Likewise, the impact of chemical discharges in the aquaculture alternatives are also factored in by assuming zero production of vertebrate species for both residents and transients.

The valuation of market-size fishes found in the forest uses market prices of adult fish observed during the field surveys. The following are the steps in valuation. First is the computation of the in-situ value of the fish which is the relevant figure in valuation. It is estimated that 87.75% of the landed price of fish covers the costs of harvesting, the remainder is the value of the fish in-situ (NSCB 1996). Next, the estimates of the value of fisheries production for the waterways are first converted to the entire forest. It is assumed that the relevant production area is thrice the area of the waterways (Sukol Creek, Palsabangon and Nahalinhan Rivers) which comes to about 30.75 has. This is used to multiply gross value of contribution to fisheries which are then divided by the total area of the mangrove forest (110.7 ha) to arrive at the average value of the production for the entire forest. The value figures in lower part Table A7 may be interpreted as conservative estimates of the value of fisheries production. The preservation of the mangrove forest contributes about 1,490 pesos per ha per year to capture fisheries in the area.

Aquaculture

The performance of aquaculture ponds converted from mangroves was also assessed as part of this study (refer to Padilla and Tanael 1996a; 1996b). Due to the changing productivity of aquaculture in the Philippines, several studies are compared to assess the long-term prospects of aquaculture operations in the mangrove reserve. The primary objective of the aquaculture studies is to identify the appropriate (sustainable) aquaculture technology and the corresponding production levels. The type recommended aquaculture technology for both semi-intensive and intensive technologies are described in Section 3.

Conversion of the mangrove forest into fishponds is an attractive alternative when equity considerations are not considered. Under controlled conditions in aquaculture systems higher fish production levels are achieved at over 6270 kg./ha/year in semi-intensive culture of milk fish or 2530 kg./ha/year when rotating intensive prawn culture with extensive milk fish culture (Table A8). Albeit requiring high capital investments and operating expenses, the present value of net profits from aquaculture ranges from 13.2 million pesos/year to 112.4 million pesos/year. Semi-intensive culture of milk fish turned out to be superior over intensive prawn culture on several counts: a) the recommended technology for the latter -- crop rotation -- while more sustainable gives lower profits; b) low prices of prawn in the international market; and c) higher development costs for intensive ponds. Intensive prawn culture may become more profitable than semi-intensive milk fish if more sustainable prawn culture technology is developed and if prawn prices improve. Profits from aquaculture are much higher compared to the value of forest products and capture fisheries. A summary of all values estimated can be found in Table A9.

1.5. The decision problem

A decision problem is characterised by alternatives, effects, decision makers and their objectives. The effects table including the management alternatives for the Pagbilao mangrove forest is shown in Table 1.3. The management alternatives were introduced in Section 3. Technical studies, presented in Section 4, were conducted to quantify the effects. The effects on shore protection, biodiversity and eco tourism linked to the different alternatives could not be predicted within these technical studies. A forestry expert, a marine biology expert and a zoology expert were invited to provide expert judgement on the relative performance of the alternatives on these three effects (Carandang, Guarin, Ong 1996). To obtain expert judgement an assessment procedure was used that asks each expert to compare for each effect all pairs of alternatives on a nine point scale (Janssen 1992). The results are included in Table 1.3. Note that Subsistence Forestry performs best on eco tourism. This alternative performs well because it preserves not only the ecosystem but also the socio-economic structure linked to subsistence forestry. The low score of Aqua-Silviculture for biodiversity may be the result of uncertainties associated with this

Table 1.3. Effects table of management alternatives for the Pagbilao Mangrove forest.

	unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
forest	ha	110.70	110.70	110.70	82.10	15.50	15.50	75.70	75.70
fishponds	ha				28.60	95.20	95.20	35.00	35.00
Fuel wood subsistence	m^3/year		184						99
Fuel wood commercial	m^3/year			65	42			35	
Timber subsistence	m^3/year		46						25
Timber commercial	m^3/year			207	134			111	
Charcoal subsistence	m^3/year		31						22
Charcoal commercial	m^3/year								
Nipa subsistence	1000/year		45						23
Nipa commercial	1000/year			45				23	
Soil accretion	cm/year	1.00	0.34	0.42	0.22	0.10	0.05	0.13	0.15
Milk fish production	tons/year				161	537	59	22	22
Prawn production	tons/year						158	57	57
Variable costs	1000 pesos				-2748	-9148	-15000	-5460	-5460
Capital costs	1000 pesos				-1287	-4284	-8568	-3150	-2574
Emissions	tons/year				-20	-40	-100	-50	-50
Residential catch/crabs	1000/year	79	77	77	59	8	8	20	20
Bay catch/shrimps	1000/year	140	140	140	104	7	7	21	21
Shore protection	index	1.00	0.36	0.14	0.14	0.14	0.06	0.14	0.14
Biodiversity	index	1.00	0.61	0.39	0.16	0.14	0.06	0.15	0.23
Ecotourism	index	0.80	1.00	0.38	0.18	0.14	0.08	0.21	0.30

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

experimental type of aquaculture.

Table 1.4. Decision makers and their objectives.

• Fishpond owner Maximise profit
• Local government Maximise net income to local government and/or to local population.
• Social planner (national government) Maximise total benefits to the Philippines (efficiency) AND More equal income distribution (equity)
• Sustainable planner (national government) Maximise total benefits (efficiency) AND More equal income distribution (equity) AND Maintain minimum level of relevant environmental stocks.
• Sustainable world planner (UNEP/GEF) Maximise global environmental benefits from mangrove forests.

Each type of decision makers has his own objectives. Decision makers and their objectives are listed in Table 1.4. The fish pond owner will be concerned with the profits generated. Local government looks after local interests. This can be either income to local government, to be used to provide local services, or income to local population. The social planner looks after the interests of the country as a whole. This involves finding a balance between efficiency and equity objectives. In addition to efficiency and equity objectives, a sustainable planner also aims to obtain a minimum level of environmental stocks. This can be expressed as minimum levels of environmental quality but also as minimum sizes of certain ecosystems. Finally, the sustainable world planner institutionalised as the Global Environmental Facility (GEF) will try to maximise total environmental benefits from the mangrove forests to the world as a whole. Because each type of decision maker has his own objectives, each decision maker will evaluate the information on the alternatives in a different way. In Section 8 the results from valuation and evaluation provided in Sections 6 and 7 will be used to select the best alternative for each type of decision maker.

1.6. Valuation: a benefit-cost approach

Valued effects

Using the prices derived in the technical studies, the effects table can be transformed to the valued effects table shown in Table 1.5. This table includes valued effects and effects that were not valued for reasons described below. Valued effects include effects representing direct and indirect use values, such as benefits to forestry and fisheries. Values shown are annual values for the entire area. Alternatives are assumed to be sustainable. This implies that the time horizon can be assumed to be indefinite. Life time of existing fishponds supports this assumption. Development costs and other capital costs are valued according to the borrowing rate for capital in real terms. It is assumed that, due to cyclones, once in every five years one of the two yearly harvest of the fishponds is completely lost. This is included as a 10 percent reduction of the annual harvest.

From the totals of the valued effects it is clear that the aquaculture alternatives perform better than the forestry alternatives and preservation. It is interesting to note that Semi-intensive Aquaculture (SA) performs better than Intensive Aquaculture (IA). This is due to high development costs linked to intensive aquaculture and to the constraints set by sustainable management of the ponds. The performance of both alternatives is very sensitive, however, to changes in prices of milk fish and prawns. Milk fish are produced for the local market and the price level is relatively stable. The price of prawns is determined on the world market and strongly fluctuates. In this study a price of 185 pesos/kg is used to value prawns. If this price increases above 247 pesos/kg the total value of intensive aquaculture will be higher than the total value of semi-intensive aquaculture. Note also the bad performance of aqua-silviculture (See also Padilla and Tanael 1996a 1996b).

Other effects

Effects of the alternatives on emissions, soil accretion, shore protection, eco tourism and biodiversity were not valued for various reasons listed below.

- No cost is attributed to emissions because with the production technique selected for aquaculture, emissions are not expected to create any water quality problems. Also in the current situation no problems with water quality are found.
- Shore protection is not valued because shore protection is provided in all alternatives, either by the mangrove forest in the preservation and forestry alternatives or by the buffer zones in the aquaculture alternatives. The value is therefore not relevant to the decision.
- Soil accretion may result in the expansion of the forest to the sea. This could be valued according to the total value of the mangrove forest. Since this is effect is very uncertain and, due to cyclones might even be non existent, also no value is attributed.
- Eco tourism is, at present, non existent. Facilities offered in the past, such as walkways, have not resulted in a substantial influx of tourists. A considerable amount of both local and foreign visitors, however, visit the site for educational or research purposes. Since no alternatives exist at the island of Luzon, no easy accessible alternatives for this function exist. The value of the forest for research is also reflected by the nearby research station. For practical reasons values attached to education and research are not included.
- If all effects listed above represent the direct and indirect use values of the ecosystem the value of biodiversity can only be linked to non use values such as the existence , alternative or even the intrinsic value of the ecosystem. Due to the importance of mangrove ecosystems the value of biodiversity is expected to be high. Valuation, however, would involve a contingent valuation approach.

Table 1.5. Annual values of management alternatives for the Pagbilao mangrove forest.

	unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Valued effects									
Subsistence forestry	1000 pesos		349						189
Commercial forestry	1000 pesos			416	217			229	
Fishponds	1000 pesos				5648	18801	9294	3417	3993
Fisheries	1000 pesos	165	161	161	124	8	8	40	40
Total value	1000 pesos	165	510	576	5989	18809	9302	3686	4222
Other effects									
Emissions	tons/year				20	40	100	50	50
Soil accretion	cm/year	1.00	0.34	0.42	0.22	0.10	0.05	0.13	0.15
Biodiversity	index	1.00	0.61	0.39	0.16	0.14	0.06	0.15	0.23
Shore protection	index	1.00	0.36	0.14	0.14	0.14	0.06	0.14	0.14
Ecotourism	index	0.80	1.00	0.38	0.18	0.14	0.08	0.21	0.30

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Contingent valuation raises the question whose values should be included (local population, national population, world population). In addition it can be questioned whether intrinsic values linked to biodiversity can be captured using valuation techniques, especially where the loss of ecosystems is irreversible (see, for example, Dixon 1994).

Comparison with other studies

A literature survey was conducted to be able to compare results from the Pagbilao studies with other mangrove studies (Spaninks and Beukering, in prep). In Table 1.6 results from studies in Thailand, Fiji and Indonesia are compared with the Pagbilao study. The values for forestry and fisheries are comparable for all studies with a relatively high value for forestry products and a relatively low value for fisheries products in Pagbilao. The value of aquaculture is listed as a negative value since this value represents the foregone benefits of not converting the forest to fishponds and can therefore be considered as an opportunity cost of preservation. The value found by Ruitenbeek for biodiversity is based on a contingent valuation approach. The value used by Lal for purification involves construction of a sewage treatment plant. Since water pollution is not a problem in Pagbilao this value can not be attributed to prevention of emissions in Pagbilao.

Table 1.6. A comparison of net annual benefits of mangrove products and functions.

	Thailand Christensen (1982) *US$/ha.*	**Fiji** Lal (1990) *US$/ha.*	**Indonesia** Ruitenbeek (1992) *US$/ha.*	**Pagbilao** (1996) *US$/ha.*
Forestry	30	6	67	150
Fisheries	130	100	117	60
Agriculture	165	52		
Aquaculture	-2106			-6793
Erosion			3	
Biodiversity			15	
Local uses	230		33	
Purification		5820		

The cost of biodiversity

As indicated above it is very difficult or even impossible to value biodiversity. It is, however, possible to calculate the benefits lost if an alternative is selected that preserves biodiversity but results in a total value lower than the maximum. In this study the value of aquaculture can be considered as an opportunity cost for alternatives that preserve the mangrove forest. Aquaculture generates 6793 US$/ha compared to 211 US$/ha for the commercial forestry alternative. This leaves a deficit of 6583 US$/ha. Under the rules of the Global Environmental Facility (GEF) this deficit can be considered to be the incremental costs to keep the forest. The issue is not how much is this forest worth in terms of biodiversity, but how much should be paid to balance the foregone benefits of a more profitable alternative without the forest. The deficit is substantial and far removed from the value of 15US$/ha as listed by Ruitenbeek. The values for erosion control and local as found by Ruitenbeek do not bridge this gap. The value found by Lal for purification is not relevant as explained above.

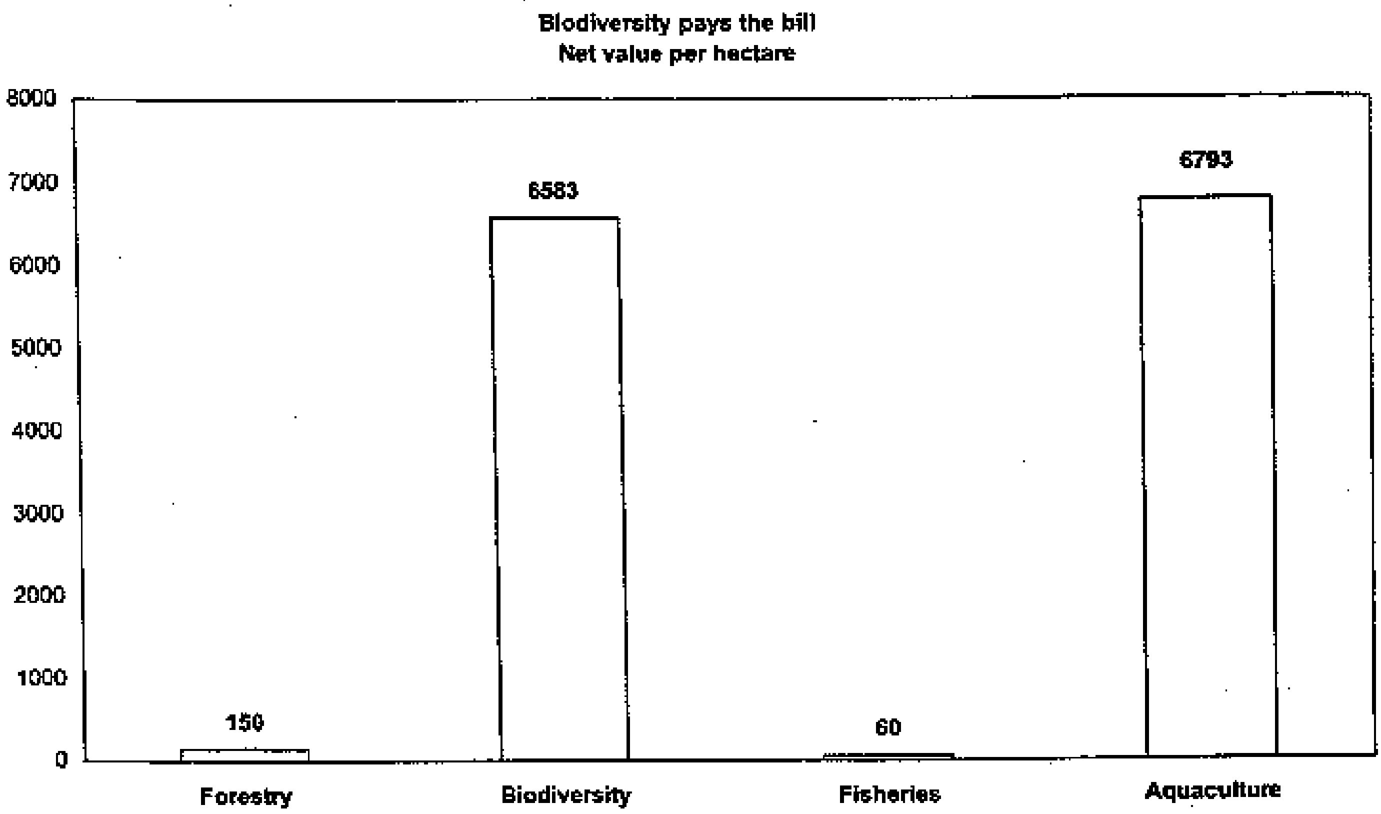

Figure 1.4. The cost of biodiversity.

1.7. Evaluation: a multi criteria approach

Starting point of the multi criteria analysis is the valued effects table introduced in the previous section (Table 1.5). A graphic presentation of this table is presented in Figure 1.5. In this presentation each effect is standardised between 1 (the best alternative) and (0 the worst alternative). Each row represents an effect. For each effect the highest bar represents the best alternative. For emissions, as an example, Preservation (PR), Subsistence Forestry (SF)and Commercial Forestry (CF) are the best alternatives. All three do not produce emissions and receive a score of 1. Intensive Aquaculture (IA) produces the most emissions and receives a score of 0. All other alternatives are scaled relatively to these two extremes. Figure 1.5 clearly shows the trade-of between revenues from fishponds and all other criteria.

This graphic representation can be used to rank the alternatives according to policy priorities. The effect that is considered most important is moved to the top row, the second most important effect to the second row etc. In Figure 1.6 priority is given to environmental effects: biodiversity is moved to the top row, followed by emissions etc. By exchanging the

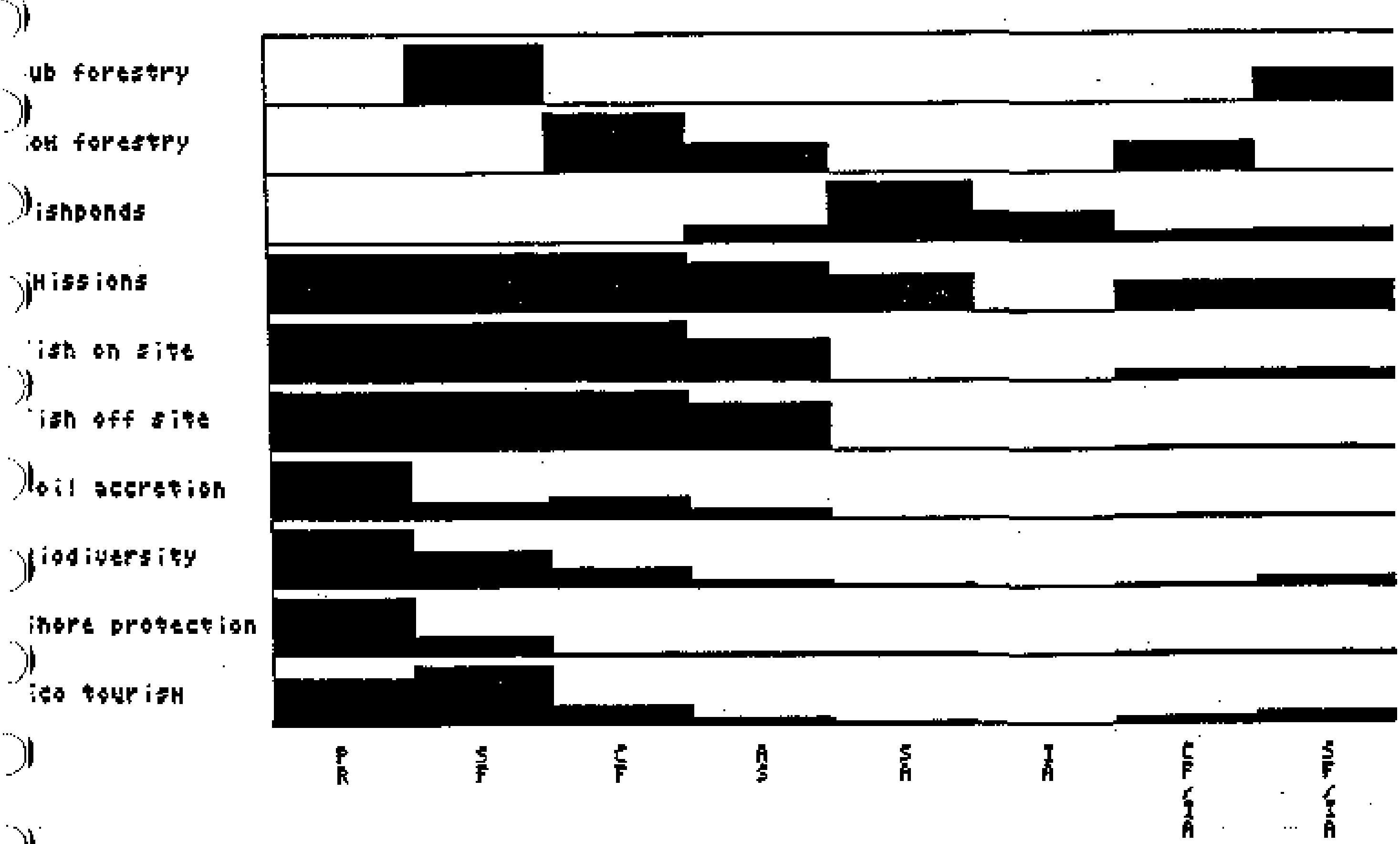

Figure 1.5. A graphic representation of the valued effects table.

columns the alternatives can be ranked visually. Given the priorities assigned to the effects Figure 1.6 shows that Preservation (PR) is the best alternative because it is the best alternative for the four effects that are considered the most important, second best for eco tourism and best for fisheries. Looking at the lower end of the ranking it can also be seen that Semi-intensive Aquaculture (SA) will always be preferred over Intensive Aquaculture (IA) because it performs worse for five of the included effects and equal on the remaining five[4].

The previous section dealt with the economic efficiency objective. As was shown in Table 1.4 decision makers also consider equity and environmental objectives in their decision. In the previous section effects were not differentiated according to income groups. Also effects on the environment were not included because these effects could not be valued.

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[4] The ranking shown in Figure 5 was derived using the expected value method to transform the priority order of effects to quantitative weights and the weighted sum of weights x standardised effects to derive a performance index for the alternatives.

Therefore equity and environmental objectives were not included. Therefore the decision problem is now redefined into a multi objective decision problem with the following three objectives:

- Maximise efficiency: maximise monetary benefits over costs.
- Maximise equity: maximise income to local population.
- Maximise environmental quality: maximise the balance of positive effects and negative effects to the environment

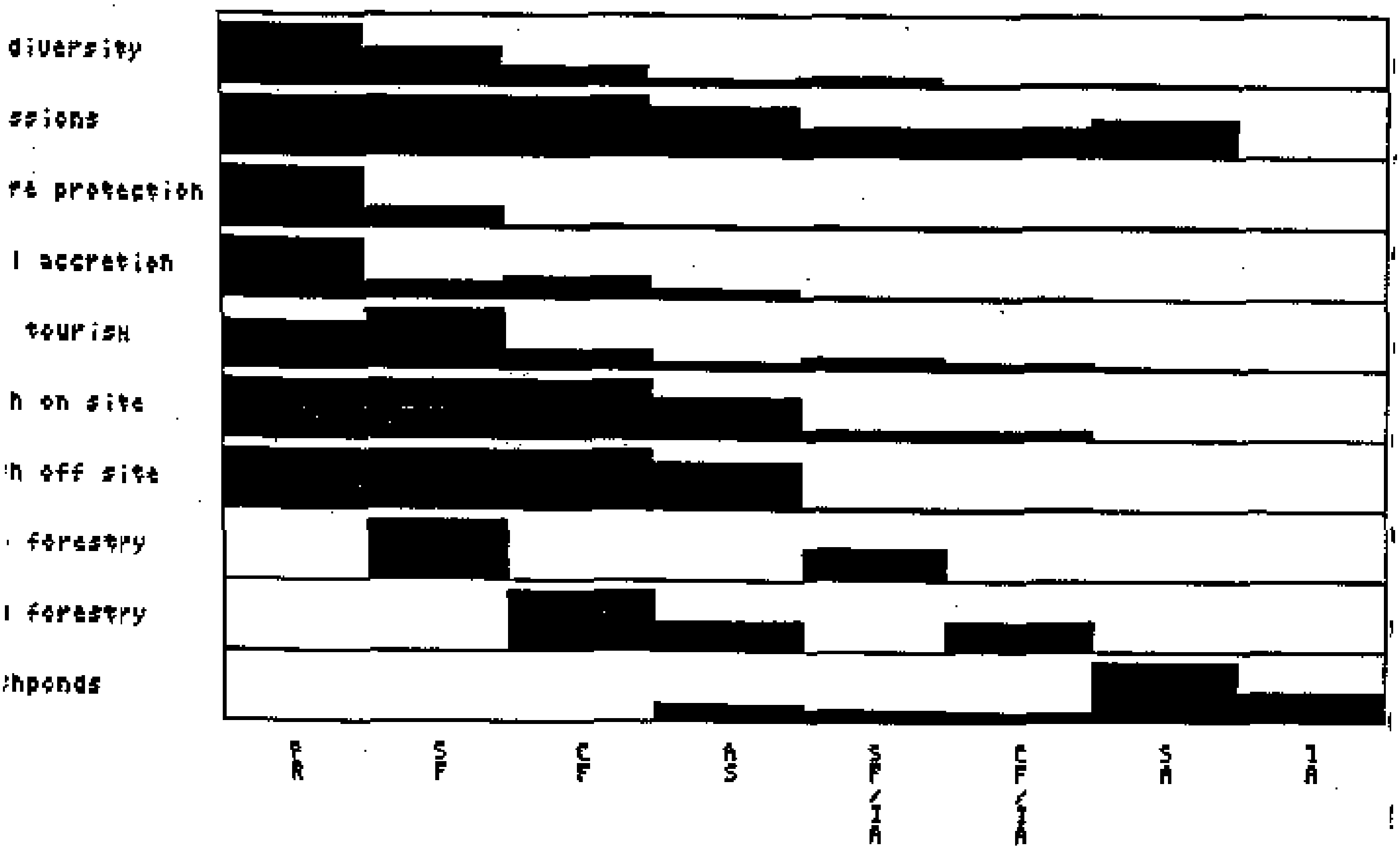

Figure 1.6. A graphical ranking of the valued effects table.

It is assumed that the country-city income distribution coincides with the poor-rich income distribution. This is reflected in the ownership of existing fishponds. Equity is defined as the benefits that go to the local poor. Environmental quality is linked to preservation of environmental functions (see Chapter 2). The performance of the alternatives on these three objectives is shown in Table 1.7. The first two objectives are measured in monetary terms: all effects are aggregated according to their prices or shadow prices. Environment is defined as an index combining effects on soil accretion, emissions, shore protection, biodiversity and eco tourism. The relative weight of biodiversity within this index is ten times the relative weight of each of the other effects.

Three scatter diagrams are used to analyse the trade-offs and level of conflict between efficiency and equity (Figure 1.7), efficiency and environment (Figure 1.8) and equity and environment and equity (Figure 1.9). Figure 1.7 shows the performance of the alternatives on the objectives efficiency and equity. The horizontal axis represents the performance on efficiency and the vertical axis the performance on equity. Scores are standardised between

Table 1.7. Performance of the alternatives on three objectives.

	unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Efficiency	1000 pesos/y	165	510	576	5989	18809	9302	3686	4222
Equity	1000 pesos/y	165	510	576	341	8	8	260	230
Environment	index	12.8	7.8	4.8	-17.9	-38.2	-99.2	-48.0	-47

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

0 (the worst alternative) and 100 (the best alternative). Therefore the most efficient alternative, Semi-intensive Aquaculture (SA), can be found on the far right of the diagram and the most equitable alternative, Commercial Forestry (CF) can be found at the top of the diagram. The ideal alternative for these two objectives would combine optimal performance on efficiency with optimal performance on equity. This ideal alternative would have score 100, 100 and would be found in the upper right corner of the diagram. It is clear from Figure 1.7 that in this case this ideal alternative does not exist. Also compromise alternatives, combining good or moderate performance on both objectives, do not exist. The level of conflict between both objectives is also reflected by the correlation coefficient. A value close to one indicates minimal conflict, a value close to minus one indicates extreme conflict. The value of -0.71 indicates high conflict between efficiency and equity. Addition or removal of alternatives may influence the relative position of the remaining alternatives and will also influence the correlation coefficient. It is therefore important that only alternatives that are relevant to the decision are included in the evaluation.

The line shown in this diagram can be used to rank the alternatives visually. In this diagram equal weight is given to efficiency and equity. This is reflected in the angle of the line. All points on this line have the same distance from the ideal alternative[5]. The alternatives can now be ranked by moving this line from top right to bottom left. The first to cross the line and therefore the best alternative is Commercial Forestry (CF) almost immediately followed at the other extreme of the diagram by Semi-intensive Aquaculture (SA). A change in relative weight of the two objectives is reflected by a change in angle of the line.

[5] Distance is defined here as the sum of the distance along the x axis and the distance along the y axis. Since the line intersects the x axis and the y axis at the same distance form the ideal alternative, all points on the line share the same distance to the ideal point.

The ranking shown in Figure 1.7 is extremely sensitive to variations in the relative weights of efficiency and equity.

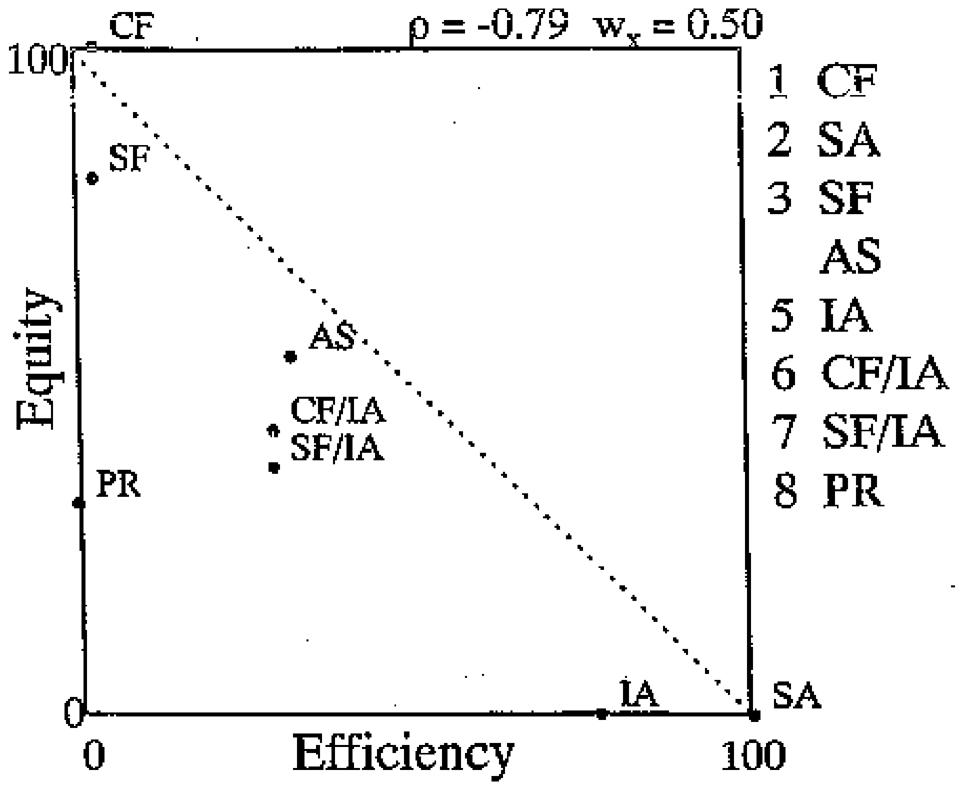

Figure 1.7. Trade-off between efficiency and equity.

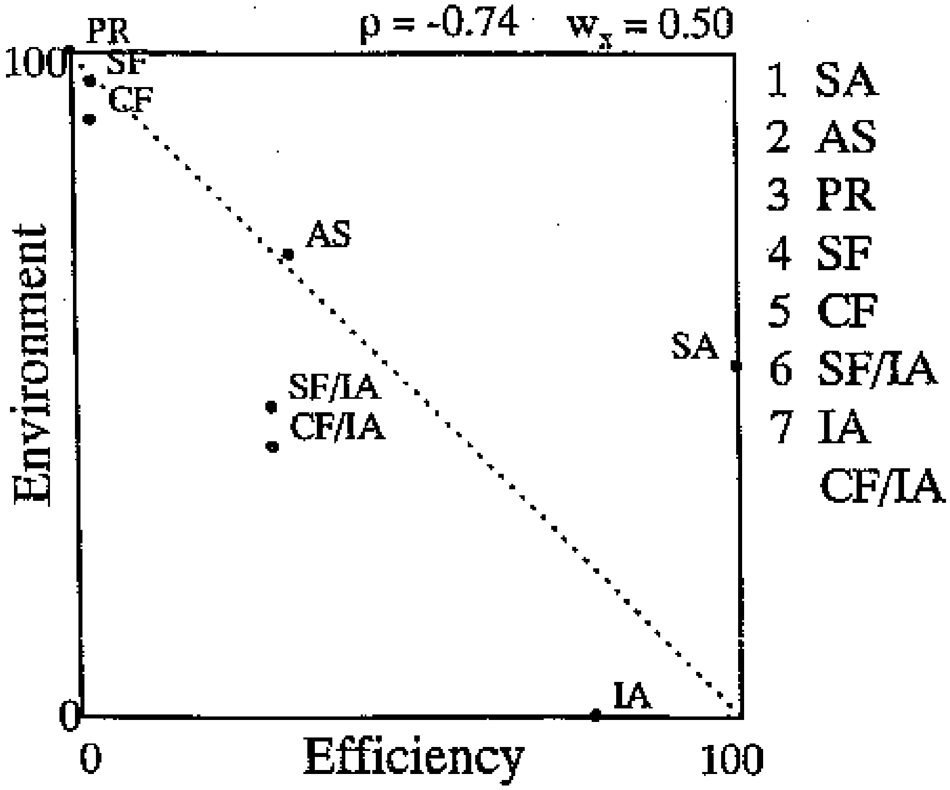

Figure 1.8. Trade-off between efficiency and environment.

The trade-off between efficiency and environment is shown in Figure 1.8. Conflict is less than between efficiency and equity, but still fairly high at -0.54. Semi-intensive Aquaculture (SA) now ranks as the best alternative. Only if the relative weight of environment is substantially increased, Preservation (PR) will move to the first position. The most interesting of the three diagrams is shown in Figure 1.9. In this diagram the trade-off between equity and environment is shown. The correlation coefficient of 0.67 indicates minimal conflict. Two alternatives can be found near the ideal alternative with Commercial Forestry (CF) as the best alternative. Note also the extreme bad performance of Intensive Aquaculture (IA) at the lower left corner of the diagram. The ranking shown to the right of the diagram is fairly insensitive to changes in the relative weights of both objectives.

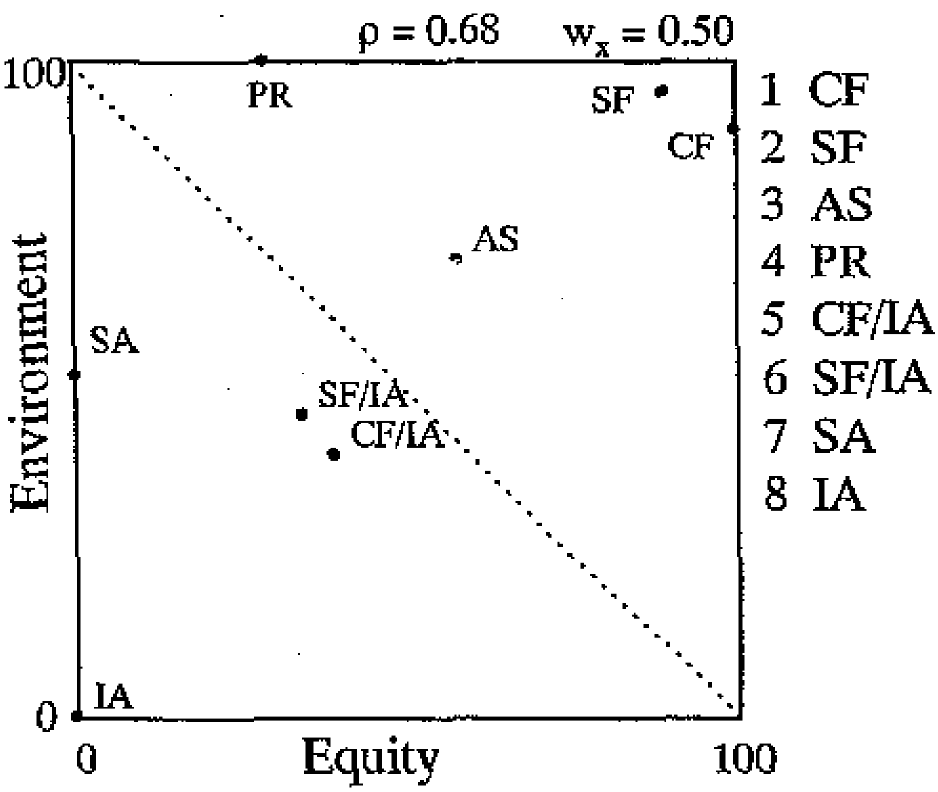

Figure 1.9. Trade-off between equity and environment.

In Figures 1.7, 1.8 and 1.9 the trade-offs between pairs of objectives were analysed. As a last evaluation step the ranking according to all three objectives simultaneously is shown in Figures 1.10, 1.11 and 1.12. In Figure 1.10 all three objectives are considered equally important. This results in Commercial Forestry (CF) as the most preferred alternative[6]. In Figure 1.11 efficiency is the most important objective followed by equity. In Figure 1.11 environment is the least important objective. This results in Semi-intensive Aquaculture

[6] The ranking shown in Figure 5 was derived using the expected value method to transform the priority order of effects to quantitative weights and the weighted sum of weights x standardised effects to derive a performance index for the alternatives.

(SA) as the most preferred alternative. In Figure 1.12 priority is given to environment followed by equity and efficiency. In this case Commercial Forestry (CF) ranks as the best alternative. Note that Preservation (PR) never ranks within the two most preferred alternatives.

The trade-off between efficiency and equity could be accommodated by policies that reallocate income from the distant fish pond owners to the local community or by policies that would channel government revenues from the auction of fishpond lease agreements to the local poor. It could also be accommodated by new types of ownership arrangements of the fishponds. In practice attempts to achieve a more equitable distribution of income from

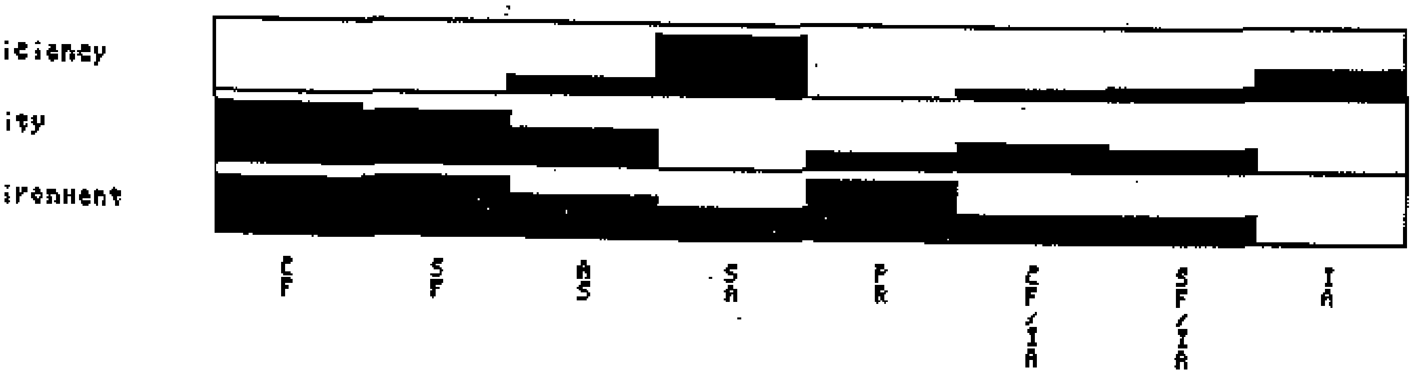

Figure 1.10. Efficiency, equity and environment are equally important.

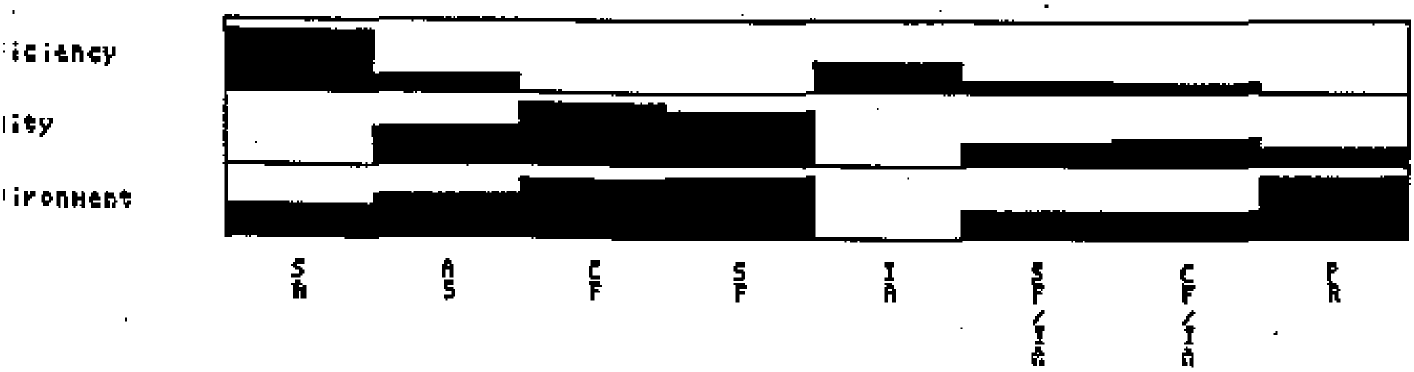

Figure 1.11. Efficiency is more important than equity; equity is more important than environment.

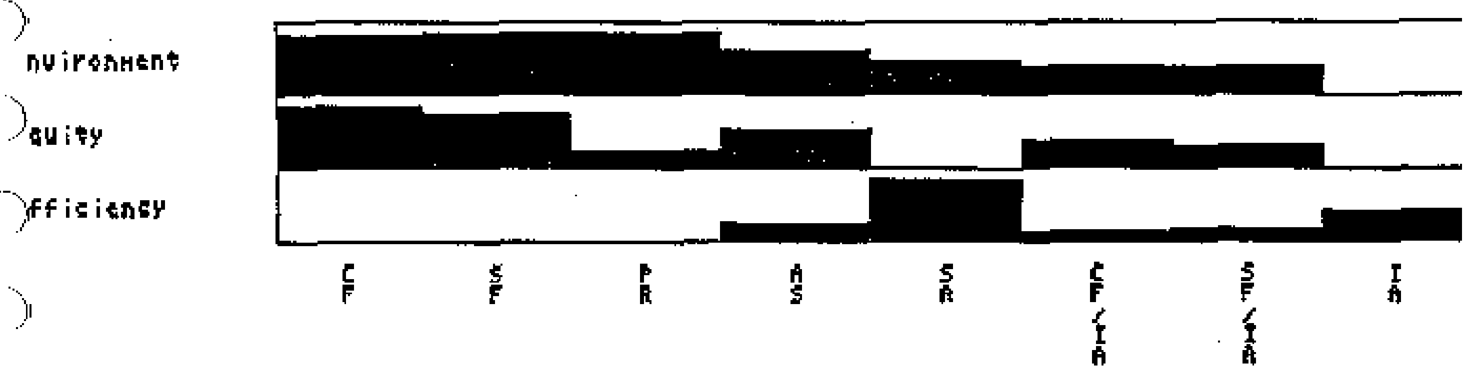

Figure 1.12. Environment is more important than equity, equity is more important than efficiency.

fishponds have failed for political and legal reasons. Change in ownership arrangements has also failed because of limited access to capital by the local poor.

1.8. Conclusions and recommendations

This study evaluated the conversion of the 110.7-hectare strip of protected mangrove forest in Pagbilao, Philippines into aquaculture, forestry and combined uses. Two points are emphasised in the specification of alternative uses of the mangrove forest. The first is that the overriding consideration is sustainability. For instance, the recommended harvesting rates in forestry alternatives are based on sound silvicultural practice. Likewise, the specified aquaculture technology is based on the recommendations of studies on Philippine milk fish and prawn farming. The second point is community-based management of forest and fishery resources which is now the strategy in natural resource management in the Philippines.

Section 1.6 showed that if efficiency is maximised, semi-intensive aquaculture is the most preferred alternative. In Section 1.7 it was shown that if equity and environment are also considered important policy objectives commercial forestry is the best alternative. Policy objectives differ according to the role of the decision maker involved. Table 1.8 lists the most preferred alternative according to type of decision maker and their objectives. A short explanation of the position of each decision maker is included below.

Table 1.8. Decision makers, their objectives and their preferred alternatives.

• Fishpond owner Maximise profit => Conversion to semi-intensive aquaculture • Local government Maximise net income to local government and to the local population from the forest => Increase the licence fees for fishponds and convert to fish ponds OR => Forestry and fisheries • Social planner Maximise total benefits to the Philippines (efficiency) AND More equal income distribution (equity) => Conversion to fishponds if efficiency is emphasised. OR => Forestry and fisheries if equity is emphasised. • Sustainable planner Maximise total benefits (equity) AND More equal income distribution (equity) AND Maintain minimum level of relevant environmental stocks. => Preservation to maintain a minimum level of mangrove ecosystems. (minimum stock of habitat, biological and genetic diversity) • Sustainable world planner (UNEP/GEF) Maximise global environmental benefits from mangrove forests => Pay a maximum of 6583 US$/ha/year to the Philippines OR => Accept the loss of the Pagbilao forest

- Under the assumption of sustainable management the individual fish pond owner will prefer semi-intensive aquaculture since this alternative generates the largest profits. This preference can also be observed at existing fish ponds in the Pagbilao region. Many of the existing fish ponds date from the fifties. This suggest that the management of these ponds is sustainable.
- If local government finds a way to increase the licence fees linked to the various activities to a level that equals the producer's surplus conversion to fish ponds would generate the highest revenues. If these revenues are fed back into the community this would also generate the largest improvement to equity. However, recent attempts to substantially increase the licence fees have failed due to political resistance. Therefore, in the current situation commercial forestry should be the choice of local government.

- A social planner should take both efficiency and equity objectives into consideration. In the absence of mechanisms to transfer income from fishponds to the local poor the choice of the social planner is dependent on the priority given to both objectives.
- In addition to a social planner, a sustainable planner will try to maintain a minimal level of mangroves. It can be argued that on a world and national scale this minimum level is already reached. Certainly for the island of Luzon this minimum level is reached. The preservation of the forest despite the potential revenues from fish ponds suggests that the Philippine government operates as a sustainable planner in this case.
- If it accepted that preservation of the mangrove forest is primarily in the interest of the world community it is not reasonable to make the Philippines pay the price of preservation. Under this assumption the sustainable world planner, institutionalised in the Global Environmental Facility, should be prepared to pay the incremental costs of 6583US$/ha/year if they consider preservation of the forest worthwhile.

For this study large effort has been invested in data collection and modelling. Despite this effort results have to be used with care. This especially holds for the results linked to off-site fisheries. It proved to be very difficult to establish a clear link between the size of the mangrove forest and the value of off site fisheries. A production function approach proved to be not feasible. Given these limitations the following can be concluded:

- For the Pagbilao mangrove forest aquaculture is the policy alternative with the highest economic value. If equity and environmental considerations are included subsistence forestry is the preferred alternative.
- Environmental services, such as biodiversity, shore protection and flood mitigation, need to be priced very highly to make preservation the alternative with the highest value.

This study used a combination of cost-benefit analysis and multi criteria analysis. Although biodiversity is considered crucial to the decision to preserve the forest it proved impossible to put a monetary value on changes in biodiversity. This raises the question of the limitations of valuation. Is it possible to value irreversible effects such as the loss of life, the loss of ecosystems, the loss of species, the loss of works of arts etc. Another crucial issue in the case of Pagbilao is the distribution of wealth. The income from the fish ponds goes to distant investors. Also the conversion to fish ponds creates areas that cannot be accessed by the local population. The equity issue can not be addressed adequately using cost-benefit analysis. Multi criteria analysis was used to supplement cost-benefit analysis. This proved to be useful to include equity and environmental objectives. From a methodological point of view the following can be concluded:

- It is questionable whether it is possible to value non use values linked to irreversible effects such as loss of biodiversity.
- It is recommended to use a combination of cost-benefit analysis and multi criteria analysis if effects on biodiversity or other important irreversible effects are important to the decision or if major changes in income distribution are expected.

Additional research is required on the following topics:

- Further research on ecological linkages both within mangrove ecosystems as between mangrove and other coastal ecosystems is essential.
- Assessment of production functions between mangroves and mangrove related products, such as fisheries, can be seen as an extension of these efforts. It is questionable, however, whether assessment of production is feasible in applications such as Pagbilao.
- Further research on approaches to value environmental values such as biodiversity is necessary. This should include an appraisal of the appropriateness of valuation to support decisions including this type of environmental values.
- The conflict between efficiency and equity could be reduced by changes in ownership arrangements or adequate mechanisms to transfer costs and benefits between income groups. Research on potential and limitations of existing transfer mechanisms and research on development of new mechanisms is therefore important.

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List of Tables

Appendix

Table A1. Wildlife of the mangrove areas of Pagbilao, Quezon, Philippines.

	Scientific Name (Family)	Common Name
I Fauna specifically reported from the mangrove areas, fishponds and mudflats at Pagbilao Bay		
A. Birds	Anas luzonica	Philippine Malard/Duck
	Bubulcus ibis	Cattles Egrets
	Butorides striatus	Green-backed Heron
	Calidris tenuirostris	Red-necked Stint
	Chilodonia hybrida	Whiskered Terns
	Egretta alba	Great White Egret
	Egretta eulophotes	Chinese Egret
	Egretta garzetta	Little Egret
	Gorsachius goisagi	Night Herons
	Numenius phaeopus	Whimbler
	Nycticorax caledonicus	Rufous Night Heron
	Sterna hirundo	Terns
	Tringa brevipes	Grey-tailed Sandpiper
	Tringa glareola	Wood Sandpiper
	Tringa hypoleucos	Common Sandpiper
	Tringa nebularia	Greenshank
	Tringa stagnatilis	Marsh Sandpiper
	Tringa Totanus	Red Shank
		Long-toed stint
		Sharp-tailed sandpiper
B. Mammals	Balaenoptera edeni	Dolphin spp.
	Macaca fascicularis	Philippine Monkey
	Small cetaceans	Marine mammals
	(Pteropodidae)	Bats
II Fauna specifically reported from the forest part of Pagbilao (Quezon National Forest Park)		
A. Birds	Buceros hydrocorax	Rufous Hornbill
	Ceyx melanurus	Philippine Forest Kingfisher
	Corvus enca sierramadrensis	Luzon Little Crow
	(Alcenidae)	Spotted Wood Kingfisher
B. Mammals	Batomys grantii	Philippine Rind Rat
	Cervus rusa philippinensis	Philippine Deer
III Birds typical of the Philippine mangrove forest (expected to occur in the Pagbilao mangrove forests)		
	Aegithia tiphia	Commonm Iora
	Cyornis rufigastras	Mangrove Blue Flycatcher
	Halcyon capensis	Stork-billed Kingfisher
	Halcyon chloris	White-collared Kingfisher
	Lalage nigra	Pied triller
	Nectarina calcostethe	copper-throated Sunbird
	Nectarina sperata	Purple-throated Sunbird
	Orthotomus sericeus	Rufous-talied Tailorbird
	Pachycephala grisola	Mangrove Whistler
	Streptopelia bitoquata	Island Collared Dove

Sources: Protected Areas and Wildlife Bureau, DENR, Davies et al., 1990.

Table A2. Major Plant Species of the Pagbilao Mangrove Reserve, By Zone.

A. Seaward Portions
Nipa (Nypa fruticans
Bakauan lalaki (Rhizophora apiculata Bl.)
Bakauan babae (R. mucronata Lamk)
Api-api (Avicennia officinalis L.)
Pagatpat (Sonneratia alba J. Smith)
B. Middleward
Tangal (Ceriops tagal (Perr.) C.B. Robins
Pototan (Brugiera sexangula (Lour.) Poir)
Api-api (Avicennia officinalis L.)
Buta-buta (Excoecaria agallocha L.)
Saging-saging (Aegiceras corniculatum (L.) Blco.)
Tinduk-tindukan (A. floridum Roem. & Schult.)
Piagau (Xylocarpus moluccensis (Lamk.) Roem.)
Gapas-gapas (Camptostemon philippinense (Vid.) Becc.)
Pototan lalaki (Bruguiera cylindrica (L.) Bl.)
Malatangal (Ceriops decandra (Griff) Ding Hou)
Tabau (Lumnitzera littorea (Jack.) Voigt.)
Taualis (Osbornia octodonta F. Mueller)
C. Landward
Api-api (A. officinalis L.)
Pi-api (A. marina (Forsk.)Vierh. var rumphiana(Hallier) Bakh.)
Dungon-late (Herritiera littoralis Dryand. ex. W. ait.)
Lagolo (Acrostichum aureum)
Buta-buta (Excoecaria agallocha L.)
Acanthus sp.
D. Riverines
Lagolo (A. aureum)
Nipa (N. fruticans)
Pagatpat (Sonneratia alba J. Smith)
Pedada (S. caseolaris (L.) Engl.)
Busain (Bruguiera gymnorhiza (L.) Lamk.)
Bakauan lalaki (R. apiculata Bl.)
Bakauan babae (R. mucronata Lamk)
Api-api (A. officinalis L.)
Pi-api (A. marina(Forsk.)Vierh. var rumphiana (Hallier)Bakh.)
Bungalon (A. marina (Forsk.) Vierh)
Nilad (S. hydrophyllaceae Gaertn.)
Tabigi (Xylocarpus granatum Koen.)

Table A3. Taxonomic identification of fish species found in the Pagbilao mangrove reserve.

Species	Family	NMC 1982	de la Paz Aragones	Pinto (1985,1988)	Fortes 1994
Total species		26	110	128	37
Total genera		25	73	82	
Total families		21	47	54	26
Total orders		6	13		
Chanos chanos	Chanidae	x	x	x	x
Epinephelus malabaricus	Serranidae		x	x	x
Epinephelus suillus	Serranidae			?	x
Epinephelus sexfasciatus	Serranidae				
Epinephelus quoyanus	Serranidae				
Lutjanus johni	Lutjanidae		x	x	
Lutjanus argentimaculatus	Lutjanidae	x	x	x	
Lutjanus russelli	Lutjanidae		x	x	
Lutjanus fulviflamma	Lutjanidae		?	?	
Siganus guttatus	Siganidae	x	x	x	x
Siganus javus	Siganidae	x	x	x	
Siganus fuscescens	Siganidae	x	?	x	x
Scatophagus argus	Scatophagidae	?	x	x	x
Valamugil cunnesius	Mugilidae	?	?	?	
Lisa tade	Mugilidae		?	?	x
Leiognathus equulus	Leiognathidae		x	x	?
Leiognathus splendens	Leiognathidae		x	x	
Leiognathus brevirostris	Leiognathidae	x	x	x	
Gazza minuta	Leiognathidae		x	x	
Cynoglossus abbreviatus	Cynoglossidae		?	?	
Pseudeorhombus arsius	Bothidae		x	x	
Apogon amboinensis	Apogonidae	x	?	?	x
Gerres filamentosus	Gerreidae	x	x	?	x
Sillago sihama	Sillaginidae	x	x	x	x
Sillago aeolus	Sillaginidae		?	?	
Lethrinus miniatus	Lethrinidae		?	?	?
Scolopsis taeniopterus	Nemipteridae				
Scolopsis affinis	Nemipteridae				
Nemipterus nematophorus	Nemipteridae				x
Upeneus tragula	Mullidae		x	x	x
Upeneus sulphureus	Mullidae		x	x	x
Sphyraena forsteri	Sphyraenidae		?	?	x
Strongylura incisa	Belonidae		?	?	
Tylosurus indicus	Belonidae		?	?	?
Scomberiodes tol	Carangidae		x	x	?
Alepes melanoptera	Carangidae				x
Therapon jarbua	Therapontidae	x	x	x	x
Pelates quadrilineatus	Therapontidae		x	x	?
Platycephalus indicus	Platycephalidae	x	x	x	
Cymbacephalus nematophthalmus	Platycephalidae			?	
Inegocia japonica	Platycephalidae			?	
Stolephorus commersonii	Engraulidae		?	?	x
Sardinella hualiensis	Clupeidae		?	?	?

Table A4. Habits and other characteristics of selected fish species found in the Pagbilao mangrove reserve.

Species	Habitat	Habit	Social Groupings	Trophic Level	Food Items
Chanos chanos	E	S, B	Pg, Gr	H	algae, invertebrates
Epinephelus malabaricus	M	BP	So	C	fishes, crustaceans
Lutjanus spp.	M	BP	So, Pg	C	shrimps, fish
Siganus spp.	M	BP	Pg	H	algae, diatoms
Liza tade, Valamugil cunnesius	E	BP	So	H	algae, diatoms, plant detritus
Leiognathus spp., Gazza sp.	M	BP	Gr	C	copepods, polychaetes, plant detritus
Apogon amboinensis	M	BP	Gr, Pg	C	shrimps, fish, plant detritus
Gobiidae	R, E	B	So, Pg	C	amphipods, isopods, nematode, plant detritus
Ambassis spp.	E	BP	Gr	C	zooplankton. shrimp, plant detritus
Cynoglossus abbreviatus	M	B	So,Pg	C	crustaceans, forams,diatoms, plant detritus
Pseudorhombus arsius	M	B	So	C	crustaceans, fishes
Gerres filamentosus	M	B	Pg	C	invertebrates, plant detritus
Sillago sihama	M,E	BP	Pg	C	annelids, crustaceans
Stolephorus commersonii	M	S	Gr	C	copepods, other crustaceans, plant detritus
Megalops cyprinoides	E,M	P	So,Pg	C	small fishes
Elops machnata	M	P	So	C	amphipods, isopods, nematodes, plant detritus

Source: Pinto (1985).

Legend: E= estuarine, M= marine, R= riverine; B= benthic, P= pelagic, BP= benthopelagic, S=surface; So= Solitary, Pg= pair, Gr= gregarious; H= herbivorous, C= carnivorous.

Table A5. Estimates of sustainable production of forest products for various management alternatives.

Forest Product	Management alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
I. Potentially Marketable								
A. Fuel wood (m^3/year)	0	184	65	42	0	0	35	99
1. Subsistence	0	184.4	0	0	0	0	0	99.4
2. Commercial	0	0	65.2	42.3	0	0	35.0	0.0
B. Timber (m^3/year)	0	46	207	134	0	0	111	25
1. Subsistence	0	46.4	0	0	0	0	0	25.1
2. Commercial	0	0	206.7	134.1	0	0	110.8	0
C. Charcoal (m^3/year)	0	31	0	0	0	0	0	22
1. Subsistence	0	31.2	0	0	0	0	0	22.3
2. Commercial	0	0	0	0	0	0	0	0
Sub-Total (Timber)	**0**	**262**	**272**	**176**	**0**	**0**	**146**	**147**
D. Nipa shingle (1000/year)	0	45.0	45.0	0	0	0	22.5	22.5
II. Ecological contribution								
Nutrient prod. (1000kg./year)								
Nitrogen	70.1	28.6	28.6	22.1	4.2	4.2	20.4	20.4
Phosphorus	23.7	23.0	23.0	17.8	3.4	3.4	16.4	16.4
Potassium	5.7	5.6	5.6	4.3	0.8	0.8	4.0	4.0

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes: Charcoal is zero in commercial forestry as production is not in commercial quantity.

Source: Carandang and Padilla. 1996. Assessment of forest resources of the Pagbilao mangrove Forest. Resources, Environment and Economics Center for Studies, Philippines, and Institute for Environmental Studies, Free University, The Netherlands.

Table A6. Valuation of Forest Products.

	Subsistence Forestry	Commercial Forestry	Unit (pesos)
A. Nipa Shingles			
Market price per shingle	2.9	2.9	per piece
Transport cost	0.2	0.2	
Gathering costs	0.9	0.9	
Shadow price	2.2	1.8	
B. Timber Products			
i) Timber alternative: coconut lumber			
Market price (4.50 pesos/bd.ft)	1,907	1,907	per m^3
Transport cost	40	40	
Gathering costs	303	303	
Shadow price	1,644	1,564	
ii) Fuel wood alternative: upland fuel wood			
Market price (5 pesos/bundle of 0.010 m^3)	500	500	per m^3
Transport cost	310	310	
Gathering cost	0	0	
Shadow price	810	190	
iii) Charcoal: Valuation is similar to fuel wood	810	190	per m^3

Source: Carandang and Padilla. 1996. Assessment of forest resource of the Pagbilao mangrove forest. Resources, Environment and Economics Center for Studies, Philippines, and Institute for Environmental Studies, Free University, The Netherlands.

Notes:

- Gathering of nipa shingles. One person can fill up one boat-load of nipa shingles over 3 hours of work. One boat-load is equivalent to about 40 shingles. Total harvest in a 6-hour-day work is 80 shingles. Imputed cost is the income to be earned from a 6-hour fishing trip where average catch is 2-3 kg equivalent to 75 pesos/day if price of fish is 30 pesos/kg. This brings the gathering cost at 0.9 pesos per shingle.
- Timber harvesting. Volume of wood harvested in 5-6 hours of work (including travel time) is about 0.577 m^3, all of which can be loaded to a carabao-drawn cart. Imputed cost is also based on income from fishing which is estimated at approximately 130 pesos per m^3. The cost of transporting timber from the forest at forest at 100 pesos (173 pesos/) per m^3 trip. Total gathering cost is the sum of the two. Cooking with liquefied petroleum gas (LPG) is not considered as the appropriate substitute considering high costs from: a) capital investment in gas stove and the gas tank; and b) uncertainty in availability of refills particularly in areas like Pagbilao.
- Fuel wood harvesting. Four bundles (0.04 m^3) may be gathered in about 6 hours travelling to a site 200 meters away. It is assumed that non-working family members do this task and hence the opportunity cost is close to zero and is assumed to be zero in this case.
- In subsistence forestry, the use value of the forest products derived from the mangroves should be net of the gathering cost. When households are denied access to mangrove forest resources, the value attached to the forest products is equivalent to the cost they incur in obtaining alternative products. Such cost is equal to the market price of the alternative product plus the transport cost from the market to the point of use. Thus, the shadow price of forest products is the market price of the alternative product plus the transport cost less gathering costs.
- In a commercial forestry regime, it is assumed that the co-operative's objective is to maximise the value of net benefits to be derived from the forest. Net benefit is the stumpage value which is equal to the market price of the good less the costs of transport, extraction and related costs incurred in managing the forest.

Table A7. Estimates of annual production and value of market-size fishes taking into account natural mortality of various fish species (kg/ha/year).

	Alternatives					Fish Prices
	PR	SF/CF	AS	SI/IA	CF/IA SF/IA	(pesos/unit)
A. Quantity of Production (kg/ha/yr)						
Mangrove Residents						
Slipmouths (3 spp.)	50.9	49.5	38.2	0.0	12.7	20
Cardinal fish (1 sp.)	2.2	2.1	1.6	0.0	0.5	20
Glass fishes (2 spp.)	360.9	351.2	271.4	0.0	90.2	20
Gobies (4 spp.)	4.4	4.2	3.3	0.0	1.1	20
Crabs (1) in #	297.2	289.2	223.4	29.7	74.3	2.7
Mud crabs (1) in #	416.7	405.4	313.3	41.7	104.2	12.5
Mangrove Transients						
Milk fish (1 sp.)	0.4	0.4	0.3	0.0	0.0	50
Rabbit fishes (2 spp.)	0.2	0.2	0.2	0.0	0.0	20
Mullets (2 spp.)	2.3	2.2	1.7	0.0	0.2	20
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0	90
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0	80
Shrimps (4 spp.) in #	1261.1	1226.9	948.1	63.1	189.2	1
B. Value of Production						
Mangrove Residents						
Slipmouths	72.1	70.2	54.2	00.0	18.0	
Cardinal fish	01.9	01.8	01.4	00.0	00.5	
Glass fishes	658.9	641.0	495.3	00.0	164.7	
Gobies	05.0	04.8	03.7	00.0	01.2	
Crabs	97.1	94.5	73.0	09.7	24.3	
Mud crabs	638.0	620.7	479.7	63.8	159.5	
Sub-total	**1,472.9**	**1,433.0**	**1,107.3**	**73.5**	**368.2**	
Mangrove Transients						
Milk fish	00.7	00.7	00.5	00.0	00.0	
Rabbit fishes	00.0	00.0	00.0	00.0	00.0	
Mullets	00.6	00.6	00.4	00.0	00.1	
Groupers	00.0	00.0	00.0	00.0	00.0	
Snappers	00.0	00.0	00.0	00.0	00.0	
Shrimps	16.2	15.8	12.2	00.8	02.4	
Sub-total	**17.5**	**17.0**	**13.2**	**00.8**	**02.5**	
Total	**1,490.4**	**1,450.0**	**1,120.5**	**74.3**	**370.7**	

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Source: Ong and Padilla. 1996. Assessment of fisheries functions of the Pagbilao mangrove forest. Resources, Environment and Economics Centre for Studies and Institute for Environmental Studies, Free University, The Netherlands.

Notes:

- Production estimates are adjusted by the percentage deviation of fish sizes caught in Sukol Creek from market sizes. Length measures are first converted to weight. These are then adjusted for adjusted downwards to reflect production of the entire forest. For simplicity, this is assumed to represent losses from natural mortality as the fish grows to market sizes.
- Fish prices listed on the rightmost column are adjusted by the percentage deviation of fish found in the creek to market sizes. This adjustment represents level of dependence of fish on the mangroves. Further, the value of fish in-situ is equivalent to 12.25% of market prices.

Table A8. Aquaculture production and computation of present value of net Profits for each management alternative over 25 Years.

	Management alternative				
	Semi-intensive aquaculture: Milk fish	Intensive aquaculture: Crop Rotation	Intensive aquaculture and commercial Forestry	Intensive aquaculture and Subsistence Forestry	Aqua-silvi-culture
Production (1000kg)	596.90	240.86	88.55	88.55	179.32
Average Prices (pesos/kg)					
-Milk fish	60	60	60	60	60
-Prawn		185	185	185	
Gross Revenue (1000pesos)	35,814	36,347	13,363	13,363	10,759
Variable Costs (1000pesos)	9,148	14,851	5,460	5,460	2,748
Gross Profit (1000pesos)	26,666	21,496	7,903	7,903	8,011
Less: Development Costs (1000pesos)	42,840	85,680	31,500	25,740	12,870
Present Value of Net Profits over 25 years (1000pesos)	112,365	35,850	13,180	13,180	33,757

Notes:

- NPV of gross profits is adjusted for one crop failure every 5 years. Revenues are 50% less every five years.
- Development costs for intensive aquaculture are estimated at P400,000 per ha when exchange rate is P11/US$.
- It is assumed that development costs moved with the exchange rate, hence, it is estimated now at P900,000 per ha. when exchange
  rate is at P25/US$.
- Development cost for semi-intensive ponds is assumed 50% of the amount.
- NPV is computed using a discount rate of 15 percent.

Table A9. Value of annual production of different marketable products for each management alternative 1000 pesos/year).

	Alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
I Forest Products								
Fuel wood	0	149.364	12.388	8.037	0	0	6.650	80.514
Subsistence	0	149.364	0	0	0	0	0	80.514
Commercial	0	0	12.388	8.037	0	0	6.650	0
Timber	0	76.282	323.279	209.732	0	0	173.291	41.264
Subsistence	0	76.282	0	0	0	0	0	41.264
Commercial	0	0	323.279	209.732	0	0	173.291	0
Charcoal	0	25.272	0	0	0	0	0	18.063
Subsistence	0	25.272	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	18.063
Nipa shingle	0	99.000	81.000	0	0	0	40.500	47.250
Sub-Total	**0**	**349.918**	**416.667**	**217.769**	**0**	**0**	**220.441**	**187.091**
II Aquaculture	0	0	0	5648	18800	9294	3417	3993
III Capture Fisheries	164.987	160.515	160.515	124.039	8.225	8.225	41.036	41.036
Residents	163.050	158.633	158.633	122.578	8.136	8.136	40.760	40.760
Transients	1.937	1.882	1.882	1.461	0.089	0.089	0.277	0.277

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:

- The value of forest products is derived from Tables A5 and A6;
- The value for fisheries is computed by multiplying total value in Table A8 by 110.7 ha.

2. THE USE OF ENVIRONMENTAL FUNCTIONS TO EVALUATE MANAGEMENT STRATEGIES FOR THE PAGBILAO MANGROVE FOREST

A.J. Gilbert and R. Janssen

2.1. Introduction

Mangroves are salt-tolerant trees or shrubs found along low-energy, tidal shorelines between latitudes in tropical and subtropical areas (approximately between 30°N and 30°S). They colonise newly formed tidal flats in the wind and wave shadows of promontories and islands, and behind wave-absorbing sand bars and seagrass beds (Carter, 1988). As much as 75 percent of low-lying tropical coastlines with freshwater drainage support mangrove ecosystems (WRI and IUCN, 1986). Mangroves provide the basis for complex and extensive ecosystems at the interface of terrestrial, freshwater and marine ecosystems (e.g. Mann, 1982; Carter, 1988; Robertson and Alongi, 1992).

Mangroves are part of rich ecosystems providing a variety of environmental goods and services. The exploitation of mangrove resources is usually not intensive in traditional subsistence economies, and settlement is quite sparse. In South East Asia this was attributed to the scarcity of freshwater for domestic use and the unsuitability of mangrove soils for long-term agricultural use. Recently exploitation of mangrove forests has intensified as traditional economies become increasingly market-integrated and modernised. The building of roads, provision of amenities in these areas, and improvements in technology have provided the impetus. As a result of this transition in use of mangrove forests, mangroves in the Philippines were reduced from their original 288,035 ha. in 1970 to 123,400 ha. in 1993.

Underestimation of their value and of the impacts of human activities is a major factor contributing to the widespread loss and degradation of mangrove and other ecosystems. Economists frequently receive the blame for such environmental ills. However, it can also be argued that ecologists inadequately communicate their knowledge to decision makers and therefore have limited influence. Our paper links information supplied by ecologists to the information required for effective and efficient mangrove management.

Ecologists face two difficulties. The first is that an anthropocentric viewpoint is often seen as incompatible with the study of ecology. Consideration of human activities tends to be 'added-on', much as the environment is 'added-on' to economics. The second is the high degree of interconnectedness within and between ecosystems. This makes it difficult to predict what is going to happen let alone understand what is going on. These two aspects are addressed in this paper through the concept of 'environmental function' used in combination with systems diagrams. The result is qualitative information on the direction and desirability of ecosystem changes under alternative management regimes.

This chapter aims to demonstrate the use of environmental functions to evaluate management strategies for the Pagbilao mangrove forest.

The structure of this paper is as follows:

- Description of the study site (Section 2.2).
- Specification of the environmental functions (Section 2.3).
- Description of feedbacks and linkages using systems diagrams to identify and value goods and services produced by the mangrove forest (Section 2.4).
- Specification and valuation of management alternatives assuming sustainability (Section 2.5).
- Assessment of the changes in these values should sustainability conditions fail (Section 2.6).
- Conclusions and recommendations (Section 2.7).

2.2. The Pagbilao Mangroves

The municipality of Pagbilao is located in the southern part of Quezon Province on the island of Luzon, the Philippines. It has an area of 15,820 ha, a population of 41,635 (1990) and an annual population growth rate of 2.77%. The original area of mangroves in Pagbilao is not known but can be deduced from the existing area of mangroves and brackish water fishponds. In 1984 the total area of mangrove forest was around 693 ha. Of this, 396 ha were within public forest lands while 297 ha were owned privately (RP-German FRI Project, 1987). Today, what remains of the public forest land is the Pagbilao mangrove forest, 111 ha experimental forest under the jurisdiction of the Department of Environment and Natural Resources. The legal basis of the experimental forest is Presidential proclamations 2151 and 2152 which, in 1981, declared certain islands and/or parts of the country to be wilderness areas. These laws withdrew much of the remaining stands of mangrove from entry, sale, settlement and other forms of disposition. The primary purpose of these proclamations was to preserve these ecosystems.

Figure 2.1 shows Pagbilao Bay. The island of Pagbilao Grande and coral reefs separate the bay from the larger Tayabas Bay. Tayabas Bay, including Pagbilao Bay, is listed among the most seriously threatened wetlands in Asia (Scott and Poole, 1989). The Pagbilao mangroves occupy the delta of the Palsabangan River and are almost surrounded by fishponds. The forest is second growth with an average age of 20 years. It has the largest number of true mangrove species of any stand in the Philippines - its 19 species comprises 56% of all mangroves. In terms of the number of tree species, associates and variations in topography and substrate, it is the also the most diverse (NRMC, 1980).

Wildlife populations, particularly of the larger vertebrates, are probably somewhat reduced due to the small size of the remaining mangrove stand. Shore birds are the most apparent wildlife species. Around 20 species have been recorded feeding in drained and disused fishponds, on mudflats at low tide, or roosting in the mangroves at high tide. Piscivores, such as kingfishers, are common and also supplement their diet, at considerable risk, with fish from the fishponds. The mangroves are a crucial stepping stone in bird migration paths through the Philippines, e.g. the Brahminy kite (Haliastur indus). Their loss could be expected to cause increased stress and thereby mortality in these populations (Ong, pers. comm.). Few mammal populations remain. The endangered Philippine monkey, Macaca fascicularis, would once have inhabited the mangrove forests. Bat populations are present and contribute to the local economy through the collection of their guano. Marine mammals (dolphins and small cetaceans) have also been recorded.

Pagbilao Bay, with its mangroves and coral reefs, is one of the richest, natural marine areas in southern Luzon. Pinto (1987) records 128 species of fish belonging to 54 families from the mangroves alone. Crustaceans (such as prawns and crabs) and molluscs (especially gastropods) are also abundant. Catch data show that a number of fish species were represented by juveniles of typically offshore species such as snappers (Lutjanus spp) and groupers (serranids).

The mangroves have traditionally been exploited by local communities for minor mangrove products such as vines (handicrafts), gastropods and crabs (food), Nipa leaves and wood (construction), plants and fungi (medicines). In the 1970's they were cut for commercial fuel wood and charcoal, and this was a major cause of degradation. These activities (with the exception of shell and crab collection) have been prohibited since 1981. However illegal cutting of pole-sized trees is still evident (Carandang and Padilla, 1996).

Fishpond development occurred primarily in the 1980's on sites where the mangrove cover had been degraded. Mangrove strips were maintained to stabilise the dikes and embankments surrounding the ponds. Aquaculture in the study area is exclusively monoculture of milkfish (Chanos chanos) by extensive or semi-intensive means (Figure 2). Fishponds are owned by wealthy individuals (a general and an ambassador own fishponds in the study area) who neither live in the municipality nor employ local residents to manage them.

There is a trend in the Philippines towards more intensive aquaculture - higher stocking density, more frequent cropping, use of artificial feeds, fertilisers and pesticides (Padilla and Tanael, 1996). Surpluses and wastes from the ponds are released into the nearby aquatic environment and so may enter the mangrove ecosystem. Soils under mangroves are often acidic and, since acidic soils are not suitable for aquaculture, lime may be applied during construction and/or preparation of ponds for stocking. This may lead to the discharge of very alkaline effluents into the aquatic and mangrove environments.

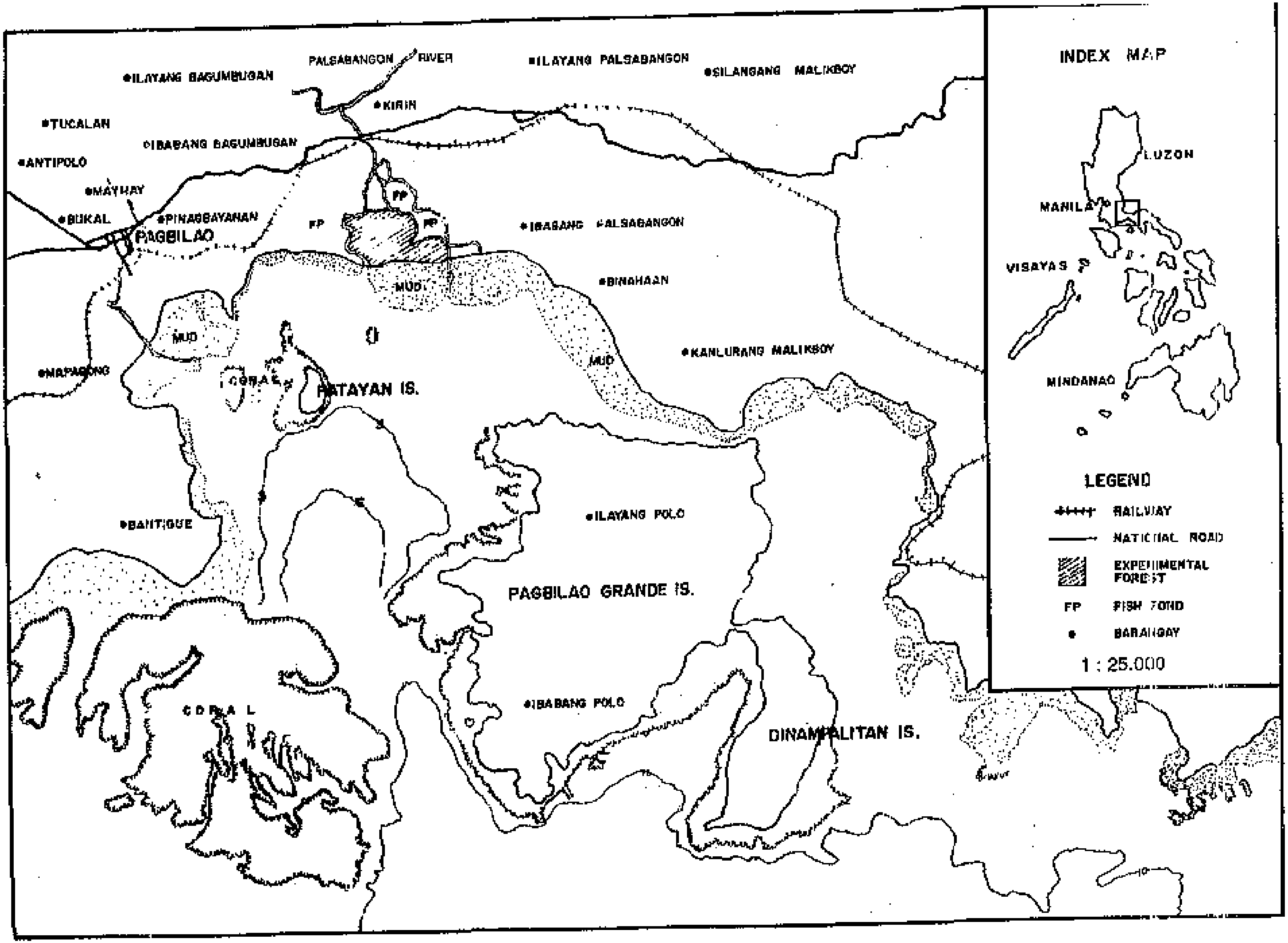


Figure 2.1. The Pagbilao region.

Figure 2.2. Fishponds near the Pagbilao mangrove forest.

The coastal villages of Pagbilao are dependent on the ecosystem's support of fishery resources which include mud crabs and gastropods (found in and near the mangroves), marine crabs, fish and prawns (taken from the bay). Commercial fishing using trawls is prohibited in the bay, and so the catch is taken using artisanal techniques - corrals, traps, bottom set gill nets, and hooks and lines.

2.3. Environmental functions of mangroves

The purpose of this section is to define and elaborate on the concept of environmental function and so to specify the environmental functions of the Pagbilao mangroves. A variety of terms, such as functions, uses, attributes, products, and amenities, have been used to describe what the natural environment contributes to human societies and so to provide ecology with an anthropocentric perspective. These terms have been applied both to specify and to classify the full range of ecological values for inclusion in management deliberations. The term 'environmental function' is used here. Environmental function has been defined as the provision of environmental goods and/or services by the natural environment for human use (e.g. Braat et al., 1979; Groot, 1992). Groot may also be credited with giving the term form by devising a lucid terminology and classification of functions (Figure 2.3). A total of 37 functions grouped into four categories - regulation, carrier, production and information - are identified.

Mangroves perform nearly all of these functions. However, there is a high degree of interaction among them. For example, all of the production functions are ultimately dependent on the regulation functions 'fixation of solar energy and biomass production', 'storage and recycling of organic matter' and 'storage and recycling of nutrients'. The 'storage and recycling of wastes and surpluses' by mangrove ecosystems also contributes to the 'regulation of the chemical composition of the oceans'. 'Fixation of solar energy and biomass production' also contributes to the 'regulation of the chemical composition of the atmosphere' and also to the 'regulation of local and global climate'. While the long list of environmental functions supports the argument that mangroves are valuable, interdependencies among functions lead to complication and ultimately to confusion. Communication is more effective if the message is simple. Further, it is legitimate to ask why two or more functions should be specified if the ultimate result is only one good or service.

The following definition of 'environmental function' has been adopted:

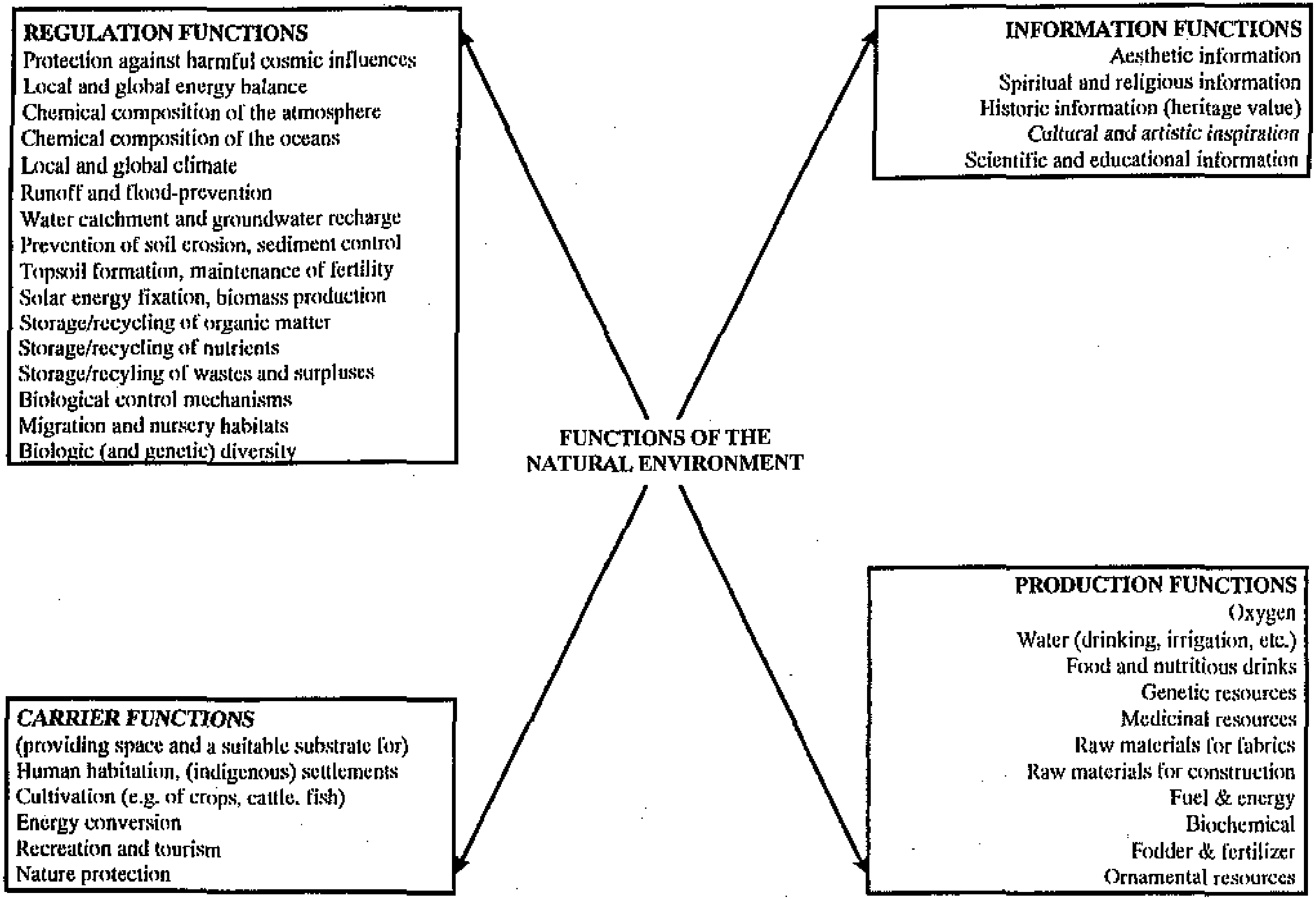
> **a set of ecological processes responsible for the provision of an environmental good or service for human use.**

The main feature of such a definition is the one-on-one match between environmental function and good/service. Further, identification of environmental functions is driven by specification of the goods or services produced. This adds weight to the anthropocentric perspective for ecologists, as well as encouraging economists to take ecosystems more into consideration.

Goods and services from mangrove ecosystems

This section discusses the range of environmental goods and services provided by mangrove ecosystems as a first step to identifying the environmental functions of the Pagbilao mangroves (following section). The discussion is based on IUCN (1983), Fisilier (1990), James (1991a&b), Ruitenbeek (1992), Groombridge (1992) and Hirsch and Mauser (1992).

Food and beverages from mangrove ecosystems include fish, crustaceans, shellfish, sea cucumbers, other invertebrates, wildlife, honey, condiments, vegetables, tea substitutes,


REGULATION FUNCTIONS
Protection against harmful cosmic influences
Local and global energy balance
Chemical composition of the atmosphere
Chemical composition of the oceans
Local and global climate
Runoff and flood-prevention
Water catchment and groundwater recharge
Prevention of soil erosion, sediment control
Topsoil formation, maintenance of fertility
Solar energy fixation, biomass production
Storage/recycling of organic matter
Storage/recycling of nutrients
Storage/recyling of wastes and surpluses
Biological control mechanisms
Migration and nursery habitats
Biologic (and genetic) diversity
INFORMATION FUNCTIONS
Aesthetic information
Spiritual and religious information
Historic information (heritage value)
Cultural and artistic inspiration
Scientific and educational information
FUNCTIONS OF THE NATURAL ENVIRONMENT
CARRIER FUNCTIONS
(providing space and a suitable substrate for)
Human habitation, (indigenous) settlements
Cultivation (e.g. of crops, cattle, fish)
Energy conversion
Recreation and tourism
Nature protection
PRODUCTION FUNCTIONS
Oxygen
Water (drinking, irrigation, etc.)
Food and nutritious drinks
Genetic resources
Medicinal resources
Raw materials for fabrics
Raw materials for construction
Fuel & energy
Biochemical
Fodder & fertilizer
Ornamental resources

sugar, alcohol, cooking oil, vinegar and fermented drinks. Traditional medicines may also be derived from (plant, fungal, etc.) species. Fish and crustaceans are caught or grown in ponds located within the mangrove ecosystem. Mangroves may also provide fodder for livestock during the dry season. Mangrove ecosystems also supply raw materials. Wood, leaves, Nipa shingles and tannins are used in building and construction. Tannins are also used in the making of clothing and household fabrics. Raw materials for industrial purposes include timber and pulp/chipwood from commercial forestry operations and products from plantations of Nipa fruticans which is used to make alcohol for biochemical industries. Via firewood collection and the making of charcoal mangroves supply fuel and energy products. Juvenile fish and shellfish suitable for (aqua)cultivation may be captured in mangrove ecosystems. Mangrove propagules may be collected, reared in nurseries then transplanted in (government-sponsored) reafforestation and afforestation programs[7]. Ornamental resources, especially feathers and flowers, may be derived from mangrove ecosystems.

Species taken from non-mangrove environments, in particular offshore fish and shellfish, may still constitute an environmental good of mangrove ecosystems. Mangrove ecosystems are widely held to be primary nursery areas for commercially important species (e.g. MacNae, 1974; Christensen 1982; WRI and IUCN, 1986) and may contribute to offshore productivity via the outwelling of detritus (e.g. Carter, 1988). These paradigms have come into question in recent years (e.g. Ong, 1984 in Fisilier, 1990; Robertson and Duke, 1987; Parrish, 1989; and Thollot et al., 1991). It would appear that the picture is much more complicated: the nursery function may be different for different species; some mangroves act more as a sink rather than as a source of detritus; considerable interaction occurs among mangroves and nearby sea grass beds, coral reefs and mud flats.

Mangroves stand anchored in inter tidal and supra tidal substrates which are frequently waterlogged and anoxic. The problem of supplying air to the roots is solved by above-ground root systems (see Figures 2.4 and 2.5) which are an essential element of this ecosystem's physical structure. These root systems retard water flow, which leads to a number of environmental services. The quiet environment not only encourages sediments to settle but also inhibits their resuspension. Stabilisation of sediments provides protection to shorelines and associated shore-based activities, and can even lead to progradation and land gains. Further, the resistance which mangroves offer to water flow is of particular service during extreme weather events such as cyclones, typhoons, hurricanes. Mangrove ecosystems mitigate against flooding and flood damage by dissipating the energy of floodwaters.

Mangrove ecosystems function as a sink. Sedimentary processes as well as uptake by organisms filter through-flowing waters, incorporating extracted substances in the sediments and/or in the ecosystem's biomass. Substances may derive from natural sources

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[7] This activity occurs in the study area. It was not identified in the literature cited.

as well as various human activities such as agriculture (fertilizer and pesticide surpluses), industry (industrial wastes) and settlements (sewage). Consequently mangrove ecosystems may perform a waste disposal service. The location of fishponds in or adjacent to mangrove ecosystems is, in part, dependent on this service. Mangroves are also a sink for carbon dioxide, and so play a role in mitigating against the Greenhouse Effect.

Figure 2.4. Mangroves on the coastal edge of the Pagbilao mangrove forest.

Interest in species found in mangrove ecosystems may be direct (e.g. as a source of food) or indirect. Indirect interest tends to stem from a general appreciation of life and the desire for it to be available for future generations. These interests may be expressed passively or actively (ecotourism). Specific aspects within this biodiversity issue include endangered species, migratory species and species with potential commercial value (e.g. to the pharmaceuticals industry). Ecotourism linked to migratory species may not be in the vicinity of the mangrove ecosystems at all, and may even occur in another country.

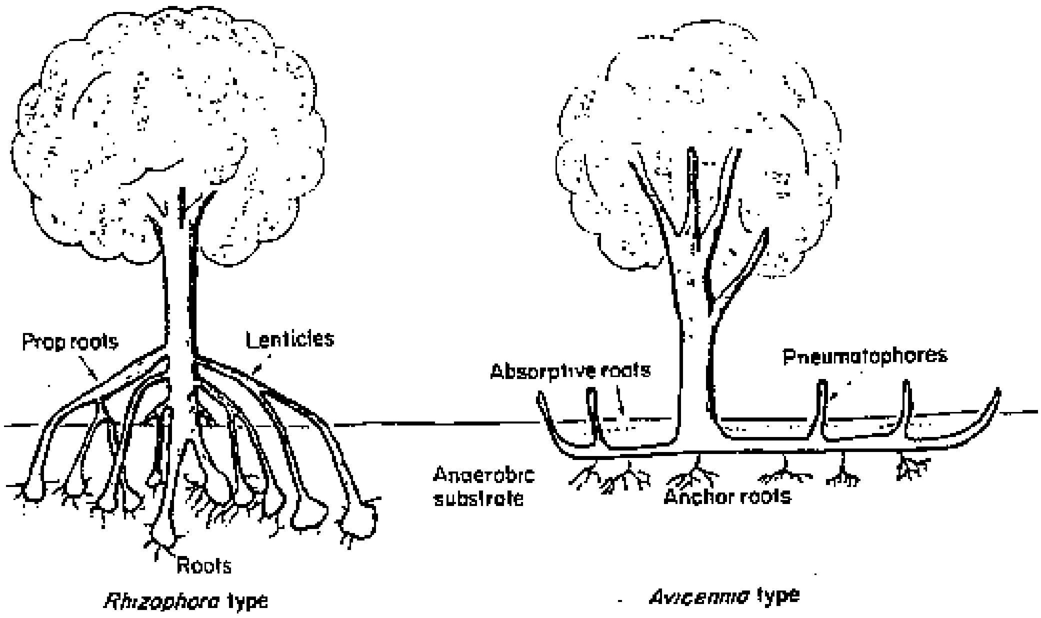

Figure 2.5. Growth forms of the mangrove species Rhizophora and Avicennia.

Mangrove ecosystems also provide the space and a suitable substrate for human activities. Human settlements may be located within or in the vicinity of mangroves and may be populated by indigenous peoples with subsistence lifestyles dependent on the ecosystem. Mangroves also provide space for cultivation. Aquaculture, rice cultivation and Nipa palm plantations may be located in or adjacent to mangrove ecosystems. Recreation and tourism are not activities that spring to mind when considering mangroves, but ecotourism associated with mangroves is developing. Legislation may be enacted to give protection to mangrove ecosystems from (over)use and development.

Mangroves provide services which are associated with knowledge. The knowledge that mangrove ecosystems and associated species exists provides an aesthetic service to some individuals. Others acquire spiritual and religious, or cultural and artistic inspiration. This is particularly the case for indigenous populations. Heritage values as well as scientific and educational information may also be derived. Finally, mangrove ecosystems may provide disservices, such as facilitating the breeding of malaria-carrying mosquitoes.

Environmental functions of the Pagbilao mangroves

Table 2.1 identifies a diversity of environmental goods and services provided by the Pagbilao mangroves (a subset of those discussed in the previous section), the environmental functions and ecological processes involved in their provision, and current and potential users of the natural mangrove forest. The terminology of Groot (1992) is used with some modification. The production of water (for use by fishponds) is, for the sake of simplicity, accredited to the mangroves. Technically it is a product of the environment which mangroves occupy. No disservices are identified. Malaria does not occur in the study area.

Table 2.1. Environmental functions of the Pagbilao mangroves.

ECOLOGICAL PROCESSES	ENVIRONMENTAL FUNCTION	GOOD OR SERVICE	USER
Hydrological cycle	Production of water	GOODS: Water	Aquaculture adjacent to mangrove forest
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients Maintenance of nursery & migration habitats	Production of food & nutritious drink	Offshore fish & shellfish On-site crabs	Artisanal fisheries
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients	Production of other biotic resources	Medicinal resources	Local communities
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients	Production of raw materials for building, construction & industry	Wood, leaves, tannins, Nipa shingles	Local communities Aquaculture adjacent to mangrove forest
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients	Production of fuel & energy	Wood, charcoal	Local communities
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients Maintenance of nursery & migration habitats	Production of juveniles for cultivation	Mangrove propagules	Government (afforestation and reafforestation programs)

Table 2.1. Continued.

ECOLOGICAL PROCESSES →	ENVIRONMENTAL FUNCTION →	GOOD OR SERVICE →	USER
		SERVICES:	
Sediment control Fixation of solar energy & biomass production Storage/ recycling of wastes & surpluses	Regulation of environmental quality	Disposal of wastes and surpluses Uptake of carbon dioxide	Aquaculture adjacent to mangrove forest Global population
Sediment control Buffering of storms	Prevention of soil erosion	Shoreline protection	Local communities Aquaculture adjacent to mangrove forest
Buffering of storms	Flood mitigation	Flood mitigation	Local communities Aquaculture adjacent to mangrove forest
Fixation of solar energy & biomass production Storage/recycling of organic matter & nutrients Maintenance of nursery & migration habitats	Maintenance of biodiversity	Biodiversity	Global population On-site ecotourism Off-site ecotourism
All ecological processes	Scientific & educational information	Knowledge	Scientific & educational community

2.4. Feedbacks and linkages in mangrove use

Table 2.1 shows that some ecological processes are common to more than one environmental function, clearly showing interconnectedness within the ecosystem. Should common processes be compromised, the repercussions could be felt over a wide range of users. Evaluation of alternative management strategies should take into account this wider picture of economic-ecological interaction. The systems diagrams presented in this section offer such an integrated approach. The result is a qualitative model which structures reasoning. The meaning of the various symbols is shown in Figure 2.6. The diagrams make use of the basic building blocks of systems analysis, viz. stocks, flows and other variables. Added to these are environmental goods and services and problem variables (see Figure 2.6).

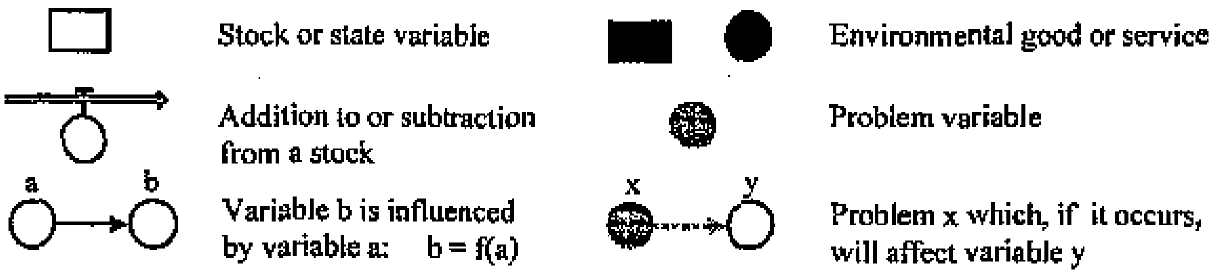

Figure 2.6. Explanation of symbols used.

The systems diagrams are presented in Figures 2.8-2.12; Figure 2.7 shows how the diagrams are linked. The quality of mangrove cover drives the ecological processes (Figure 2.8) which control the environmental functions and so the supply of environmental goods and services (Figures 2.9 and 2.10). Use of these goods and services contributes value to the users (Figures 2.11 and 2.12). An environmental 'problem' develops with overuse where demand for any good or service exceeds its supply. A problem may trigger feedbacks within the ecosystem, or generate costs via linkages between the ecological and the economic systems.

Aggregate land use and ecological processes

Two quality categories for mangrove cover- good and degraded - are identified in Figure 2.8, with degradation and regrowth generating dynamics between them. Mangroves are removed with fishpond development. Historically, this has concentrated on degraded sites. Current information on the profitability of fish farming suggests that the costs incurred in removing mangroves no longer constrain pond development. Fishpond development on sites with good mangrove cover is now possible.

It is assumed that the better the mangrove cover, the better the performance of ecological processes and so of environmental functions. The quality of mangrove cover has a direct influence on two key variables - productivity and physical structure - which direct other ecological processes. The variable 'productivity' is an aggregate of stocks and flows associated with the fixation of carbon and the storage and recycling of carbon and nutrients. Mangrove ecosystems are believed to be highly productive (e.g. WRI and IUCN, 1986). 'Productivity' influences two ecological processes. Firstly, mangrove ecosystems offer a habitat with abundant food for temporary residents. Secondly, by extracting substances from through-flowing waters and incorporating them in biomass, mangrove ecosystems serve to process and recycle wastes and surpluses from adjacent fishponds.

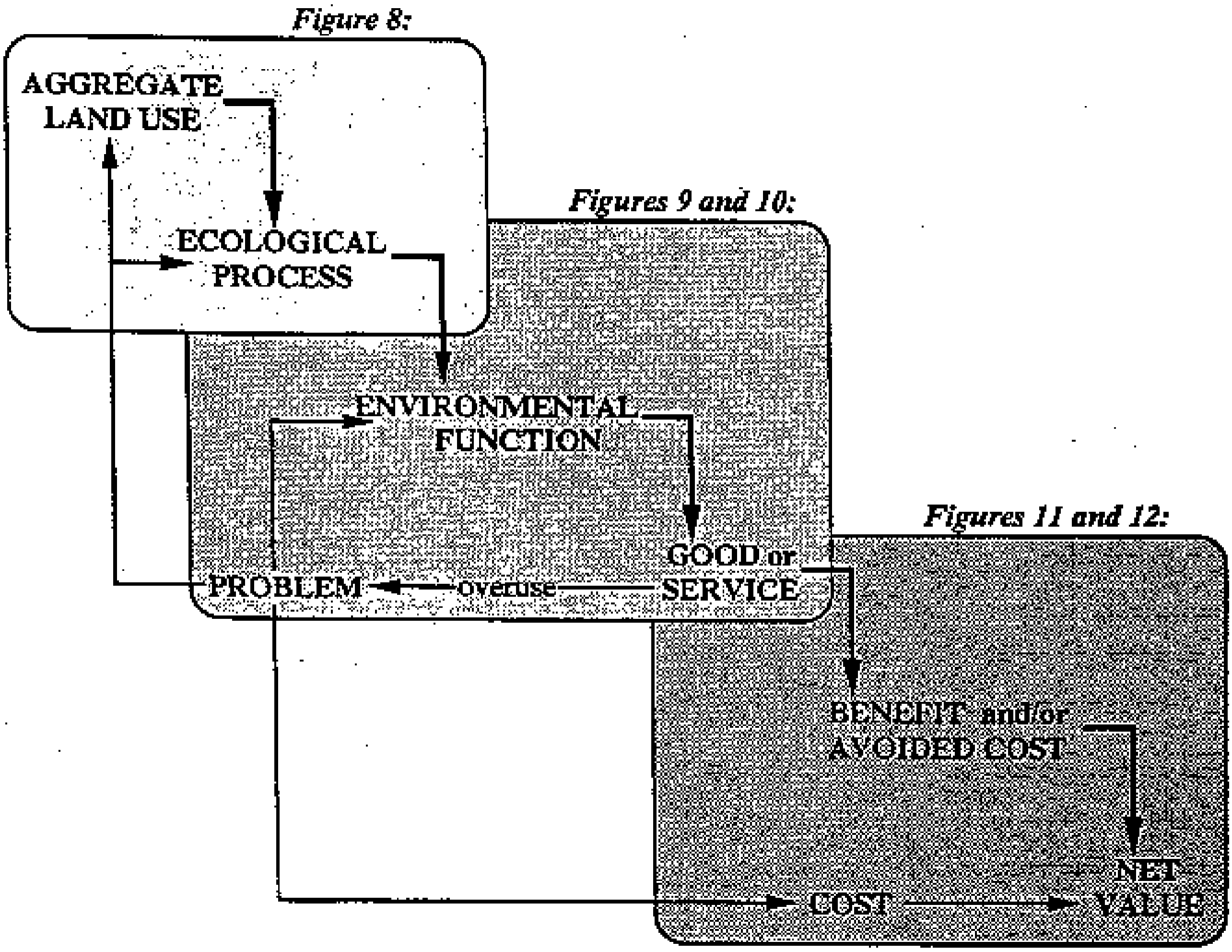

Figure 2.7. Structure of the systems diagrams.

The physical structure of mangroves is largely determined by their above-ground root systems and this contributes to four ecological processes. The quiet environment contributes to habitat, particularly for juvenile aquatic species. The exposure of through-

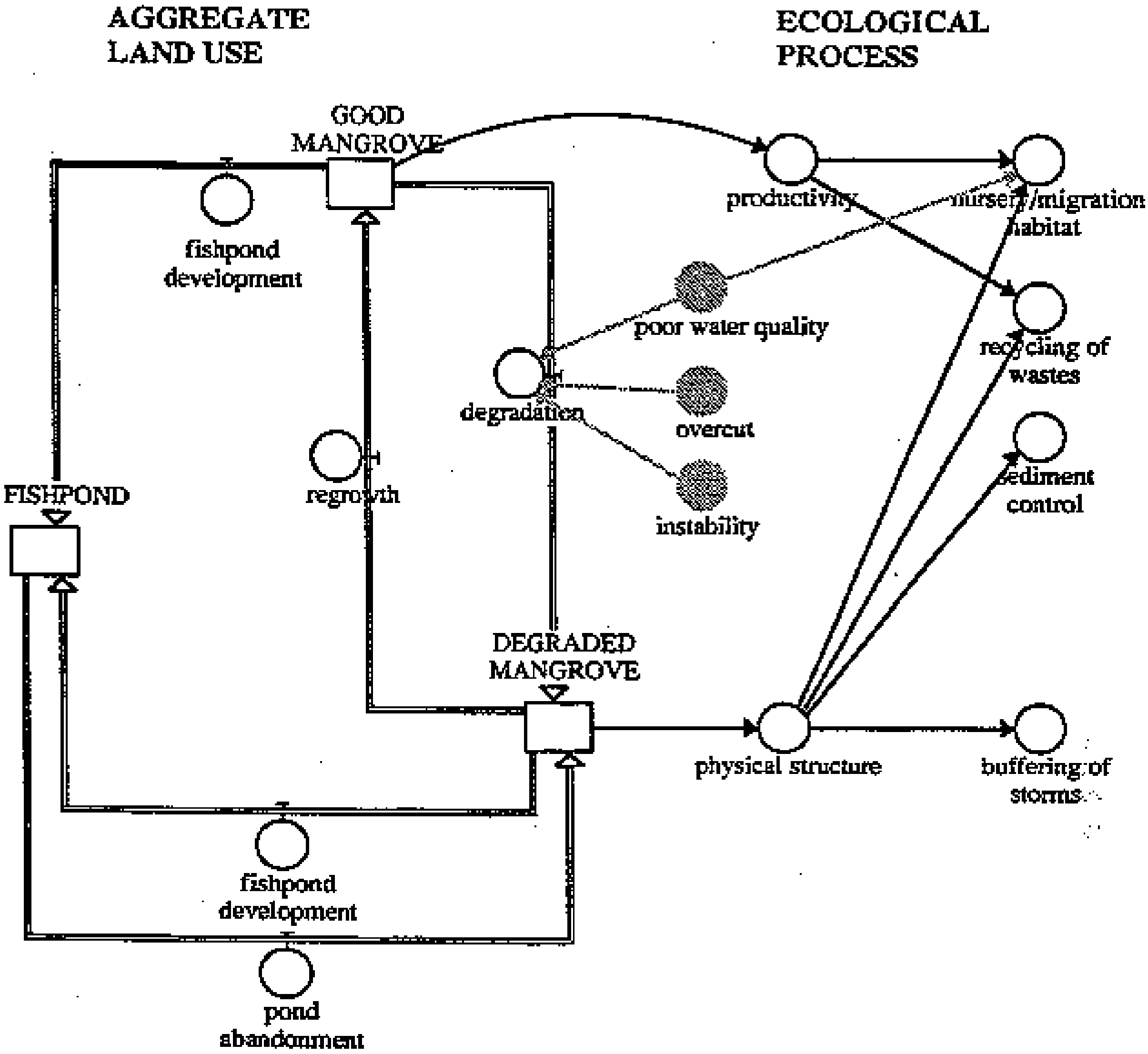

Figure 2.8. Aggregate dynamics and ecological processes.

flowing waters to organisms fixed onto the roots assists in the recycling of wastes. The retardation of water flow, as well as the roots themselves, facilitate sediment control. The physical structure also mitigates against flooding. Three problem variables are also shown in Figure 2.8. These are defined in Figures 2.9 and 2.10. Degradation will be stimulated should these environmental problems occur. Poor water quality also has a direct negative effect on nursery/migration habitat.

The figure implies a smooth transition between all combinations of good and degraded mangrove cover and fishpond development, as well as essentially linear relationships between cover and ecological processes. The real possibility of irreversibilities or discontinuities has not been considered. A key question here is: what is the minimum forest size which could maintain a viable ecosystem? In the absence of information on this point, it is assumed that the current stand is capable of maintaining itself. If such an assumption was unrealistic, then preservation of the Pagbilao mangroves would not be a serious management option.

Production of environmental goods and services

Figures 2.9 and 2.10 describe the production of environmental goods and services by the Pagbilao mangroves. The figures use a common format moving from left to right: - ecological process, environmental function, environmental good or service, and environmental problem. Environmental functions and the goods and services they provide are presented as stock-and-flow combinations. The production of environmental goods is straightforward being, in most cases, based on simple population dynamics with harvesting. No distinction is made between the production of wood for construction purposes or for fuel and energy purposes. Overextraction of environmental goods leads to three problems which, should they occur, trigger costs for users by requiring greater harvesting effort (Figure 2.11). 'Overcut' also feeds back to Figure 2.8 by stimulating ecosystem degradation.

The products of fishponds are not environmental goods and so do not appear in Figure 9. While they may be species, they are still economic goods totally dependent on human inputs; environmental goods are dependent on ecological/environmental processes. A fish farm is a fish factory, no different from a power plant occupying space once covered by ecosystems and using water in its production of a good.

Ecological processes in the mangrove ecosystem may affect the structure of waterways, but beyond this they have little influence on water volumes and flows. Water is used to flush fishponds which also releases contaminated water to the environment. Some portion of these wastes and surpluses enters the mangrove ecosystem where they may be taken up by organisms. The problem variable 'poor water quality' develops if the waste load exceeds the system's capacity for removal. Poor water quality feeds back to Figure 8 by stimulating degradation and adversely affecting habitat. It also triggers costs for aquaculture by killing or retarding the growth of the cultured stock (Figures 2.11 and 2.12). Chemically persistent pesticides, antibiotics, etc. may accumulate in sediments, have direct toxic effects on species, and/or bioaccumulate in food chains. This may lead to adverse effects on biodiversity.

The services 'shoreline protection', 'flood mitigation' and 'biodiversity' are treated similarly. It is assumed that there is a capacity for supplying these services as a result of the quality of mangrove cover. This capacity is represented by a stock. Changes in the quality of cover filters through various ecological processes to cause a change in this capacity. The environmental problems 'sediment instability' and 'flooding' occur if the quality of mangrove cover declines such that insufficient capacity in relation to conditions in the bay remains. Both problems are linked to economic consequences (Figures 2.11 and 2.12) while sediment instability also feeds back to stimulate ecosystem degradation (Figure 2.8). No problem variable is associated with biodiversity. Feedbacks from a decline in biodiversity are uncertain, probably long term, and so have been ignored. Rather biodiversity is viewed as the ultimate indicator of ecosystem quality. Its decline does not trigger costs, merely a reduction in the values derived from this service.

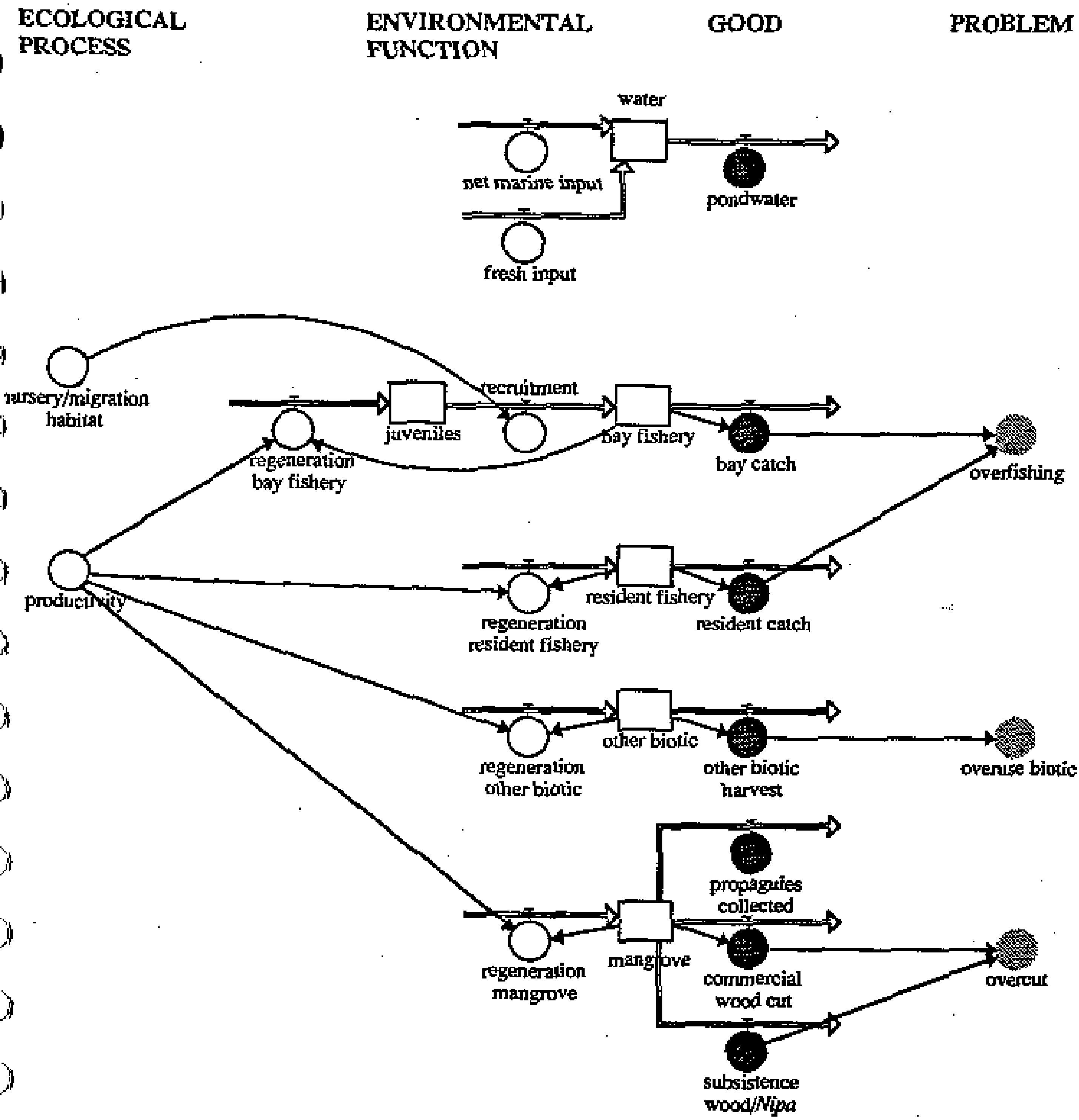

Figure 2.9. Production of environmental goods by the Pagnilao mangroves.

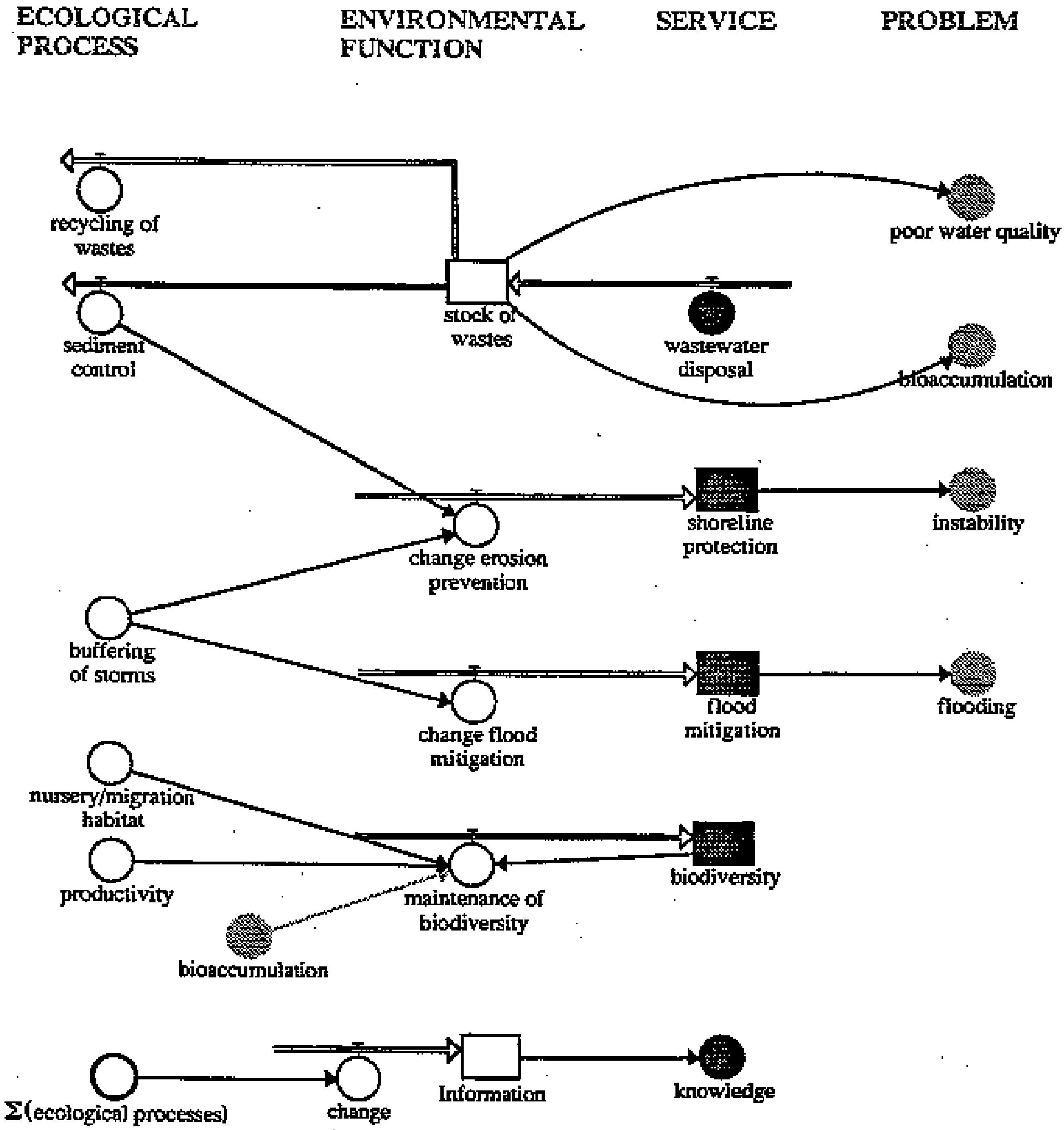

Figure 2.10. Provision of environmental services by the Pagbilao mangroves.

The information content of the ecosystem is assumed to be related directly to the quality of mangrove cover and the performance of ecological processes, as well as subject to changes in cover and performance. The service provided is knowledge, a subset of the total information contained. No problem variable is identified, essentially for the same reasons as with a decline in biodiversity.

Value of goods and services provided by the mangrove forest

Figures 2.11 and 2.12 attempt to capture environmental-economic aspects of using the Pagbilao mangroves. Nine sectors are identified. The approach taken is to imply a net value per sector but considering only 'environmental' benefits and costs. The figures show an annual value derived from using environmental goods and services (flows) accumulating in a net value per sector (stocks). The catch of fish, crabs and shellfish contributes value to the artisanal fisheries. Mud crabs caught on-site comprise about 95% of the value of fisheries. Various goods, mainly for medicines and construction purposes, may be taken by locals from the mangrove ecosystem and so contribute to the value of the subsistence forestry sector. Should the problem variables 'overfishing', 'overcut' and 'overuse biotic' be triggered, costs to these two sectors will rise with increased effort required to harvest these environmental goods.

Aquaculture appears in both figures, its activities split into 'Aquaculture - fish production' emphasises environmental goods, and 'Aquaculture -waste management', which emphasises environmental services. Value accruing to this sector is a function of the area of fishponds (currently zero), water used to flush the ponds, wood used in and around the ponds, and costs avoided by releasing contaminated water into the ecosystem. Costs are incurred should the mangroves be overused as a source of wood; should water quality decline and the stock be killed or its growth retarded; should the ponds be flooded and the stock escape (this occurred during the typhoon in November 1995); and/or should the dikes enclosing the ponds be breached, resulting in the escape of the stock and the need to reconstruct the ponds.

The mangrove nursery derives value from the collection of mangrove propagules. It is assumed in the diagrams that sufficient propagules are available. Commercial forestry derives value from cut wood. Costs are incurred should the problem variable 'overcut' be triggered.

The shoreline protection and flood mitigation services of mangrove ecosystems help governments and private individuals to avoid the costs of constructing, say, dikes to limit storm and erosion damage. Should the frequency and/or severity of flooding increase or erosion of the shoreline occur, the damage control sector would incur costs: repair of existing infrastructure, investment in new infrastructure, and emergency costs if the local population is endangered by extreme weather events. Biodiversity provides an annual value to two sectors, ecotourism and existence value. Migratory bird species which use the Pagbilao mangroves may contribute to ecotourism in, say, Australia. The knowledge gained from the information content of the ecosystem contributes value to the scientific and educational community.

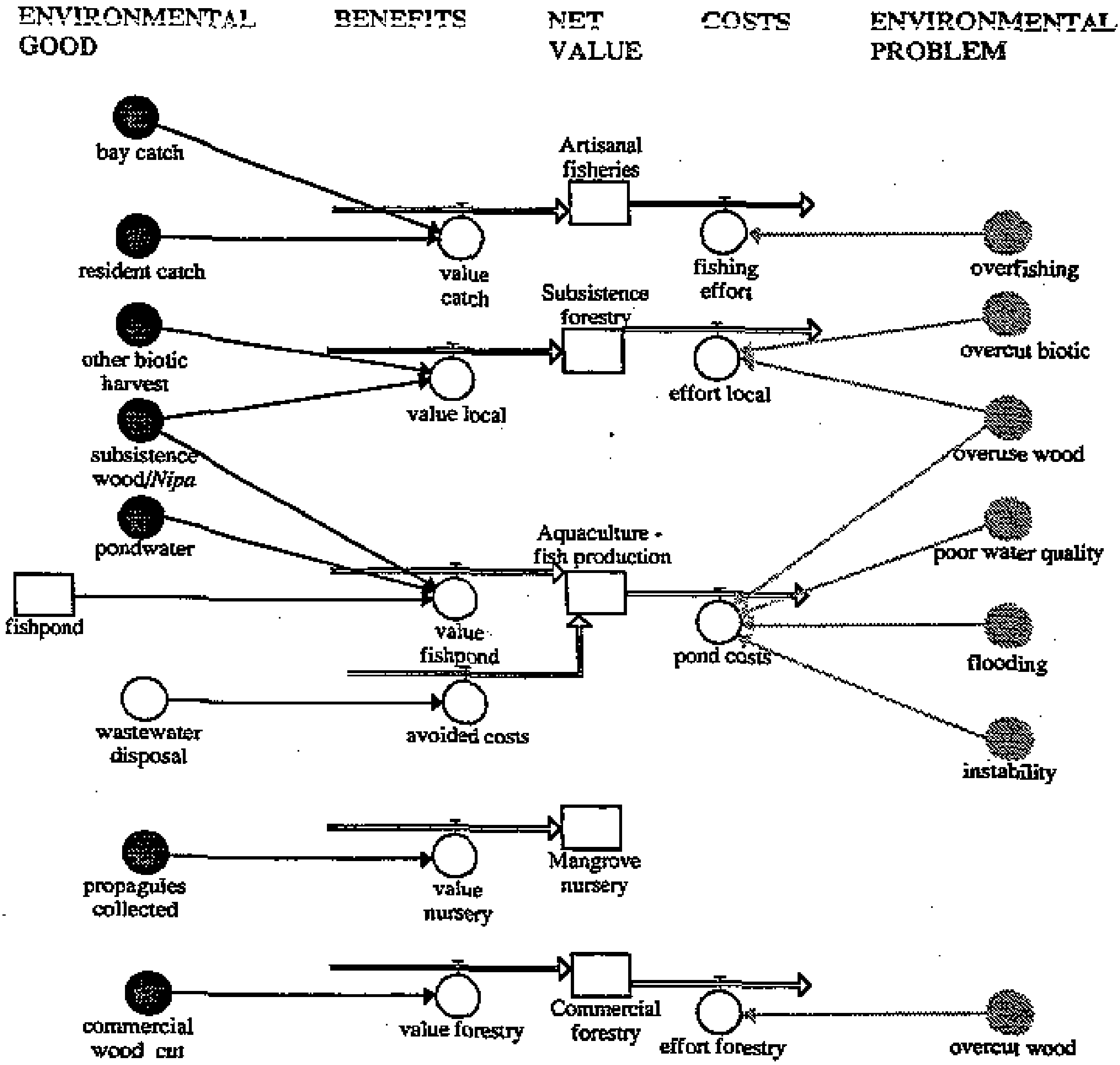

Figure 2.11. Values of environmental goods by the Pagbilao mangroves.

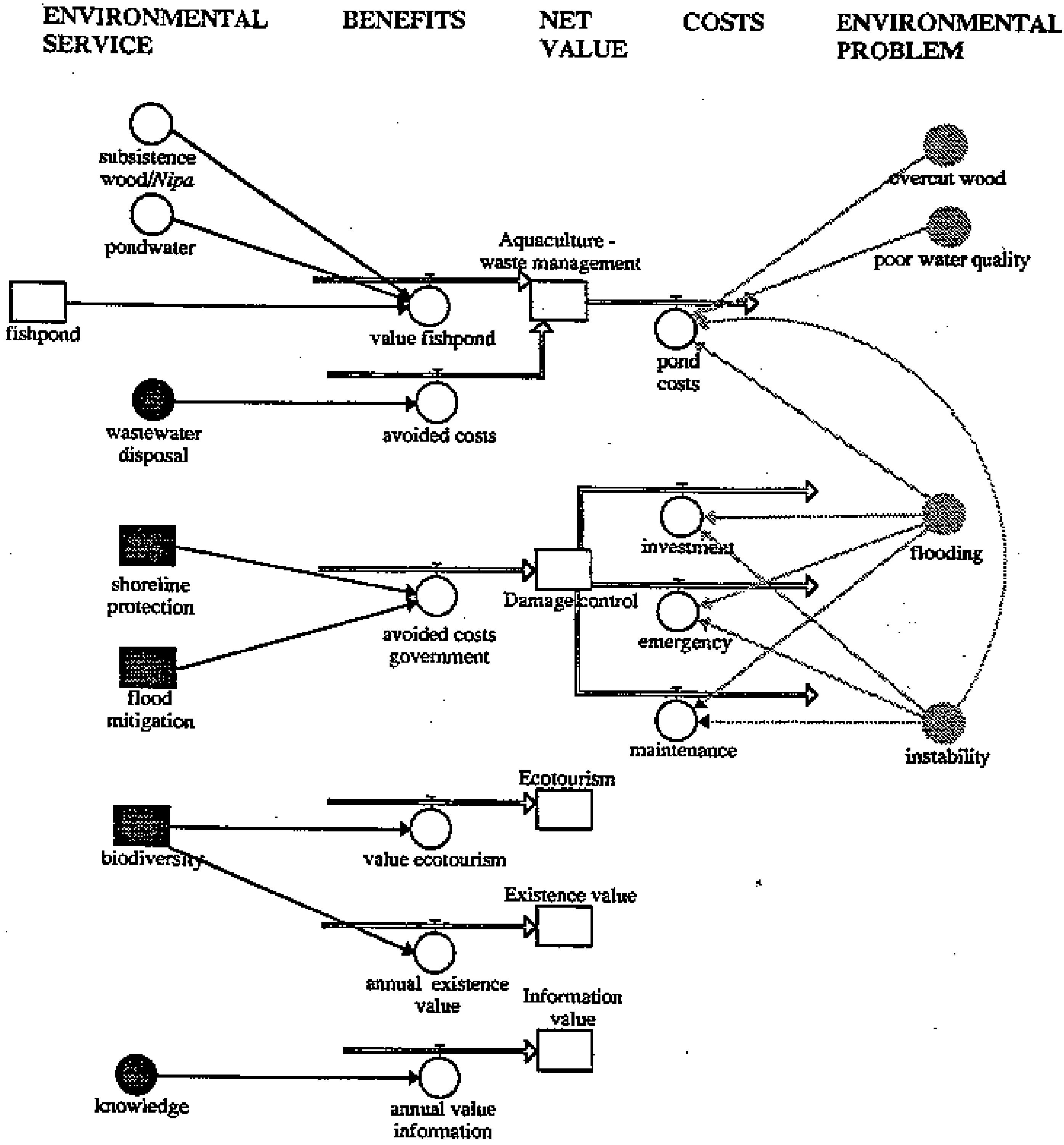

Figure 2.12. Values of environmental services by the Paglibao mangroves.

2.5. Evaluation of management alternatives

Preservation is the current management strategy of the Pagbilao mangrove forest. Only the cutting of mangrove branches for fuel wood and poles and the collection of resident fish, crabs and gastropods is allowed. However there is continuous pressure to convert part or all of the ecosystem to fishponds. An attempt to develop a fishpond without formal approval is now under litigation. Evaluation of different management alternatives for the site of the forest is performed in the following steps:

- specification of management alternatives;
- assessment of goods and services produced for all management alternatives;
- valuation of goods and services produced for all management alternatives; and,
- evaluation of management alternatives.

Comparison of preservation with other management alternatives puts the benefits and cost of preservation into perspective and gives insight into the pressures for change to other types of use. All alternatives involve management regimes that can be considered sustainable under certain conditions. The costs of unsustainability, when these conditions are not met, are analyzed in the next section.

Management alternatives

Eight management alternatives have been formulated and are described below. The conditions under which the alternative may be considered sustainable are also specified. A condition for all alternatives is that poaching is effectively prevented.

1. Preservation: Extraction of forest products (wood, Nipa shingles, biotic resources for medicines etc.) is not allowed, while the gathering of gastropods and crabs from the ecosystem is. Based on past recovery of the ecosystem under its current management regime, it is reasonable to assume that the ecosystem is capable of further recovery under this alternative. This alternative is essentially continuation of the status quo but with effective prevention of poaching.
2. Subsistence forestry: This management alternative recognises the dependence of coastal communities on the mangroves for forest products such as fuel wood, charcoal and poles (timber) for fences and posts. Management of the forest will be in the hands of the communities themselves. To sustain the benefits derived from the mangroves, a maximum allowable cut must be imposed and held constant despite projected increases in the demand for forest products. This alternative is sustainable under the following four conditions: the maximum allowable cut takes into account system-wide effects of use; since the maximum allowable cut is less than current estimated demand for forest products, the shortfall can and will be met by increased imports from mountain areas; information on how the allowed cut should best be taken can be communicated to and implemented by the forest users, and entry into this sector is controlled.
3. Commercial forestry: This alternative provides for exploitation of the mangroves by commercial forestry where a specified commercial volume can be harvested. High value

products are to be harvested, primarily timber with incidental fuel wood from tree branches. Various techniques will be applied to encourage regeneration of the forest. Associated sustainability conditions are: the maximum allowable cut takes into account system-wide effects of use; and, information on how the allowed cut should best be taken can be communicated to and implemented by the foresters.

The following alternatives incorporate aquaculture to varying degrees. A condition for all of these alternatives is the retention of a mangrove strip (buffer zone) of at least 50 meters between ponds and the sea, and at least 20 meters between ponds and waterways. This conforms to current requirements for pond development. It is estimated that the buffer zones will limit storm damage to loss of the stock once every five years on average. Exploitation of this buffer zone will not be permitted.

4. Aqua-silviculture: Excluding the buffer zone, approximately one-third of the mangroves will be converted to fishponds. The culturing technique will be based on the semi-intensive monoculture of milkfish. The remaining mangroves will be contained within the ponds. Litter falling from the mangroves will be captured by the ponds in the hope that this will reduce dependency on artificial feeds. The forest will be harvested sustainably by the fishpond owners for their own needs but may also supplement incomes. The following three sustainability conditions must be met: the buffer zone is sufficient for shoreline stabilisation and flood mitigation; the buffer zone is not exploited; and, wastes released by the ponds into the nearby environment do not overload the system's capacity for self-purification and so good water quality is maintained.
5. Semi-intensive aquaculture: This alternative converts the forest to fishponds and their water distribution system, with the only remaining mangroves in the buffer zones. Ponds will be stocked with milkfish at around 6,000 fingerlings/hectare/crop and managed using semi-intensive techniques. Sustainability conditions are the same as for Aqua-silviculture (4).
6. Intensive aquaculture: This alternative also converts the mangrove stand to fishponds, but management of the ponds is on a more intensive basis (higher cropping densities, more frequent cropping and greater use of food supplements and chemicals). The recommended intensive technology is alternation of intensive prawn farming with extensive or semi-intensive milkfish farming. Sustainability conditions are the same as for Aqua-silviculture.
7. Commercial forestry/intensive aquaculture: This alternative is a mix of alternatives 3 and 6. Excluding the buffer zones, approximately one-third of the mangroves will be converted to fishponds for intensive aquaculture and the remainder will be exploited by commercial forestry. The two activities are separate. Sustainability conditions from alternatives 3 and 6 apply.
8. Subsistence forestry/intensive aquaculture: This alternative is the same as alternative 7 except that the remaining forest, excluding the buffer zones, is exploited sustainably for subsistence forestry products. Sustainability conditions from alternatives 2 and 6 apply.

Effects on goods and services

System diagrams as presented in Section 2.4 were used to identify the effects which each management alternative would have on the production of goods and services. Field surveys were then undertaken to assess current production and changes in production resulting form alternative management regimes. The effects on shore protection, biodiversity and ecotourism linked to the different alternatives could not be quantified. A forestry expert, a marine biology expert and a zoology expert were invited to provide expert judgement on the relative performance of the alternatives with regards to these three effects (Carandang, Guarin, Ong 1996; see also Janssen 1992). Table 2.2 shows the results. Consumption or negative production could occur if an ecosystem drained resources from other systems, for example through export of pollutants or import of clean water. This is not the case for the study site.

Table 2.2. Annual production of goods and provision of services under different management alternatives.

	Unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Goods									
Pond water	—/+++	0	0	0	++	+++	+++	++	++
Bay catch/shrimps	1000/y	140	140	140	104	7	7	21	21
Residential catch/crabs	1000/y	79	77	77	59	8	8	20	20
Other biotic	—/+++	0	+++	+++	+	+	+	+	++
Propagules	—/+++	+++	+++	+++	0	0	0	+	+
Commercial wood	m^3/y	0	0	317	176	0	0	169	0
Subsistence wood	m^3/y	0	307	0	0	0	0	0	170
Nipa shingles	1000/y	0	45	45	0	0	0	23	23
Fishponds: milkfish	tons/y	0	0	0	161	537	59	22	22
Fishponds: prawns	tons/y	0	0	0	0	0	158	57	57
Services									
Wastewater disposal	tons/y	0	0	0	21	41	100	50	50
Shoreline protection	—/+++	+++	+++	+++	++	+	+	++	++
Flood mitigation	—/+++	+++	+++	+++	++	+	+	++	++
Biodiversity	—/+++	+++	++	+	+	0	0	+	+
Knowledge	—/+++	+++	++	+	+	0	0	+	+

Alternatives:
PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: Combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Legend:
+++ large production
++ moderate production
+ small production
0 no production

Production of goods

Resident and transient fish species were sampled to assess fisheries productivity of the mangrove reserve. The fisheries component of this study (Ong and Padilla 1996) also updated information from more thorough studies conducted in previous years (e.g., de la Paz and Aragones 1985; Pinto 1985 and 1988; Fortes 1994). The experimental forest supports both on-site (resident species) and off-site (transient species) fisheries. The estimation of sustainable harvest of fishery resources presented difficulties as the fisheries surveys for this study, as well as previous studies, did not cover stock assessment. Simplifying assumptions were made to arrive at some measure of abundance and productivity. The results show that the experimental forest supports a small on-site fishery and contributes minimally to off-site fisheries. Use of a production function would have provided a more precise approach to assess the impacts of the management alternatives on the value of off-site fisheries. Limited knowledge on the complex interactions involved and total lack data on the size of stocks of fish over time prevented such an approach (Spaninks and van Beukering 1997).

Fuel wood, timber and Nipa shingles are the primary forest products to be derived from the Pagbilao mangrove reserve. Subsistence forestry yields goods demanded by coastal communities, mostly fuel wood, charcoal and poles (timber) for fences and posts. The quantification and valuation of goods and services proceeded from field surveys of the mangrove reserve in 1995. Three zones or ecotones were identified: landward, middleward and seaward. Sample plots were established in each ecotone and tree density, tree dimensions and subsequently wood volume were measured or computed. Litter traps were set to estimate litter fall and to determine nutrient content. Projected timber yield was estimated over time using an empirical equation for the Philippines with age of stand and site index as explanatory variables. Subsistence forestry is estimated to produce about 262 m^3 of wood products compared to 272 m^3 per year by commercial forestry; commercial forestry is therefore the more efficient (Carandang and Padilla, 1996).

The performance of aquaculture ponds converted from mangroves was also assessed (Padilla and Tanael 1996a; 1996b). Several studies were compared to assess the long-term prospects of aquaculture operations in the mangrove reserve. The primary objective was to identify the appropriate (sustainable) aquaculture technology and the corresponding production levels. Conversion of the mangrove forest to fishponds results in high production levels. For Semi-intensive aquaculture production was estimated to exceed 597 tons/year of milkfish; for Intensive aquaculture of prawns alternating with extensive culture of milkfish, estimates of 66 tons/year of milkfish combined with 175 tons of prawns were derived (Padilla and Tanael, 1996a and b).

Production of services

Waste water disposal is an environmental service used only by aquaculture. Padilla and Tanael (1996a and b) were able to quantify use of this service for the various aquaculture alternatives. Intensive aquaculture is the highest user due to higher stocking rates and the use of artificial feeds, pesticides and fertilisers. For non-aquaculture alternatives it is assumed that no use is being made of the waste processing capacity of the mangrove forest. Use of the remaining services is estimated qualitatively. While the buffer zones are intended to secure the coastal plain from erosion and from flooding, their capacity in this regards is still less than that of an intact ecosystem, or of one which is only two-thirds its original size. Biodiversity and knowledge services are most abundant in the Preservation alternative (1) and non-existent for Semi-intensive and Intensive aquaculture (5 and 6). Of the remaining alternatives, subsistence forestry with its softer intervention into the ecosystem is considered to perform best with regards to these services.

Valuation of goods and services

Market prices and shadow prices of substitutes were used to value goods. Market prices of fish observed at local markets during the field surveys were used to value fisheries. It is estimated that 87.75% of the landed price of fish covers the costs of harvesting, the remainder is the value of the fish in-situ (NSCB 1996). The use value of the forest products derived from the mangroves by subsistence forestry is net of gathering cost. When households are denied access to mangrove forest resources, the shadow price attached to the forest products is equivalent to the cost they incur in obtaining alternative products. Such a cost is equal to the market price of the alternative product plus the transport cost from the market to the point of use. Shadow prices for fuelwood and other goods not traded on the market were linked to the cheapest substitute. For commercial forestry net value is calculated using market prices of the timber products less the costs of transport, extraction and related costs incurred in managing the forest. Net value of aquaculture is calculated using data on production, market prices and operating costs of existing fishponds in the vicinity of the study site.

Net value of the management alternatives can be estimated using these results and is shown in Table 2.3. In this table values are combined to show the values produced according to economic sectors in the local economy: bay and residential catch are combined into fisheries, Nipa is included in subsistence and commercial forestry, and milkfish and prawns are combined into aquaculture. Net values linked to other biotic resources and propagules are considered marginal and therefore ignored. Values shown are annual values for the entire study area. Since alternatives are assumed to be sustainable, the time horizon can be assumed to be indefinite. With regards to aquaculture, the long life of ponds in the vicinity, some around 40 years old, lends support to this assumption. Development costs and other capital costs are valued according to the borrowing rate for capital in real terms. Typhoon damage through flooding of the ponds or breaching of the dikes is included as a ten percent reduction of the annual harvest, based on two crops per year and loss of one crop once every five years.

For the five alternatives which permit harvesting of forest products, the highest value is generated by Commercial forestry (3). Aquaculture alternatives perform better than the Forestry (2/3) and Preservation (1) alternatives in terms of the value of goods produced. Semi-intensive aquaculture (5) performs better than Intensive aquaculture (6) due to high development costs linked for the latter and to constraints set by sustainable management of the ponds. However the performance of both alternatives is very sensitive to changes in prices. Milkfish are produced for the local market and their price level is relatively stable. The price of prawns is determined on the world market and shows strong fluctuations. In this study a price of 185 pesos/kg is used for prawns. Should this price increases above 214 pesos/kg the value of goods produced by Intensive aquaculture will be higher than those produced by Semi-intensive aquaculture. Aqua-silviculture performs better than the alternatives combining forestry and aquaculture. Note that the mangrove nursery is unlikely to survive the conversion to fish farming.

Table 2.3. Annual contribution to value by each management alternatives.

	Unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Goods									
Fisheries	1000 pesos	165	161	161	124	8	8	40	40
Subsistence forestry	1000 pesos	0	349	0	0	0	0	0	189
Commercial forestry	1000 pesos	0	0	416	218	0	0	229	0
Aquaculture - fish	1000 pesos	0	0	0	5648	18801	9294	3417	3993
Mangrove nursery	0/+++	+	+	+	0	0	0	0	0
Total goods	1000 pesos	165	510	576	5989	18809	9302	3686	4222
Services									
Aquaculture - waste	0/+++	0	0	0	+	++	+++	++	++
Damage control	0/+++	+++	+++	+++	++	+	+	++	++
Ecotourism	0/+++	+++	++	0	0	0	0	0	+
Existence value	0/+++	+++	++	++	+	0	0	+	+
Information value	0/+++	+++	+++	++	+	0	0	+	+
Total services	0/+++	+++	+++	++	+	+	+	+	+

Alternatives:
PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: Combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Legend:
+++ large production
++ moderate production
+ small production
0 no production

Services are valued only qualitatively in Table 2.3 and an attempt is made to aggregate these sources of value. The improvements to the ecosystem which Preservation (1) provides is felt across all users permitted by this alternative. The main gains are felt by damage control (avoided costs), fisheries, the mangrove nursery, and existence and scientific values. No use is made of the ecosystem's capacity to process wastes, and so this service scores a zero. However, such a capacity exists. The total value from services is considered a maximum for this alternative. Subsistence forestry (2) also scores a maximum, even though this alternative scores somewhat lower with regards to the ecotourism and existence value sectors: harvesting of forest products is assumed to affect biodiversity adversely. Commercial forestry's (2) aggregate score is lower than alternatives 1 and 2. This alternative precludes contributions to ecotourism as well as reducing biodiversity and information values. As with Subsistence forestry, the forest remains intact and so its capacity to mitigate against flooding and prevent erosion is high.

The aquaculture alternatives (4 to 8) score poorly with regards to the system's capacity to provide services for use. While the waste disposal capacity of the system is used in these alternatives, the buffer zones supply only a minimal capacity for damage control. Where more of the stand is kept, this capacity is larger. All alternatives, except that including subsistence forestry (8), preclude any contribution to ecotourism. Some existence and information values remain in alternatives where more mangroves than just the buffer zone are retained.

2.6. Costs of unsustainability

The values of each management alternative were estimated in the previous section. The management alternatives are designed to be sustainable, with sustainability holding under a number of conditions. Failure of these conditions generates costs and/or reductions of benefits. The purpose of this section is to assess what could happen if certain conditions do not hold and the management alternatives fail in being sustainable (see also Parks and Bonifaz 1994). Because sustainability is the norm, the effect of failure to meet this norm may be labelled the 'costs of unsustainability'. Four conditions are tested in this section:

1. Failure of the buffer zones to mitigate against flooding and stabilizing the shore;
2. Excessive extraction of wood
3. Poaching of wood products cannot be prevented; and,
4. Overloading of natural waste management to process and remove wastes and surpluses.

Effects may be traced through Figures 2.5-2.9 by linking failure of a condition with the problem variable triggered and subsequent effects on the supply of environmental goods and services. The link between condition and problem variable is presented in Table 2.4 for each management alternative. Table 2.5 presents total (monetary) value and effects on the provision of environmental services when all sustainability conditions fail simultaneously. The discussion below explains how this table is derived.

Failure of the buffer zones

An essential condition in all alternatives including aquaculture (4-8) is the retention of buffer zones which will ensure sediment stability and mitigate against flooding. If buffer zones are inadequate for these purposes, the problem variables 'instability' and 'flooding' will be triggered (Figure 2.7). 'Instability' stimulates ecosystem degradation (Figure 2.5) and will lead to the poorer performance of all environmental functions.

Both 'instability' and 'flooding' cause direct costs to users (Figures 2.8 and 2.9). The bulk of these costs will be borne by aquaculture which will lose its stock more frequently. Aquaculture alternatives (4, 7 and 8), where more mangrove cover than just the buffer zones is retained, will be less vulnerable to sediment instability and flooding and the impacts of these problems are more

Table 2.4. Problem variables triggered by failure of management conditions.

Condition	PR	SF&CF	AS	SI	IA	CF/IA-SF/IA
Failure of buffer zones			instability, flooding	instability, flooding	instability, flooding	instability, flooding
Excessive wood harvest		overcut				overcut
Poaching of wood products	overcut, instability	overcut, instability	instability, flooding	instability, flooding	instability, flooding	overcut, instability, flooding
Overloading of natural waste management			poor water quality	poor water quality	poor water quality, bio-accumulation	poor water quality, bio-accumulation

Alternatives:
PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: Combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

likely to remain small-scale. There is the risk with Semi-intensive and Intensive aquaculture (5 and 6) that sediment instability could spread beyond the study site and/or that flood waters could penetrate further inland. Damage would then be incurred by more economic activities, with costs borne by the damage control sector.

Excessive extraction of wood

Management alternatives 2, 3, 7 and 8 are based on the sustainable extraction of forest products. A condition with Subsistence forestry (2 and 8) is that entry into the sector can be controlled so that extraction will not exceed a maximum allowable cut. Local demand for wood products already exceeds this maximum (Carandang and Padilla, 1996) and, will only increase with population growth. It is highly unlikely that agreements between government and local communities to limit entry into the subsistence forestry sector will be effective under such pressure, and so over-extraction is inevitable. Similar controls are required for Commercial forestry (3 and 7) to limit harvest to a maximum allowable cut. Given pressure for short-term profit maximization, this condition is also likely to fail.

Excessive extraction of wood triggers the problem variable 'overcut' (Figure 2.6) in all alternatives containing forestry. This, in turn, stimulates ecosystem degradation (Figure 2.5) and poorer performance of environmental functions, with all mangrove users being worse off. The forestry sectors, now with a limited lifetime of activities, will bear the brunt of the costs of unsustainability.

Poaching of wood products

A key condition for sustainable management is the effective prevention of poaching. Under the current management regime, wood is poached by local residents for construction purposes and fuel, and by fishpond managers who use wood for fencing, reinforcing dikes, delivery of feeding supplements and construction purposes. Given the local demand for wood and the difficulties in limiting access to the mangrove ecosystem, it is highly unlikely that poaching can be prevented. Two possible effects of wood poaching are identified.

Firstly, poaching would cause wood harvesting in all forestry alternatives to exceed the maximum allowable cut. It could also lead to a level of illegal wood extraction above the ecosystem's capacity for regeneration within the Preservation(1) alternative given the growing demand for wood products and their increasing availability within the mangrove ecosystem. The problem variable 'overcut' (Figure 2.6) would then be triggered. As discussed above, this would stimulate ecosystem-wide degradation (Figure 2.5) and reduce performance of all environmental functions.

Secondly, poaching will be concentrated in areas of easy access and particularly along the edges of waterways. This may cause bank erosion and even trigger the problem variable 'instability' (Figure 2.7). 'Instability' has implications for degradation (Figure 2.5). In alternatives excluding aquaculture, the impacts of poaching are likely to remain localized. However in alternatives incorporating aquaculture poaching could compromise the buffer zones, with impacts and costs which have been discussed above.

Overloading of natural waste management

All alternatives including aquaculture depend on the natural system's capacity to remove and process wastes and surpluses released into the natural environment. Semi-intensive and extensive aquaculture in Pagbilao Bay has not yet overloaded this capacity, although the possibility exists that even more aquaculture could exceed a threshold and so cause water quality problems to develop. The likelihood of this is greatest with intensive aquaculture techniques which use high stocking rates, chemicals to control pests and diseases, and feeding supplements.

'Poor water quality' is one of two problem variables which could be triggered (Figure 2.7). This not only stimulates degradation, it also has direct impacts on the mangrove habitat (Figure 2.5). Poor water quality causes costs to aquaculture and, if it is persistent, these activities will become uneconomic. This is most likely for Intensive aquaculture (6) and possible for Semi-intensive aquaculture (5). Alternatives 7 and 8, which comprise some intensive aquaculture could experience periodic problems with water quality. It is assumed that this would reduce, but not compromise, the profitability of these activities.

The second problem variable, 'bioaccumulation', would be triggered only by intensive aquaculture through the use of chemicals (see Figure 2.7). Bioaccumulation of persistent micropollutants could have an adverse effect on biodiversity, and so on dependent activities (viz. ecotourism, existence value and information value). However these effects are relevant only for aquaculture/forestry alternatives (7 and 8) since insufficient biodiversity and information remain with Intensive aquaculture (6).

Changes in the ranking of alternatives if all sustainability conditions fail

Failure of the sustainability conditions are not independent events. For example, inadequate enforcement of environmental regulations can result in inadequate buffer zones, excessive extraction, poaching and unauthorized emissions of wastes. Table 2.5 shows for each good and service the range of expected change in value if all sustainability conditions fail simultaneously.

Table 2.5. Change in net annual value if all sustainability conditions are violated simultaneously.

	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Goods								
Fisheries	↓	↓	↓	↓↓	↓↓	↓↓	↓↓	↓↓
Subsistence forestry		↓↓						↓↓
Commercial forestry			↓↓				↓↓	
Aquaculture				↓	↓↓↓	↓↓↓	↓↓	↓↓
Mangrove nursery	↓	↓	↓					
A: total goods (min)	111	227	249	4044	3	3	1789	1775
B: total goods (max)	165	395	440	5949	6398	4622	3525	3498
C: total goods (sust)	165	510	577	5990	18809	1358 5	5261	5221
Services								
Aquaculture					↓↓	↓↓↓	↓	↓
Damage control	↓	↓	↓	↓↓	↓↓↓	↓↓↓	↓↓	↓↓
Ecotourism	↓	↓						↓
Existence value	↓	↓	↓	↓↓			↓↓↓	↓↓↓
Information value	↓	↓	↓	↓↓			↓↓↓	↓↓↓
A: total services (min)	++	++	+	0	0	0	0	0
B: total services (max)	+++	+++	++	+	0	0	0	+
C: total services (sust)	+++	+++	++	+	+	+	+	+

Alternatives:
PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: Combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Legend:

↓↓↓ large reduction in value (67-100%)
↓↓ moderate reduction in value (33-67%)
↓ small reduction in value (0-33%)
no reduction in value

These ranges are combined with the values of goods and services (Table 2.3) to calculate the value of total goods and services. The table provides: A: total goods and services (min) representing the pessimistic end of the ranges (↓,↓↓, ↓↓↓=-33%, -66%,-100%), B: total goods and services (max) representing the optimistic end of the ranges (↓,↓↓, ↓↓↓=-0%, -33%,-66%) and C: total goods and services (sust) representing sustainable conditions as listed in Table 2.3.

From Table 2.5 it can be concluded that violating the sustainability conditions results in a lose-lose situation - the total value of all alternatives decline. Preservation shows a decline because of ecosystem degradation. The forestry alternatives show a decline in long term wood production combined with a decline in the provision of most services. The aquaculture alternatives face a loss in long term fish production. Although the pattern of changes differs considerably between alternatives the ranking of alternatives is relatively insensitive to failure of these sustainability conditions. The rankings associated with Total goods (max) are the same as the ranking under sustainability: with Semi-intensive (5) on the first position and Preservation (1) on the last. However if the pessimistic values (total goods min) are compared with the ranking under sustainability, Semi-intensive aquaculture (5) and Intensive aquaculture (6) shifted to last position. This is the disaster scenario for both alternatives where pollution prevent operations completely. The most likely position between these extremes is difficult to predict. Uncertainty centres on two questions: how much waste can the system manage without water quality declining and at what stage are

the effects of declining water quality irreversible? In general, Semi-intensive aquaculture runs fewer risks than Intensive aquaculture, as does partial conversion to aquaculture compared to conversion of the whole mangrove stand.

2.7. Conclusions and recommendations

In this study ecological and economic information are combined to support the evaluation of management alternatives for the Pagbilao mangrove forest. A key problem which ecologists face is the high degree of interconnectedness within and between ecosystems. This makes it difficult to predict what is going to happen let alone understand what is going on. The concept of 'environmental function' is used in combination with systems diagrams to address this problem. System diagrams are used to identify and assess goods and services produced by the ecosystem under different management regimes. These goods and services are then valued to assess the economic efficiency of the management regimes. This final section assesses the usefulness of the concept of environmental function, summarizes the results of the study and offers recommendations for further research.

Mangroves are complex systems which provide a variety of goods and services for human use. The high degree of interconnectedness within such ecosystems leads to uncertainty and unpredictability. In particular it means that environmental goods and services are rarely produced independently. The concept of environmental function was used in this study to communicate the environmental values of the Pagbilao mangroves. The interface between environmental supply and societal demand for goods and services from the mangroves could then be detailed. This was effective in demonstrating the complexity of ecosystem performance to non-ecologists, and in particular the multiple interdependencies involved in providing environmental goods and services. Systems diagrams were use to envisage ecosystem performance and to 'think through' what the alternative management options and their associated conditions meant in terms of future supply of mangrove goods and services. In combination with valuation of selected products, the evaluation of alternative management regimes was then based on the integration of ecological and economic information.

Although biodiversity is considered crucial to the decision to preserve the forest, it proved impossible to put a monetary value on changes in biodiversity. This raises questions regarding the limitations of valuation. Is it possible to value irreversible effects such as the loss of life, the loss of ecosystems, the loss of species, the loss of works of art etc. Another crucial issue in the case of Pagbilao is the distribution of wealth. The income from the fish ponds is earned by distant investors. Also conversion to fishponds creates areas inaccessible to the local population. Equity issues cannot be addressed adequately using net value as a decision criterion.

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3. ECONOMIC VALUATION OF MANGROVE ECOSYSTEMS: POTENTIAL AND LIMITATIONS

F. Spaninks and P. van Beukering

3.1. 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 3.1). 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 chapter 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.

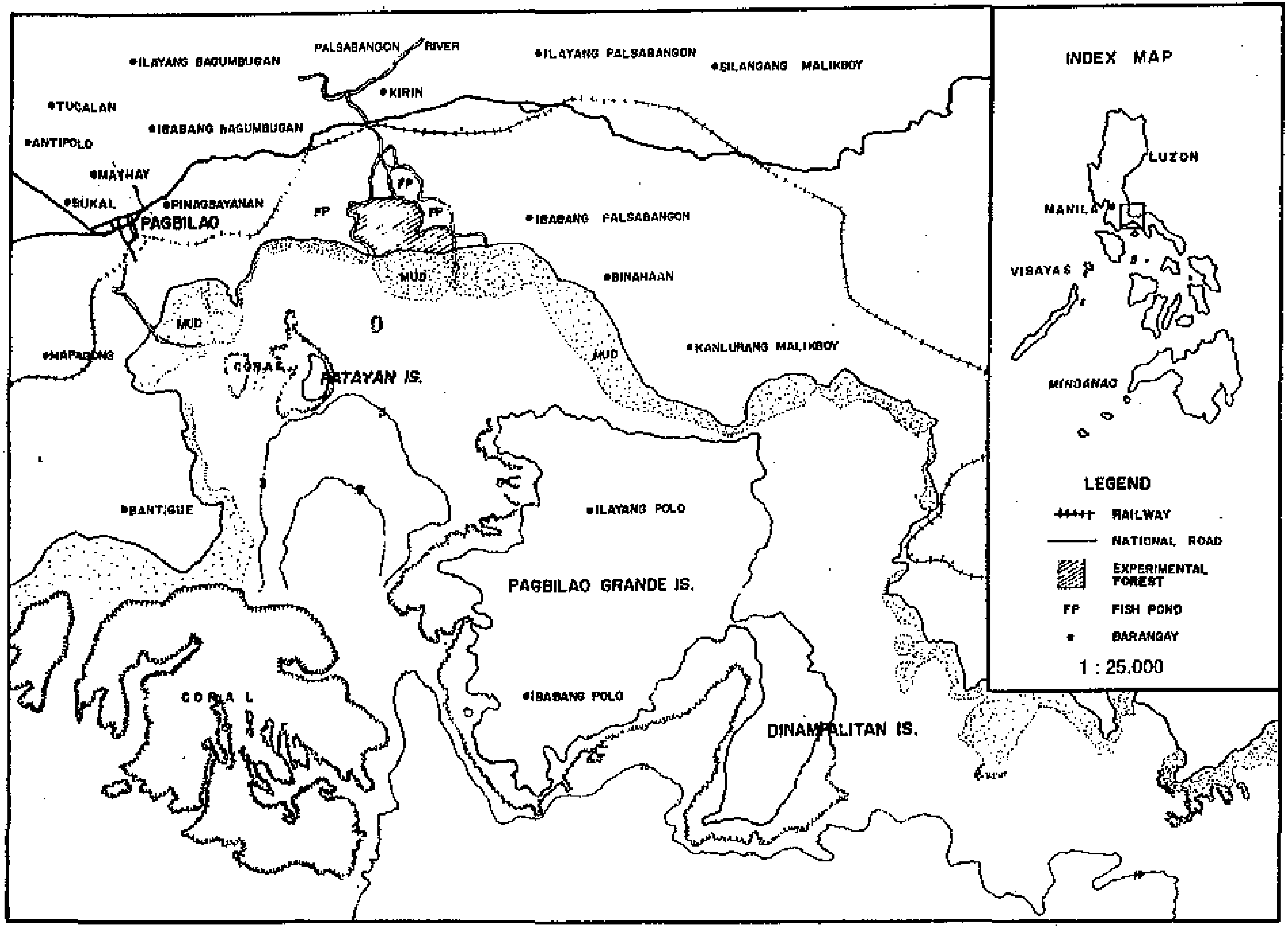

Figure 3.1. Pagbilao Bay

3.2. 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 3.1 and 3.2. Table 3.1 presents the range of values incorporated in the mangrove studies. Values are converted into US$ to facilitate comparison. Table 3.2 summarises the valuation techniques and assumptions which underlie the studies.

Table 3.1. 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$230/ha/year*. -**on-site fisheries**: commercial harvest by small, medium and large scale fishermen of fish, trash fish, prawns and shrimp, based on a weighted market price of US$.0.35/kg. *US$30/ha/year*. -**forestry**: charcoal production is 1 m^3/ha/year (potential of 12 m^3/ha/year). *US$30/ha/year*. -**aquaculture**: the current yield from shrimp farming is 184 kg/ha/year at a price US$.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*. -**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*. -**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*. -**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. -**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. -**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. -**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*. -**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*. -**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*. -**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*. -**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*.

Table 3.1. Continued.

	direct use values	indirect use values & non-use values
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. **-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. **-forestry:** local fuelwood consumption is valued through shadow wage and input cost 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.	**-off-site fisheries:** a pseudo production function including mangrove coverage and effort was used to estimate artesenal

Table 3.2. 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. -**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. -**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. -**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. -**time horizon**: 50 years (no rationalisation). -**environmental linkages**: linkage scenarios varying from 20% to 100% decline in fish harvest if mangroves are destroyed. In main valuation it is assumed that I hectare of mangrove produces 331 kg of fish per annum. -**economic assumptions**: marginal values of labour and capital in fishing and forestry industries are zero. -**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. -**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. -**shadow price**: livestock, fish and fuelwood are corrected for transportation costs at US$ 0.25 per kg. -**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. -**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. -**environmental linkages**: scenarios depend upon impact intensity and impact delay parameters. Various ecosystems (ie. mangrove and fisheries) are linked. -**other assumptions**: 30 year forestry rotation cycle.

Table 3.2. Continued.

Study	Valuation Techniques	Key-assumptions
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. -**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. -**time horizon:** 56 years going till 2050. -**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. -**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 3.3 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 3.3. 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).

3.3. 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.[8] 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 3.4 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 3.4 may comprise an option value component. If it is thought that option values may be important and should be included in the valuation, contingent valuation is essentially the only method capable of measuring these values.

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8 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).

Table 3.4. 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 - potentially medicinal plants - ecotourism	

Table 3.4 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 3.4 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 3.4 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[9] 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 3.4. 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 3.4 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.

3.4. Valuation

Table 3.5 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 3.5, 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

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

products that are not marketed, neither of these methods is appropriate and prices of marketed substitutes would have to be used, if available.

Table 3.5. Linking the products and services with valuation methods.

product/service	applicable valuation methods
forestry products (fuelwood, timber, poles, nipa shingles)	demand/supply analysis market prices 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 averting behaviour (cost of replacement) (rehabilitation cost method) (additional establishment cost) (cost of relocation)
aquacultural products (fish, shrimps)	demand/supply analysis market prices
carbon sequestration	reduction in expected future damage cost from climate change
plants used in traditional medicine	substitute price contingent valuation
biodiversity conservation - potential medicinal plants - ecotourism - non-use value	 expected value of a plant as a source of medicinal substances travel cost method contingent valuation 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 $b*p_m$, where p_u denotes the market price of 1cu.m of upland fuelwood.[10] 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

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10 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.

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)[11]

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 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 3.2. 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

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11 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 tose households that choose to gather is simply the ratio of the market price and the time spent gathering.

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[12].

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).

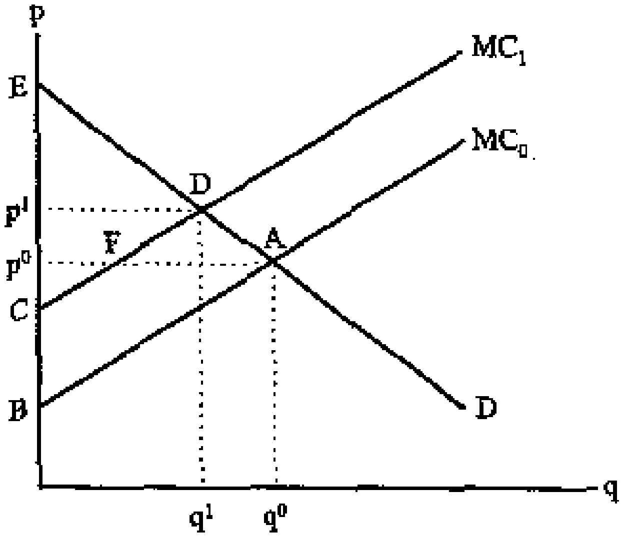

Figure 3.2. The change in consumers' and producers' surplus from a loss of mangrove cover.

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.

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12 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.

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[13]. 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

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[13] 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).

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).

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[14].

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,

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14 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.

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 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[15]. 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

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

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15 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.

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[16]. 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 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

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[16] 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.

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.

3.5. 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

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 3. 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[17]

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[18].

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

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17 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"

18 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).

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

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. Some alternative calculations of the value of the nursery function.

Model: $^{10}\log(\text{catch}) = a + b + {}^{10}\log(\text{mangrove area})$				
Species group	**a**	**b**	**n**	**r**
Cavalia	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 3.5.

Two approaches could be taken to calculate the effect of a loss of mangrove area using the equations in Table 3.5. 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 × 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 3.14.

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 46×0.43=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: I 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 fuel*wood, 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.

PART TWO
TECHNICAL DOCUMENTS

4. ASSESSMENT OF FOREST RESOURCES OF THE PAGBILAO MANGROVE FOREST

Antonio P. Carandang and Jose E. Padilla

4.1. Introduction

This paper presents the findings of the soils and forestry component of the project. The specific objectives of this component are:

a. to describe the structure of the Pagbilao mangrove forest;
b. to estimate the primary productivity of the mangrove forest;
c. to measure the rate of litter fall and its rate of decomposition and equivalent nutrient production;
d. to estimate the potential timber yield of the mangrove forest;
e. to estimate the current and future timber harvesting rates under various management alternatives for the mangrove forest; and
f. valuation of forest-based products that may be derived under each management scenario.

4.2. Structure/Characterization of Pagbilao Mangrove Forests

The town of Pagbilao is located in the province of Quezon in Luzon Island, approximately 180 km Southeast of Manila (Figure 4.1). Its mangrove forests occur on tidal flats at the mouth of Nahalinan and Palsabangon Rivers flowing to Pagbilao Bay and along its shore forming a protective lining to the numerous fishponds which are concentrated starting near the shore towards the inland portions. A southern island called Pagbilao Grande forms part of the mangrove forest which reportedly contains few stands of pure *Rhizophora* species. The Pagbilao Bay area belongs to Type II climate where there is no dry season with very pronounced maximum rainfall from November to January. The sea current patterns prevailing in the coastal waters adjacent to mangrove areas are highly affected by the prevailing wind surface tidal ebb and flow (NMC, 1986). The prevailing currents generally emanate from the eastern portion above Pagbilao Grande Island and along the coast and mouth of rivers towards Tayabas Bay.

4.2.1. Area and land-use

In 1984, the total area of Pagbilao mangrove forests is around 693 ha. Of this, 396 ha are within public forest lands while 297 ha within alienable and disposable (A & D) lands (RP-German FRI project, 1987). Today, much of the 396 ha within public lands is gone with only 110-ha covered by an Experimental Forest under the jurisdiction of the Department of Environment and Natural Resources (DENR). Areas outside experimental forest are heavily exploited except for those used as protection forests for fishponds. The current utilization of the original mangrove forest cover in Pagbilao is shown in Table 1.

Most of the mangrove areas within A & D lands are now covered with fishponds with an area of 297 ha. In public forests lands, fishponds are covered by Fishpond Lease Agreements (FLA) which total 604.57 ha (Table 4.2). Of these, 33 percent remained undeveloped. In fact 3 FLA holders have not started development as of 1993 while others have not fully-developed their areas due to lack of funds. In 1981, Proclamation No. 2151 provided that the whole mangroves of Quezon be declared as wilderness areas, which withdrew them from entry, sale, settlement and exploitation of whatever nature or form of disposition. Thus, conversion of mangroves for fishpond purposes was halted. However, there are still pending and unresolved claims to some of these areas specially those within the degraded portions.

4.2.2. Forest subtypes/species zonation

Pagbilao Bay has the most number of true mangrove species at 19 species compared to other mangrove areas in the Philippines (Table 4.3). This comprises 56% of the total true mangrove species. It also appears to be the most botanically diverse in terms of number of tree species, associates and variations in the nature of topography and substrate (NRMC 1980). The most important of the true mangrove families observed in Pagbilao are the *Rhizophoraceae* and *Aviceniaceae* where the *bakawans* and *api-api* species belong, respectively.

There are three distinct species zones within the Pagbilao mangrove forests namely: the landward, middleward and seaward portions (Figure 4.2 and Table 4.4). The zones are distinct specially in the experimental forest where the area is relatively large. Outside this, the zonation is not distinct as the areas had been exploited and converted to fishponds. A fourth zone which is the riverine portion possesses the characteristic species of the above three zones except that they exist in association with riverine species.

The landward portion is the mangrove part which is the most interior and bordering towards the ecotone[1]. Among the landward species are *nilad, buta-buta, api-api, pi-api, tinduk-tindukan*, etc. Except for *api-api* and *pi-api*, most species in this portion are small in diameter with plenty of thickets underneath. Vines such as *bagnit* and *gatasan* also abound. The middleward portion is the part immediately after the landward and constitute the central portion of the forest. This portion has big trees of *api-api* and *pi-api* abounding together with *busain, pototan, tangal*, and *malatangal*. Likewise, it has relatively clear underneath (forest floor) with vines such as *bagnit* and *gatasan* occurring sparsely. The seaward portion begins from the shore towards the middleward portion. The species common in this portion are *bakawan lalaki, bakawan babae, bagatpat*, etc. Trees are stunted in this portion, a characteristic effect of heavy exploitation in the past. Regenerations underneath are also observed in this part. In the riverine portions, *tabigi, pagatpat, nipa, lagolo, pedada, bagnit*,

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1 An ecotone is a transition area between two adjacent ecological communities usually exhibiting competition between organisms common to both.

and *galivario* (thorny vine) exist in association with the species as observed in the previously described zones wherever the riverine portion is located.

4.3. Primary Productivity

Primary productivity refers to the total of organic matter produced by plants through photosynthesis. In the process of growth, new tissues are formed replacing old tissues of which some are incorporated in the build-up of biomass while others are discarded naturally through litters and root decay. These materials add to the fertility of the soil, and together with trapped debris in the roots of mangrove trees during floods and tide actions, continuously help in the build-up of soil. In case of death, the total biomass adds to the organic matters which enrich the soil.

4.3.1. Wood biomass production

The mangroves of Pagbilao are all second growth with an average age of 20 years. However, the remaining second growth including the experimental forest has been subject to poaching even in recent years. To estimate the current wood content of the forests for trees 10 cm or higher, 12 plots measuring 10m by 10m were established mostly in the landward and middleward portions while those of the seaward portions were estimated using simple estimation during the ocular inspections and in the photographs taken. Table 4.5 shows the summary of plot information taken from the experimental forest.

It was observed that the volume of Pagbilao mangroves tend to be lower on the ecotones, that is, in the landward and seaward portions. In the landward portion, the average plot volume of wood is around 26.67 cu.m. with less than 10 cu.m. in the extreme landward. The average wood volume in the middleward portion is 93.20 cu.m. with some plots having volumes over than 120 cu.m. In the seaward portion, the estimated volume is less than 20 cu.m. per ha. The difference in volume among mangrove zones is explained by disturbances received by the zones relative to their location. The middleward portion is relatively stable and protected by a layer of trees both in the seaward and landward portions. Thus, the trees are bigger and taller. On the other hand, the seaward portion is exposed to strong waves and wind resulting to stunting and slow growth of trees while in the landward portion, the area dries first thus favoring the growth of grasses and other mangrove associates with low wood volume.

4.3.2. Litter fall/litter production

Previous observations in the Pagbilao Bay area show that the average production of litter for all 1-sq m plots/litter traps was 1.54 gOM/day (Fortes, 1993). The results of the study further showed that litter traps under *nilad* (*Scyphiphora hydrophyllaceae*) had the greatest litter fall in terms of weight with 2.48 gOM/m2/day while the last was *taualis* (*Osbornia octodonta*) with 0.83 gOM/m2/day (Table 4.6). Additional litter traps were established to verify the results of previous studies. It was found that the middleward portion produced more litter (1.31 gOM/m2/day) than the landward portion (1.20 gOM/m2/day) (Table 4.7). Species-wise, the most prolific species is *api-api* (2.11 gOM/m2/day in plot no 6, 1.91 in plot no 10), followed by *buta-buta* (1.64 in plot no 3) and Nilad (1.48 in plot No 1). Considering the 10 plots established, the average daily litterfall is around 1.27 gOM/M2. This translates to approximately 4.65 tons of dried organic matter per hectare yearly.

4.3.3. Accretion estimates

The mangroves are capable of land-building through the continuous deposition of both organic and inorganic matters trapped in the roots, stems and pneumatophores of frontline trees. This process of land build-up is called accretion. Out of 13 accretion plots established in Pagbilao, Balangue (1994) observed that 7 plots increased in soil height during the seven month observation period while 6 plots actually decreased in height. The study indicated that there was an average net soil accretion of 2.4 cm for 7 months for all plots.

In ecological viewpoint, soil accretion can be viewed as both beneficial and harmful. Beneficial in a way that the process of land build-up is really a reclamation process. Through time, continuous deposition of inorganic and organic matters on the mangrove areas slowly decreases the tidal reach and pushes the land-mangrove ecotone towards the sea, thus providing ideal conditions for takeover of land species in this ecotone. It also replenishes soil lost due to erosion, thus contributing to shoreline protection. Likewise, because of soil build-up in the mangrove-sea ecotone, new seedlings grow in this shallow portion formerly not occupied by mangrove species. This process adds new areas for eventual mangrove takeover. However, accretion does not only occur in the mangrove but also in the coral fringes as soil and other sediments are washed out due to tidal actions and frequent flooding of rivers. This may slowly kill the corals near the mangrove fringes.

4.4. Potential Timber Yield

The potential timber yield of mangroves depends on the fertility of the site as indicated by its site index (SI). In Carandang et. al. (1994), the following site index guide equation was derived:

ATH	=	6.2833 + 0.0690 * Age
Std. Error	=	0.0151
F (1,34)	=	20.973
Prob	=	0.00006
R-squared	=	0.3815

where ATH is the average total height of trees in the stand while AGE is the approximate age in years of the second growth mangrove stand. The model was accepted because age is a significant explanatory variable for total height considering that the low probability level. Given 36 plots used in the study, no other model using various variable transformations has higher value of R. Besides, no other variable can conveniently predict site index except height because it is the most easily verifiable predictor of site, hence, the variable is used. Through algebraic manipulation, the site index guide equation was transformed into:

SI	=	0.690 - 0.0690 * Age + ATH

With the above equation, it was estimated that the site indices of landward, middleward and seaward zones of Pagbilao mangrove forests are 6.7, 8.1 and 4.5 m, respectively (Table 4.8).

Corresponding to the site indices of different mangrove zones in Pagbilao are the potential timber yield (Table 4.9). This yield table may be interpreted in a way that if we leave the mangrove in its natural state, the middleward zone with an estimated SI of 8.1 would be able to grow an average of 100.47 cu.m. per ha in 50 years. Likewise, the landward and seaward zones would yield 89.89 and 71.18 cu.m., respectively, considering the same growing period of 50 years. These translate to a projected mean annual wood increment per ha of 2.01, 1.80 and 1.42 cu.m. for middleward, landward and seaward mangrove portions, respectively. Compared to other sites like that of Palawan, the mangroves of Pagbilao are less productive considering that its site indices area relatively low. On the same zones, Palawan mangroves have average site indices of 12.5, 11.2, and 6.2 for middleward, landward and seaward portions, respectively (Table 4.10). Consequently, the potential timber yields are higher with a projected mean annual wood increment per ha of 2.59, 2.42 and 1.72 cu.m. for middleward, landward and seaward mangrove portions, respectively.

Wood biomass also includes branches, base and root props in addition to trunk which is converted to timber. Branches are used as fuelwood. The volume of economically useful tree parts is computed using the percentage share of trunks and branches to wood biomass from empirical calculations of Balangue et al. (1995) which are 52.39% for trunk, 16.53% for branches and 31.08% for base and root props. The volume of branches is useful in quantifying forest products that can be derived from the experimental forest.

4.5. Resource Management and Utilization

4.5.1. Past and Current Uses

The mangroves of Pagbilao in the past served a variety of purposes. Before Proclamation No. 2151 in 1981 declaring the mangroves of Quezon as wilderness area, cuttings of mangroves for fuelwood and charcoal, timber for house posts, fencing materials, and for fish traps were rampant. Prior to 1974, there were even timber permits issued to cut trees in Pagbilao mangroves. With Proc. 2151 and the subsequent declaration of the Pagbilao mangroves as experimental forest, timber harvesting is not allowed. However, illegal cutting primarily of pole-sized trees may be inferred from stumps while traversing the forest during the field visits. The volume is estimated at around 30 cu m/year or around 0.25 cu. m/ha/yr.

Nevertheless, the single important factor that contributed to the decline of mangrove areas was the conversion of mangroves to fishponds. The Pagbilao Municipal Assessors Office estimated that the total area of fishponds with legitimate FLAs is 604.57 ha. This figure excludes those in private lands and those which were illegally established. Conversion was not allowed with Proc. 2151.

Through the years, the mangroves also served for the livelihood needs of countless Pagbilao residents. Among the common economic use the forests provided for the community were gathering of minor mangrove products such as vines for handicraft, shells and crabs for food, nipa leaves for home construction, and bark for tannins, etc. Among the common shellfishes gathered by the communities are as follows: *damuko (Uca thalasus vocans vocans), alimango (Portunus pelagicus), tapalan* (unidentified) and a variety of *suso* (snails) and other shells.

4.5.2. Potential Uses: Alternative Management Alternatives

Theoretically, the experimental mangrove forests of Pagbilao can be put into different management alternatives. For the purpose of this study several management alternatives are considered.

a. status quo, i.e., preservation with no extractive activities in forest products;
b. preservation with sustainable subsistence forestry to be allowed;
c. development for sustainable commercial forestry;
d. development for aquasilviculture;
e. conversion to semi-intensive aquaculture;
f. conversion to intensive aquaculture;
g. development for commercial forestry and intensive aquaculture; and
h. development for subsistence forestry and intensive aquaculture.

The alternatives range from preservation of the status quo to those which recognize the multiple uses of mangrove in the Philippines. Some alternatives permit expropriation of the mangrove forest in totality or its products by an interest group (community or fishpond operators) while the multiple-use alternatives satisfy the two competing users. Environmental considerations are satisfied in all alternatives, for instance, the rate of timber harvesting is limited to the sustainable levels. In respect of aquaculture[2], the prescribed technology takes into account the sustainability criterion.

The specification of each management alternative is discussed below. Further, the quantity of major forest products generated under each alternative is estimated annually and extrapolated over a 50-year period. The forest products considered are those whose quantities can be estimated using data collected by the project and other previous studies in the Philippines. Potential benefits in each alternative are not included. For instance, under status quo the increase in the volume of wood is not valued as harvesting is not allowed. Ecological functions of mangroves, except the export of nutrients, are not included in the computations in this paper[3].

Perhaps, in addition to the physical quantities of forest products and their monetary equivalent, there are relevant qualitative criteria in assessing the various management alternatives. First is with respect to the acceptability of each alternative to the local communities and other interest groups or stakeholders. Local communities may prefer subsistence forestry but other interest groups primarily fishpond owners which are well represented in all branches of government would favor fishpondification. In this regard, the politically acceptable alternative is that which addresses the needs of the competing users. Another qualitative criterion is the ease with which the management alternative are

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2 Refer to aquaculture report (Padilla and Tanael 1995).

3 Ecological functions are estimated or discussed in the integrative report.

implemented. Subsistence forestry may be more difficult to implement as this would entail monitoring of harvesting and regulation of access while commercial forestry is easier to implement if harvesting rights are granted to one entity. The transition towards community-based management of natural resources and legal issuances supportive of this management scheme favor the more equitable subsistence forestry alternative. Other qualitative criteria may be imposed in the decision support system that is formulated.

4.5.3. Status quo

This alternative adopts the present management system employed in Pagbilao mangrove forests as an experimental forest. Extraction of forest products is not allowed but the gathering of mollusks and crabs is permitted. The mangrove forest is expected to regain lost volume and approximate its old-growth condition within thirty (30) years with standing volumes ranging from 70 to 100 cu.m. per ha. The increase in the volume of wood from the growth of the trees represent marketable benefits from this management alternative albeit potential due to prohibition of timber harvesting.

Other forest products that accrue include nutrients from litterfall. The projected total annual litterfall (ovendry weight: ODW) is 8,155.8 tons while the equivalent nutrient production would be 70.1 tons annually (Table 4.11 from estimates in Table 4.13). Over the 50 year period, the total litterfall is estimated at 407,788 tons while total nutrient production is 3,507 tons. Annual soil accretion is 4.6 cm although the projected accretion over 50 years may not simply be a linear function of time as indicated.

4.5.4. Sustainable subsistence forestry

Another management alternative recognizes the dependence of adjacent communities to the Pagbilao mangroves for forest products. Subsistence forestry may be instituted where communities are allowed to obtain wholly or partly their forest products needs from the forest. The communities themselves shall manage the forest in consonance with existing policies on community-based forest management. To sustain the benefits, however, a maximum allowable harvest must be imposed such that extraction rate does not exceed the capacity of the forest to regenerate and develop naturally. This is in consideration that unrestricted access to the mangroves would result to resource depletion as there are 180 households within the two nearest barangays (Ibabang Palsabangon and Kanlurang Malicboy) who have access to the mangroves and would potentially draw from its forest resources. Currently, however, approximately 75 households are actual users of mangrove forest resources (Pabuayon et al. 1995).

The estimated annual demand for mangrove forest products in Pagbilao by actual and potential users is listed in Table 4.14. The estimates also reflect the volume of wood households would be getting if allowed unrestricted access. Of the average household demand of 8.61 cu.m. per year, 67.8% is for fuelwood. The 75 households currently using the forest require about 645 cu.m. yearly which would totally deplete the forest resources in 8.7 years (Table 4.15). To attain sustainability, the dependency rate on the mangrove forest must be lowered to 42% of the current users (32 of 75 households) with an equivalent annual demand of 272.3 cu. m. annually. This imply that the remaining households must source their wood requirements elsewhere. Likewise, restrictions on what, where, and how much to cut must be carefully planned and communicated to the forest users considering the spatial differences in tree growth in the mangrove forest.

Under subsistence forestry management alternative, the total projected litterfall is 7,928.9[4] tons while the equivalent nutrient production would be 68.2 tons (Table 4.11). Over the 50 year period, the total sustainable wood production would be 13,595 cu.m., total litterfall would be 396,445 tons, total nutrient production would be 3,409.4 tons while total accretion cannot be determined (Table 4.12). Considering an annual increase of 1.25 percent of mangrove dependent households, wood consumption would increase by an average of 3.0 cu.m. annually (Table 4.16). To provide this, the community must employ silvicultural treatments to enhance growth (e.g., assisted natural regeneration, liberation cutting, cleaning, etc.). For simplicity of analysis, however, the rate of harvesting is not assumed to increase despite the projected increase in demand. The number of dependent households may increase but the average demand for each household should decrease.

4.5.5. Sustainable commercial forestry;

This alternative provides for the conversion of mangrove areas into commercial forestry where a specified commercial volume can be harvested. The required silvicultural system for this is the seedtree method with planting. This system requires that seedtrees (mother trees) are selected to be left to provide propagules for the harvested areas. Planting on open areas is required. Assisted natural regeneration for areas with plenty of wildlings is also recommended to speed up site restoration.

Based on the growth behavior of Pagbilao mangroves, the maximum volume of wood that may be harvested yearly also approximates the sustainable subsistence level of approximately 272.3 cu.m. yearly (Table 4.15) which includes branches and trunk but excludes base and props. This is approximately equal the recommended production but the difference is in the nature of the forest product. In this management scenario, timber from tree trunks which may have higher value is the primary product while branches are harvested for fuelwood. (In subsistence forestry the type of wood products supplied are those demanded by households.) A harvesting plan must be formulated and followed such that areas with higher volume must be harvested first. Likewise, the area must be blocked or compartmentalized where stand volume is the primary consideration for easier scheduling. Under this alternative, total litterfall is 7,928.9 while total nutrient production is 68.2 tons annually. Over the 50 year period, the total timber production is 10,335 cu.m. plus 3,260 cu.m. of fuelwood. The total litterfall would be 396,445 tons, total nutrient production would be 3,409 tons, and total accretion is indeterminate (Table 4.12).

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4 The volume of litterfall for this management option and in the sustainable commercial forestry option is lower compared to the status quo notwithstanding the same area of the mangrove forest. The difference lies in the trees cut for timber.

4.5.6. Aquasilviculture

Aquasilviculture is also a potential alternative for Pagbilao mangrove forests. Under this alternative, a certain percentage of the mangrove area shall be converted to fishpond while some portions shall be retained as forested. Buffer zones are allocated based on legal requirements of 50 meters for areas facing the sea and 20 meters along river channels. The buffer zone is about 15.5 ha. (The allocation of the area between mangroves and fishponds is shown in Table 4.17.) The remaining area is devoted to aquasilviculture assuming a 30 to 70 ratio for fishpond and forest. The total area to be converted to fishpond is 28.6 ha while 66.7 ha shall be maintained with forest trees. Thus the distribution of area is 25.8% for fishponds and 74.2% forest. The total annual sustainable timber production for this alternative is 176.4 cu.m. while total litterfall and nutrient production are 6,128.8 and 52.7 tons, respectively. Over the 50 year period, the total timber production would be 8,820 cu.m., Likewise, the total litterfall would be 306,438 tons, total nutrient production would be 2,635.4 tons while total accretion could not be determined (Table 4.12).

4.5.7. Semi-intensive aquaculture

Another management alternative is to convert the mangrove forest to fishponds employing semi-intensive aquaculture while observing the required buffer zone estimated at 15.5 ha. The remaining area of 95.2 ha will be covered by a system of ponds and water distribution systems. Forest products may still be derived in the buffer zone but extraction will not be allowed to preserve this critical area. Only environmental goods in the form of litterfall would be produced at 1,157 tons while the equivalent nutrient production would be 10 tons annually (Table 4.12). Over the 50-year period, the total litterfall would be 57,850 tons and the total nutrient production would be 497.5 tons while total accretion would also be indeterminate (Table 4.12).

4.5.8. Intensive aquaculture

This management alternative is similar to semi-intensive aquaculture in terms of allocation of area between the required buffer zone and fishponds. The only difference is that the aquaculture technology employed is intensive. Forest-based products derived in this management alternative include litter fall at 1,157 tons with the equivalent nutrient production at 10 tons annually (Table 4.11). Over the 50 year period, the total litterfall would be 57,850 tons, total nutrient production would be 497.5 tons and total accretion would be indeterminate (Table 4.12). As in the preceding alternative, cutting of trees will not be allowed in the buffer zone.

4.5.9. Commercial forestry and intensive aquaculture

This management alternative is a combination of alternatives 2 and 6. Under this alternative, a certain part of the mangrove would be converted to fishpond, specifically, in the landward zone towards the middleward portion. The total proposed area for fishponds is 35 ha. Excluding the buffer zone, the total area of the mangrove forest for commercial forestry would be 60.2 ha (Figure 4.2). The total sustainable timber production under this alternative would be 145.8 cu.m. annually. With respect to other environmental goods associated with the mangrove forest, total litterfall would be 5,651 tons while the equivalent nutrient production would be 48.6 tons annually (Table 4.11). Over the 50-year period, the total timber production would be 5,540 cu.m., total litterfall would be 282,550 tons, total nutrient production would be 2,430 tons and total accretion would be indeterminate (Table 4.12).

4.5.10. Subsistence forestry and intensive aquaculture.

This a combination of alternative 2 and alternative 6. The total area for fishpond is 35 ha while 60.2 ha will be devoted to forestry. Total timber production would be 146.7 cu.m. With respect to environmental services, total annual litter fall would be 5,651 tons while the equivalent nutrient production would be 48.6 tons annually (Table 4.11). Over the 50 year period, the total litterfall would be 282,550 tons, total nutrient production would be 2,430 tons and total accretion would be indeterminate (Table 4.12).

4.6. Valuation of Forest Products

The valuation of forest products is focused on those where market prices can be derived, namely: nipa shingles, timber, fuelwood and charcoal. With the prohibition of harvesting of mangrove forest resources in the entire country, there is no market price for timber, fuelwood and charcoal. The only exception is nipa shingle derived from other mangrove sites and traded freely. The valuation of mangrove forest products therefore, has to use prices of close substitutes. Further, the forest management alternative becomes relevant as explained below. With respect to forestry, there are basically two types of management alternatives, namely: subsistence and commercial forest regimes.

In subsistence forestry the point of reference in valuation is the community which is the potential user of forest resources. If households in the community are denied access to forestry resources, the value attached to the mangrove forest products is equivalent to the cost they incur in obtaining alternative products. Such cost is equivalent to the market price of the alternative plus the cost of transporting the product from the market to the point of use. However, if access to forest resources is allowed, the imputed value of forest products is the cost of the alternative less the cost of harvesting the corresponding mangrove forest product plus the cost of transport. From the point of view of the household where cost may be the overriding consideration, the alternative product is the cheapest substitute which may not necessarily have the same attribute or quality as the mangrove product. In the case of timber, the cheapest substitute is coconut lumber while for fuelwood, two substitutes may be considered: liquefied petroleum gas (LPG) and upland fuelwood although the latter is used in the computations.

In a commercial forestry regime, it is conceivable that a single entity, e.g., the entire community operating as a business enterprise, will manage the forest resources as sole owner. We assume that the objective is to maximize the value of net benefits to be derived from the forest in harvesting the quantity of forest products specified in Table 4.11. Net benefit is the stumpage value which is equal to the market price of the good less the costs of transport, extraction and related costs incurred in managing the forest. Costs of gathering and transport are to be incurred by the business enterprise. Again, in the absence of a market value of mangrove forest products, the prices of alternative products are used. In this case, the same alternative products as in subsistence forestry are adopted.

The computation of appropriate prices and costs for the valuation of forest products is shown in Table 4.18a for subsistence forestry and Table 4.18b for commercial forestry. The valuation of subsistence and commercial forestry products differs in the treatment of gathering or extraction cost. The rationale is already explained. The estimation of this cost, however, requires explanation. For timber products, the gathering cost is the foregone earnings from fishing in the two forestry management alternatives. If the community of fishers collectively manages the forest commercially, forest workers may be willing to receive a salary equivalent to their foregone earnings (not the legally prescribed minimum wage) as the community members share the profits realized in commercial forestry. In fuelwood gathering for subsistence use, the gathering cost is zero as non-working household members are assumed to do this task. In the case of commercial fuelwood, the gathering cost is also zero as it is a by-product in timber harvesting. Mangrove trees are felled primarily for timber and the smaller branches are cut for fuelwood which becomes an incidental product. Work required for this may be marginal.

Transport cost is computed using results of interviews in the study site. The cost of the most practical means of transport employed in the gathering of each product is adopted. For nipa shingles a banca is usually employed while for timber products, work animals are used.

The annual value of potentially marketable forest products is quite substantial (Table 4.19). Depending on the forestry management alternative, total production ranges from 3,270 pesos/ha/yr (aquasilviculture) to over 6,000 pesos/ha/yr (commercial forestry). Between the full subsistence and commercial forestry alternatives (alternatives 2 and 3), the difference is about 40,000 pesos for the entire forest but on a per hectare basis, this amounts to only 400 pesos per year. The imputed value of the nutrients produced from mangroves is based on the current market prices of chemical fertilizers. These are 3.85 pesos, 5.2 pesos and 4.3 pesos per kg of nitrogen, phosphorus and potassium, respectively. This valuation method does not take into account the costs of extraction of the nutrients from the mangrove forest. Total value of nutrients per ha per year for the entire area is highest for the status quo, as expected. The average per ha. value, however, is not highest for the status quo but for alternatives 5 and 6 where the remaining mangrove cover are those which give the highest litterfall.

The annual value of potentially marketable forest products and the imputed value of nutrients produced from the mangrove forest ranges from 2,677 pesos to 6,365 pesos per ha. The commercial forestry alternative is ranked first while the status quo is ranked last. The breakdown shows that the alternative which gives the highest value in potentially marketable forest products is ranked highest overall. This underscores the importance of timber, fuelwood, charcoal and nipa in the mangrove forest, notwithstanding the overvaluation of nutrients. Timber is obviously the highest valued product as shown by the value of the next best alternative product. Fuelwood and charcoal are minimal.

The value of forest products is now compared with the similar studies. One is by Schatz (1991) which estimated net annual economic value of wood products from Philippine mangroves at 3,900 pesos, 2,250 pesos and 1,050 pesos per ha per year, respectively for mangrove plantation, managed naturally regenerated stands and unmanaged understocked stands. For comparison, Pagbilao is a managed naturally regenerated stand which should have a net economic value of 2,250 pesos per ha per year per Schatz' study. For this study, taking the value of subsistence forestry alternative the value of wood products at 2,636 pesos/ha/yr is close to the Schatz estimate. In terms of physical volume of wood harvested, however, Schatz estimated a higher 7.5 cu.m/ha/yr compared to 2.75 cu.m./ha/yr estimated in this study. However, this study with the computation of sustainable levels of cutting of mangrove trees gives a more conservative albeit more accurate estimate of the value of timber products from a mangrove forest.

4.7. Summary and Recommendations

The forestry studies for this project identified various forest-based products that may be derived from the Pagbilao mangrove forests. Field surveys provided information necessary to estimate the quantity and value of these products. Mangrove forests are legally not amenable to conversion of any sort. Moreover, the gathering of mangrove forest products is prohibited. In this study, however, different management scenarios were assumed for the Pagbilao mangrove forest and forest products were estimated for each scenario. The valuation of forest products for each scenario shows that the best alternative is sustainable subsistence forestry which gives the highest value. The subsistence forestry is also superior in terms of equity considerations as the fuelwood and timber from mangroves are supplied by the mangrove reserve. The contribution of the mangrove forest to primary productivity is not compromised as the difference in litterfalll and, subsequently nutrient production, between subsistence forestry and preservation is not significant.

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Table 4.1. Area and landuse of Pagbilao mangrove forests (1994).

Land use	Approximate area (ha)	% to total
A. Public Forests Lands		
Experimental forest (second growth)	110.72	8.53
Remaining second growth outside expt'l forest	60.00	4.62
Degraded fores/some with adverse claims	225.28	17.36
Total forest lands	396.00	30.51
Fishponds (with FLA)	604.57	46.59
B. A & D Lands		
Fishponds	297.00	22.89
Total	1,297.57	22.89

Table 4.2. Fishpond lease agreement (FLA) issued in Pagbilao, Quezon (as of 1993).

FLA No.	Lessee	Location	Area Granted	Developed	Undeveloped
2490	Bautista Gabriel x. ref Layos Deogracias	Brgy. Malicboy	12.03	11.03	1
1951	Celso, Diona Fisheries	Kanluran Malicboy	8.84	8.84	0.00
3339	Dequito, Efipanio	Kanluran Malicboy	22.47	22.47	0.00
3355	Dequito, Venancio	Kanluran Malicboy	6.20	6.20	0.00
2650	Fontanilla, Jesus x. ref Heirs of Adela Ponce	Bgy. Mapagong	32.08	32.08	0.00
2183	Guevarra, Leonora x. ref Guevarra, Demetrio	Silangang Malicboy	13.32	13.32	0.00
4325	Guillen, Pio	Kanluran Malicboy	9.79	9.79	0.00
1899	Inland Sea Dev. & Aquaculture Corp. x. ref Santos Palomo	Bgy. Palsabangon	57.13	57.13	0.00
2908	Lauro, Gregorio x. ref Dealino, Catalino	Brgy. Malicboy	5.00	5.00	0.00
4476	Piscan Treasure Inc. c/o Jose Manguit Jr.	Palsabangon, Binahan, Malicboy	128.36	0.00	128.36
2749	Ramos, Helen	Pagbilao proper	13.88	13.88	0.00
2881	Ramos, Helen	Pagbilao proper	30.70	30.70	0.00
1603	Rivera, Francisco	Pagbilao proper	12.95	6.00	6.95
1164	Rivera, Modesto	Brgy. Bantigue	27.00	27.52	(0.52)
2905	Rodriguez, Benjamin	Iringan, Palsabangon	20.63	5.00	15.63
2967	Ruidera, Domingo	Kanluran Malicboy	17.53	17.53	0.00
4501	San Jose Agro Marine Corp x. ref Dona Ind Corp.	Kanluran Malicboy	94.27	65.00	29.27
2839	San Jose Mgt. Corp.	Brgy. Pinagbayanan	16.80	16.80	0.00
2884	San Jose Agro Marine Corp x, ref Quimson, Pangilinan	Bgy. Palsabangon	31.52	31.52	0.00
2807-A	Garcia, Efipanio	Brgy. Malicboy	18.55	18.55	0.00
3177	Zumel, Teodore	Pagbilao proper	9.29	9.29	0.00
4381	Sabater, Benjamin	Pagbilao proper	11.10	0.00	11.10
4834	Jaca, Damasino	Kanluran Malicboy	5.12	0.00	5.12
Total Area			604.56	407.65	196.91

Source: Municipal Assesor's Office, Pagbilao, Quezon.

Table 4.3. Classification of Philippine Mangrove Flora.

Classification	Family	No. of Species	Family	No. of Species
True Mangroves	Acanthaceae	3	Malphigiaceae	1
	Aizoacea	1	Meliaceae	2(1)
	Avicenniaceae	5(3)	Merbaceae	1
	Bombacaceae	1(1)	Palmae	2(1)
	Combretaceae	2(1)	Pteridaceae	1 (1)
	Euphorbiaceae	1(1)	Rhizoporaceae	9(7)
	Graminae	1	Rubiaceae	1 (1)
	Lythraceae	1	Sonneratiaceae	2(2)
Mangrove Associates	Apocinaceae	4	Liliaceae	1
	Araliaceae	1	Malvaceae	3
	Barringtoniaceae	2	Meliaceae	3
	Bignonniaceae	1	Mimosaceae	2
	Caesalpiniaceae	3	Myrsinaceae	2
	Celastraceae	1	Palmae	1
	Compositae	1	Polipodiaceae	1
	Cyperaceae	2	Rubiaceae	1
	Euphorbiaceae	3	Sterculiaceae	2
	Fabaceae	4	Tiliaceae	1
Vines	Asclepidiaceae	4	Flagellariaceae	1
	Caesalpiniaceae	2	Malphigiaceae	1
	Convolvolaceae	1	Vitaceae	1
	Fabaceae	2		
Epiphytes	Aspleniaceae	1	Polipodiceae	2
	Orchidaceae	5	Rubiaceae	3

Source: Bennagen and Cabahug, 1991.
Note: Those enclosed in parenthesis are number of true mangrove species found in Pagbilao.

Table 4.4. Zonation of mangrove species in Pagbilao Bay.

A. Seaward Portions
Nipa (Nypa fruticans)
Bakauan lalaki (Rhizophora apiculata Bl.)
Bakauan babae (R. mucronata Lamk)
Api-api (Avicennia officinalis L.)
Pagatpat (Sonneratia alba J. Smith)
B. Middleward
Tangal (Ceriops tagal (Perr.) C.B. Robins
Pototan (Brugiera sexangula (Lour.) Poir)
Api-api (Avicennia officinalis L.)
Buta-buta (Excoecaria agallocha L.)
Saging-saging (Aegiceras corniculatum (L.) Blco.
Tinduk-tindukan (A. floridum Roem. & Schult.)
Piagau (Xylocarpus moluccensis (Lamk.) Roem.
Gapas-gapas (Camptostemon philippinense (Vid.) Becc.
Pototan lalaki (Bruguiera cylindrica (L.) Bl.
Malatangal (Ceriops decandra (Griff) Ding Hou
Tabau (Lumnitzera littorea (Jack.) Voigt.
Taualis (Osbornia octodonta F. Mueller)
C. Landward
Api-api (A. officinalis L.)
Pi-api (A. marina (Forsk.)Vierh. var rumphiana(Hallier) Bakh.
Dungon-late (Herritiera littoralis Dryand. ex. W. ait.)
Lagolo (Acrostichum aureum)
Buta-buta (Excoecaria agallocha L.)
Acanthus sp.
D. Riverines
Lagolo (A. aureum)
Nipa (N. fruticans)
Pagatpat (Sonneratia alba J. Smith)
Pedada (S. caseolaris (L.) Engl.
Busain (Bruguiera gymnorhiza (L.) Lamk.
Bakauan lalaki (R. apiculata Bl.)
Bakauan babae (R. mucronata Lamk)
Api-api (A. officinalis L.)
Pi-api (A. marina(Forsk.)Vierh. var rumphiana (Hallier)Bakh.
Bungalon (A. marina (Forsk.) Vierh
Nilad (S. hydrophyllaceae Gaertn.)
Tabigi (Xylocarpus granatum Koen.)

Table 4.5. Summary of plot information used in determining yield.

Plot No.	Portion	No. of Species	No. of Trees	Average Base Dia (cm)	Average Top Dia (cm)	Average Merch Ht (m)	Average Total Ht (m)	Ave Volume	Total Volume	Estimated Volume per ha (cu m)
1	LW	2	3	15.3	4.2	3.0	6.7	0.2160	0.0647	6.47
2	LW	2	5	23.4	10.9	3.5	8.0	0.0837	0.4186	41.86
3	LW	2	11	14.5	5.9	1.9	5.6	0.0390	0.4293	42.93
4	LW	2	3	20.6	9.1	2.8	8.0	0.0932	0.2795	27.95
5	MW	2	7	17.6	11.8	4.6	9.1	0.0871	0.6097	60.97
6	MW	4	7	26.1	11.8	4.6	9.1	0.1749	1.2242	122.42
7	MW	2	5	34.8	14.3	5.6	11.2	0.2842	1.4211	142.11
8	MW	4	6	15.3	8.3	2.2	6.3	0.0305	0.1827	18.27
9	MW	3	6	28.2	11.8	4.8	9.5	0.1891	1.1345	113.45
10	MW	2	6	26	12.4	3.6	8.4	0.1457	1.0199	101.99
11	LW	2	5	13.7	3.4	2.6	8.2	0.0210	0.1048	10.48
12	LW	3	5	26.8	11.6	2.1	8.5	0.0758	0.3033	30.33

Table 4.6. Litterfall production of selected mangrove species in Pagbilao Bay.

Station	Species	Average Litter Weight (gOM/M2/Day)
Station 1	Scyphiphora hydrophyllacese	2.48
	Ceriops decandra	1.53
	Avecinnea officinalis	1.37
Station 2	Rhizophora apiculata	1.34
	Avicennia officinalis	1.22
	Osbornia octodonta	0.83
Average		1.54

Source: Fortes, 1993.

Table 4.7. Litterfall production in 10 plots established.

Plot No.	Ovendry Welgth (in grams)		Total	gOM/M2/Day
	1st Measurement (14 days)	2nd Measurement (14 days)		
1	31.6	9.7	41.3	1.48
2	8.7	12.3	21.0	0.75
3	14.8	31.1	45.9	1.64
4	15.9	10.4	26.3	0.94
5	5.5	22.5	28.0	1.00
6	26.7	32.5	59.2	2.11
7	8.8	10.6	19.4	0.69
8	14.0	10.7	24.7	0.88
9	12.3	23.9	36.2	1.29
10	27.5	26.1	53.6	1.91
Average for all plots			35.6	1.27

Table 4.8. Estimated site indeces of different mangrove zones in Pagbilao.

Zone	Approximate Area (ha)	Age (in yrs)	Ave Total Ht (m)	Estimated SI (m)
Landward	22.1	20.0	7.4	6.7
Middleward	16.6	20.0	8.8	8.1
Seaward	22.1	20.0	5.2	4.5

Table 4.9. Projected timber yield of Pagbilao mangrove forests by zone (in cu m per ha).

Year	Landward SI=6.7	Mean Annual Increment (mai)	Middleward SI=8.1	Mean Annual Increment (mai)	Seaward SI= 4.5	Mean Annual Increment (mai)
0	2.76	0.00	3.08	0.00	2.18	0.00
5	15.75	2.60	17.60	2.90	12.47	2.06
10	26.60	2.17	29.73	2.43	21.07	1.72
15	36.15	1.91	40.41	2.13	28.63	1.51
20	44.94	1.76	50.23	1.96	35.59	1.39
25	53.21	1.65	59.47	1.85	42.14	1.31
30	61.08	1.57	68.26	1.76	48.37	1.25
35	68.63	1.51	76.71	1.69	54.35	1.20
40	75.93	1.46	84.86	1.63	60.13	1.16
45	83.00	1.42	92.77	1.58	65.73	1.12
50	89.89	1.38	100.47	1.54	71.18	1.09
55	96.61	1.34	107.98	1.50	76.51	1.05
60	103.18	1.31	115.33	1.47	81.71	1.04
65	109.63	1.29	122.52	1.44	86.81	1.02
70	115.95	1.26	129.59	1.41	91.82	1.00
75	122.16	1.24	136.53	1.39	96.74	0.98
80	128.27	1.22	143.36	1.37	101.58	0.97
85	134.29	1.20	150.09	1.35	106.35	0.95
90	140.23	1.19	156.73	1.33	111.04	0.94
95	146.08	1.17	163.27	1.31	115.68	0.93
100	151.86	1.16	169.73	1.29	120.26	0.92
Average mai		1.49		1.67		1.18

Log Yld = 0.1842 + 0.7565 (LogAge) + 0.5862 (LogSI).

Table 4.10. Comparative projected yield of Pagbilao mangrove forests on the same zones (in cu m per ha).

Year	Landward			Middleward			Seaward		
	Pagbilao SI=6.7	Palawan SI=11.2	Diff. (%)	Pagbilao SI=8.1	Palawan SI=12.5	Diff. (%)	Pagbilao SI= 4.5	Palawan SI=6.2	Diff. (%)
0	2.76	3.73	26.01	3.08	3.98	22.46	2.18	2.64	17.13
5	15.75	21.28	26.01	17.60	22.70	22.46	12.47	15.05	17.13
10	26.60	35.95	26.01	29.73	38.34	22.46	21.07	25.42	17.13
15	36.15	48.86	26.01	40.41	52.11	22.46	28.63	34.55	17.13
20	44.94	60.74	26.01	50.23	64.78	22.46	35.59	42.95	17.13
25	53.21	71.91	26.01	59.47	76.69	22.46	42.14	50.84	17.13
30	61.08	82.55	26.01	68.26	88.03	22.46	48.37	58.36	17.13
35	68.63	92.76	26.01	76.71	98.92	22.46	54.35	65.58	17.13
40	75.93	102.61	26.01	84.86	109.44	22.46	60.13	72.55	17.13
45	83.00	112.18	26.01	92.77	119.64	22.46	65.73	79.31	17.13
50	89.89	121.48	26.01	100.47	129.56	22.46	71.18	85.90	17.13
55	96.61	130.57	26.01	107.98	139.25	22.46	76.51	92.32	17.13
60	103.18	139.45	26.01	115.33	146.72	22.46	81.71	98.60	17.13
65	109.63	148.16	26.01	122.52	158.01	22.46	86.81	104.75	17.13
70	115.95	156.70	26.01	129.59	167.12	22.46	91.82	110.79	17.13
75	122.16	165.10	26.01	136.53	176.07	22.46	96.74	116.73	17.13
80	128.27	173.36	26.01	143.36	184.88	22.46	101.58	122.57	17.13
85	134.29	181.49	26.01	150.09	193.56	22.46	106.35	128.32	17.13
90	140.23	189.51	26.01	156.73	202.11	22.46	111.04	133.99	17.13
95	146.08	197.42	26.01	163.27	210.55	22.46	115.68	139.59	17.13
100	151.86	205.24	26.01	169.73	218.88	22.46	120.26	145.11	17.13

Table 4.11. Annual production of different forest products and services under the different management alternatives.

Forest Products	Management Alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
A. Fuelwood (cu m/yr)								
1. Subsistence[1]	0.0	184.4	0.0	0.0	0.0	0.0	0.0	99.4
2. Commercial	0.0	0.0	65.2	42.3	0.0	0.0	35.0	0.0
B. Timber (cu m/yr)								
1. Subsistence[2]	0.0	46.4	0.0	0.0	0.0	0.0	0.0	25.1
2. Commercial[3]	0.0	0.0	206.7	134.1	0.0	0.0	110.8	0.0
a. LW			39.2				0.0	
b. MW			144.0				87.2	
c. SW			23.5				23.6	
C. Charcoal (cu m/yr)								
1. Subsistence[4]	0.0	31.2	0.0	0.0	0.0	0.0	0.0	22.3
2. Commercial								
D. Nipa ('000 Shingle/yr)[5]	0.0	45.0	45.0	0.0	0.0	0.0	22.5	22.5
E. Soil Accretion (cm/yr)[6]	4.6	i	i	i	i	i	i	i
F. Litterfall (ton/yr)[7]	8,155.8	7,928.9	7,928.9	6,128.8	1,157.0	1,157.0	5,651.0	5,651.0
a. LW (1.20 gOM/m2/day)	1,569.8							
b. MW (1.31 gOM/m2/day)	5,475.6							
c. SW (1.13 gOM/m2/day)	1,110.4							
G. Nutrient Prdn (ton/yr)[8]	70.1	68.2	68.2	52.7	10.0	10.0	48.6	48.6
N (.29% of OM)	23.7	23.0	23.0	17.8	3.4	3.4	16.4	16.4
P (.07% of OM)	5.7	5.6	5.6	4.3	0.8	0.8	4.0	4.0
K (.50% of OM)	40.8	39.6	39.6	30.6	5.8	5.8	28.3	28.3

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:
1 5.84 cu m/household/yr (Pabuayon, et al, 1995) * 70 households.
2 1.47 cu m/household/yr (Pabuayon, et al, 1995) * 70 households (includes house and fencing materials).
3 Based on the growth capacity of the whole forest.
4 Based on the 1.3 cu m/yr household demand on charcoal.
5 Based on Pabuayon, et al, 1995 estimate, 100% dependency.
6 Based on the 2.4 cm accretion for 7 months, Balangue (1994).
7 Total for all zones (rate in gOM/m2/day * 10,000 m2 / 100 g/kg/1000 kg/ton). Annualized figures.
8 Sum for NPK (% NPK * Total OM produced).
i Indeterminate

Table 4.12. Annual production of different forest products and services under the different management alternatives (50 year period).

Forest Products	Management Alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
A. Fuelwood (cu m/yr)								
1. Subsistence[1]	0.0	9,220.0	0.0	0.0	0.0	0.0	0.0	3,750.0
2. Commercial	0.0	0.0	3,260.0	0.0	0.0	0.0	0.0	0.0
B. Timber (cu m/yr)								
1. Subsistence[2]	0.0	2,320.0	0.0	0.0	0.0	0.0	0.0	945.0
2. Commercial[3]	0.0	0.0	10,335.0	6,705.0	0.0	0.0	5,540.0	0.0
a. LW			1,960.0				0.0	
b. MW			7,200.0				4,360.0	
c. SW			1,175.0				1,180.0	
C. Charcoal (cu m/yr)								
1. Subsistence[4]	0.0	2,055.0	0.0	0.0	0.0	0.0	0.0	840.0
2. Commercial								
D. Nipa ('000 Shingle/yr)[5]	0.0	2,250.0	2,250.0	0.0	0.0	0.0	1,125.0	1,125.0
E. Soil Accretion (cm/yr)[6]	230.0	i	i	i	i	i	i	i
F. Litterfall (ton/yr)[7]	407,788.5	396,445.0	396,445.0	306,438.5	57,850.0	57,850.0	282,550	282,550
a. LW (1.20 gOM/m2/day)	78,490.0							
b. MW (1.31 gOM/m2/day)	273,780.0							
c. SW (1.13 gOM/m2/day)	55,520.0							
G. Nutrient Prdn (ton/yr)[8]	3,507.0	3,409.4	3,409.4	2,635.4	497.5	497.5	2,429.9	2,429.9
N (.29% of OM)	1,182.6	1,149.7	1,149.7	888.7	167.8	167.8	819.4	819.4
P (.07% of OM)	285.5	277.5	277.5	214.5	40.5	40.5	197.8	197.8
K (.50% of OM)	2,038.9	1,982.2	1,982.2	1,532.2	289.3	289.3	1,412.8	1,412.8

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:

1 5.84 cu m/household/yr (Pabuayon, et al, 1995) * 70 households.

2 1.47 cu m/household/yr (Pabuayon, et al, 1995) * 70 households (includes house and fencing materials).

3 Based on the growth capacity of the whole forest.

4 Based on the 1.3 cu m/yr household demand on charcoal.

5 Based on Pabuayon, et al, 1995 estimate, 100% dependency.

6 Based on the 2.4 cm accretion for 7 months, Balangue (1994).
7 Total for all zones (rate in gOM/m2/day * 10,000 m2 / 100 g/kg/1000 kg/ton). Annualized figures.
8 Sum for NPK (% NPK * Total OM produced).
i Indeterminate

Table 4.13. Estimates of litterfall and NPK yield for the Pagbilao mangrove forest for current use of the forest.

Year	Litterfall (t/yr/ha)				Nitrogen Content		Phosphorus Content		Potassium Content	
	Landward	Middleward	Seaward	Wt.Ave.	%	kg/yr	%	kg/yr	%	kg/yr
1 = 20th	43.8	47.8	41.2	46.0	0.29	0.13	0.07	0.03	0.50	0.23
2	44.6	48.7	42.0	46.9	0.31	0.15	0.07	0.03	0.51	0.24
3	45.5	49.7	42.8	47.8	0.34	0.16	0.07	0.03	0.51	0.25
4	46.4	50.6	43.7	48.7	0.36	0.18	0.07	0.03	0.52	0.25
5	47.3	51.6	44.5	49.7	0.39	0.19	0.07	0.03	0.53	0.26
6	48.2	52.6	45.4	50.6	0.42	0.21	0.07	0.03	0.54	0.27
7	49.1	53.6	46.2	51.6	0.46	0.23	0.07	0.04	0.54	0.28
8	50.0	54.6	47.1	52.6	0.49	0.26	0.07	0.04	0.55	0.29
9	51.0	55.7	48.0	53.6	0.53	0.28	0.07	0.04	0.56	0.30
10	52.0	56.7	48.9	54.6	0.57	0.31	0.07	0.04	0.57	0.31
11	53.0	57.8	49.9	55.7	0.61	0.34	0.07	0.04	0.58	0.32
12	54.0	58.9	50.8	56.7	0.66	0.38	0.07	0.04	0.59	0.33
13	55.0	60.1	51.8	57.8	0.71	0.41	0.07	0.04	0.59	0.34
14	56.1	61.2	52.8	58.9	0.77	0.45	0.07	0.04	0.60	0.35
15	57.2	62.4	53.8	60.1	0.83	0.50	0.07	0.04	0.61	0.37
16	58.3	63.6	54.9	61.2	0.89	0.55	0.06	0.04	0.62	0.38
17	59.4	64.8	55.9	62.4	0.96	0.60	0.06	0.04	0.63	0.39
18	60.5	66.1	57.0	63.6	1.04	0.66	0.06	0.04	0.64	0.41
19	61.7	67.3	58.1	64.8	1.12	0.73	0.06	0.04	0.65	0.42
20	62.9	68.6	59.2	66.1	1.21	0.80	0.06	0.04	0.66	0.43
21	64.1	69.9	60.3	67.3	1.30	0.88	0.06	0.04	0.67	0.45
22	65.3	71.3	61.5	68.6	1.40	0.96	0.06	0.04	0.68	0.46
23	66.6	72.7	62.7	69.9	1.51	1.06	0.06	0.04	0.68	0.48
24	67.8	74.1	63.9	71.3	1.63	1.16	0.06	0.04	0.69	0.50
25	69.1	75.5	65.1	72.7	1.76	1.28	0.06	0.05	0.70	0.51
26	70.5	76.9	66.4	74.0	1.90	1.40	0.06	0.05	0.71	0.53
27	71.8	78.4	67.6	75.5	2.04	1.54	0.06	0.05	0.73	0.55

Table 4.13. Continued.

Year	Litterfall (t/yr/ha)				Nitrogen Content		Phosphorus Content		Potassium Content	
	Landward	Middleward	Seaward	Wt.Ave.	%	kg/yr	%	kg/yr	%	kg/yr
28	73.2	79.9	68.9	76.9	2.20	1.69	0.06	0.05	0.74	0.57
29	74.6	81.4	70.2	78.4	2.38	1.86	0.06	0.05	0.75	0.58
30	76.0	83.0	71.6	79.9	2.56	2.05	0.06	0.05	0.76	0.60
31	77.5	84.6	73.0	81.4	2.76	2.25	0.06	0.05	0.77	0.63
32	79.0	86.2	74.4	83.0	2.98	2.47	0.06	0.05	0.78	0.65
33	80.5	87.9	75.8	84.6	3.21	2.71	0.06	0.05	0.79	0.67
34	82.0	89.6	77.3	86.2	3.46	2.98	0.06	0.05	0.80	0.69
35	83.6	91.3	78.7	87.9	3.73	3.28	0.06	0.05	0.81	0.71
36	85.2	93.0	80.3	89.6	4.02	3.60	0.06	0.05	0.82	0.74
37	86.9	94.8	81.8	91.3	4.33	3.95	0.06	0.05	0.84	0.76
38	88.5	96.6	83.4	93.0	4.67	4.34	0.06	0.05	0.85	0.79
39	90.2	98.5	85.0	94.8	5.03	4.77	0.06	0.05	0.86	0.82
40	92.0	100.4	86.6	96.6	5.43	5.24	0.06	0.06	0.87	0.84
41	93.7	102.3	88.3	98.5	5.85	5.76	0.06	0.06	0.89	0.87
42	95.5	104.3	90.0	100.4	6.31	6.33	0.06	0.06	0.90	0.90
43	97.4	106.3	91.7	102.3	6.80	6.96	0.06	0.06	0.91	0.93
44	99.2	108.3	93.4	104.3	7.33	7.64	0.06	0.06	0.92	0.96
45	101.1	110.4	95.2	106.3	7.90	8.40	0.06	0.06	0.94	1.00
46	103.1	112.5	97.1	108.3	8.52	9.22	0.06	0.06	0.95	1.03
47	105.1	114.7	98.9	110.4	9.18	10.13	0.06	0.06	0.97	1.07
48	107.1	116.9	100.8	112.5	9.90	11.14	0.06	0.06	0.98	1.10
49	109.1	119.1	102.8	114.7	10.67	12.23	0.06	0.06	0.99	1.14
50	111.2	121.4	104.7	116.9	11.50	13.44	0.05	0.06	1.01	1.18
Total	3,623	3,955	3,411	3,807		148		2		29
Average	71.03	76.05	66.89	74.65	2.99	2.91	0.06	0.05	0.70	0.57

Notes: Percent increase in litterfall per year is 1.92; litterfall for LW, MW, SW are respectively, 1.20, 1.31, 1.13 gOM/sq.m./day; percent change in N, P, and K per year, are respectively, 7.8, -0.5 and 1.44. Year 1 represents current year where the average age of mangrove forest is 20 years.

Table 4.14. Quantity of Forest Products Utilized by Households.

Forest Products/Purpose	Ave. Household Demand / yr.		Current Demand	Total Volume / Level of Dependence			
	Quantity	% of Total	No. of HH = 75	100%	75%	50%	30%
1. Timber:	8.61	100.0	645.8	1,549.8	1,162.4	774.9	464.9
Housing Materials (cu.m.)	0.53	6.2	39.8	95.4	71.6	47.7	28.6
House Fencing (cu.m.)	0.94	10.9	70.5	169.2	126.9	84.6	50.8
Fuelwood (cu.m.)	5.84	67.8	438.0	1,051.2	788.4	525.6	315.4
Charcoal (cu.m.)	1.30	15.1	97.5	234.0	175.5	117.0	70.2
2. Non-Timber:							
Nipa Shingles (pcs.)	250.00		18,750.0	45,000.0	33,750.0	22,500.0	13,500.0

Total Number of Households = 180.
Source of Basic Data (Pabuayon et al 1995).

Table 4.15. Comparison of Sustainable Harvest Rates Under Subsistence Forestry[1].

Accounts	Landward	Middleward	Seaward	Weighted Average	Total
A. Physical Capability					
1. Area (ha)	22.1	72.0	16.6		110.7
2. Projected yield (cu m)	59.1	66.0	46.8	61.7	171.9
3. Available volume (cu m)	1,306.7	4,757.8	777.2	3,471.9	6,841.7
4. Annual ave. yield (cu m)	2.4	2.6	1.8	2.5	6.8
5. Sustainable harvest rate[2]	53.0	189.4	29.9	138.3	272.3
B. Dependency Level (No. of Households)[3]		**Harvest Rate**[4]		**Year of Depletion**[5]	
1. 100% (75)		645.5		8.7	
2. 75% (56)		482.5		18.1	
3. 50% (37)		321.7		40.8	
4. 42% (32)		272.3		none	
5. 25% (19)		160.8		none	

Notes:

1 Wood volume includes branches.

2 Based on (average annual yield) * (area).

3 No. of households based on 75 households currently using the forest.

4 (No. of Subsistence household) * (Average household demand in Table 13).

5 Number of years when the total wood supply would be depleted considering growth for that Period.

Table 4.16. Volume needed from subsistence level to meet a 1.25% yearly increase in subsistence demand in (cu m).

Year	Subsistence level with 25% increase per year	Additional Volume needed
1	205.9	0.0
2	208.5	2.6
3	211.1	2.6
4	213.7	2.6
5	216.4	2.7
6	219.1	2.7
7	221.8	2.7
8	224.6	2.8
9	227.4	2.8
10	230.3	2.8
11	233.1	2.9
12	236.0	2.9
13	239.0	3.0
14	242.0	3.0
15	245.0	3.0
16	248.1	3.1
17	251.2	3.1
18	254.3	3.1
19	257.5	3.2
20	260.7	3.2
21	264.0	3.3
22	267.3	3.3
23	270.6	3.3
24	274.0	3.4
25	277.4	3.4

Table 4.17. Area allocation by Management Alternative.

Management Alternative	Fishpond		Forest*	
	Area (ha.)	% of Total	Area (ha.)	% of Total
1. Status Quo	0	0	110.7	100
2. Sustainable Subsistence Forestry	0	0	110.7	100
3. Sustainable Commercial Forestry	0	0	110.7	100
4. Aquasilviculture	28.6	26	82.1	74
5. Semi-intensive Aquaculture	95.2	86	15.5	14
6. Intensive Aquaculture	95.2	86	15.5	14
7. Commercial Forestry and Intensive Aquaculture	35.0	32	75.7	68
8. Subsistence Forestry and Intensive Aquaculture	35.0	32	75.7	68

Includes 15.5 has. of buffer zone for alternatives 4,5,6,7,8.

Table 4.18a. Market prices and costs of forest products in subsistence forestry alternative.

	Pesos/unit	
A. Nipa Shingles		
Market price per shingle	8.6	
Add: Transport cost	0.5	
Subtract: Gathering costs (a)	2.7	
Shadow price	6.4	
B. Timber Products		
i) Timber: Cheapest alternative is coconut lumber		
Market price (P4.50/bd.ft)	1907	per cu.m.
Add: Transport cost (b)	40	
Subtract: Gathering costs (b)	303	
Shadow price	1644	
ii) Fuelwood: Cheapest similar alternative is upland fuelwood		
Market price (P5/bundle of 0.010 cu.m.)	500	per cu.m.
Add: Transport cost	310	
Subtract: Gathering cost (c)	0	
Shadow price	810	
iii) Charcoal: Valuation is similar to fuelwood	810	

Assumptions on computations:

a. Gathering of nipa shingles

One person can fill up on boat-load of nipa shingles over 3 hours of work. One boat-load is equivalent to about 14 shingles. Total harvest in a 6-hour-day work is 28 shingles.Imputed cost is the income to be earned from a 6-hour fishing trip where average catch is 2-3 kg of catch (Pabuayon et.al. 1995) equivalent to 75 pesos/day if price is 30 pesos/kg shingle.

b. Timber harvesting

Two poles measuring 3 m by 35 cm (diameter) can be harvested in 5-6 hours of work, (including travel time) which can be loaded i a carabao-drawn cart. volume of wood. harvested is 0.577 cu.m. Imputed cost is also based on income from fishing which brings the cost of harvesting at approximately 130 pesos per cu.m. The cost of transporting the timber from the forest at 100 pesos (173 pesos/cu.m.) per trip is part of the gathering cost.

c. Fuelwood harvesting

From Balangue et al. (1995) four bundles may be gathered in about 6 hours travelling to a site 200 meters away. One bundle is equivalent to 0.010 cu.m. (Pabuayon et.al. 1995). It is assumed that non-working family members do this task and hence the opportunity cost is close to zero and is assumed to be zero in this case.

Table 4.18b. Market prices and cost of forest products in commercial forestry alternative.

A. Nipa Shingles	**Pesos/unit**	
Market price per shingle	2.9	
Subtract: Transport cost (a)	0.2	
Subtract: Gathering costs (b)	0.9	
Stumpage value (c)	1.8	
B. Timber Products		
i) Timber: Cheapest substitute is coconut lumber		
Market price (P4.50/bd.ft)	1,907	per cu.m.
Subtract: Transport cost	40	
Subtract: Gathering costs	303	
Stumpage value	1,564	
ii) Fuelwood: Cheapest similar alternative is upland fuelwood		
Market price (*P5/bundle of 0.010 cu.m.*)	500	per cu.m.
Subtract: Transport cost	310	
Subtract: Gathering cost (c)	0	
Shadow price	190	
iii) Charcoal: Valuation is similar to fuelwood	190	

a. Transport cost is the cost of bringing the product from the mangrove forest to the market.
b. Gathering costs are computed using opportunity income in the area.
c. Stumpage value as computed still includes margin for profit and risk. This value is that which accrues to the operator in the commercial forestry management alternative.

Table 4.19. Value of annual production of different marketable forest products under the different management alternatives.

Forest Products	Management Alternative							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
I. Potentially Marketable								
A. Fuelwood	0	149,364	12,388	8,037	0	0	6,650	80,514
1. Subsistence	0	149,364	0	0	0	0	0	80,514
2. Commercial	0	0	12,388	8,037	0	0	6,650	0
B. Timber	0	76,282	323,279	209,732	0	0	173,291	41,264
1. Subsistence	0	76,282	0	0	0	0	0	41,264
2. Commercial	0	0	323,279	209,732	0	0	173,291	0
a. LW	0	0	61,309	0	0	0	0	0
b. MW	0	0	225,216	0	0	0	136,381	0
c. SW	0	0	36,910	0	0	0	36,910	0
C. Charcoal	0	25,272	0	0	0	0	0	18,063
1. Subsistence	0	25,272	0	0	0	0	0	18,063
2. Commercial	0	0	0	0	0	0	0	0
D. Nipa shingle	0	94,500	81,000	0	0	0	40,500	47,250
Sub-Total	0	345,418	416,667	217,769	0	0	220,441	187,091
Average per ha. - a	*0*	*3,628*	*4,377*	*3,270*	0	0	3,662	3,118
II. Ecological Contribution								
Nutrient Production								
Nitrogen	91,245	88,550	88,550	68,530	13,090	13,090	63,140	63,140
Phosphorus	29,640	29,120	29,120	22,360	4,160	4,160	20,800	20,800
Potassium	175,440	170,280	170,280	131,580	24,940	24,940	121,690	121,690
Sub-Total	296,325	287,950	287,950	222,470	42,190	42,190	205,630	205,630
Average per ha. - b	2,677	2,601	2,601	2,710	2,722	2,722	2,716	2,716
III. Total	296,325	633,368	704,617	440,239	42,190	42,190	426,071	392,721
Average per ha. - c	2,677	6,230	6,978	5,980	2,722	2,722	6,378	5,834
Average per ha. - d	2,677	5,721	6,365	3,977	381	381	3,849	3,548

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:

a. Forst area for extraction (excludes buffer zone)

b. Entire forest area (includes buffer)

c. Relevant forest area

d. Entire experimental forest area (110.7 ha.).

5. ASSESSMENT OF FISHERIES-RELATED FUNCTIONS OF THE PAGBILAO EXPERIMENTAL MANGROVE FOREST[5]

Perry S. Ong and Jose E. Padilla

5.1. Introduction

The Department of Environment and Natural Resources (DENR) Mangrove Reserve in Pagbilao, Quezon (13°57' to 13°59' N, 121°42'' 121°46'E) has only 111 hectares left and is classified as an experimental forest. It is flanked by the Nahalinan River in the west and the Palsabangon River in the east (Carandang and Padilla, 1995; Fortes, 1994). Extensive areas of fishponds are found just outside the mangrove reserve, especially near the mouths of Pagbilao, Nahalinan, and Palsabangon Rivers (Carandang and Padilla, 1995; Bagarinao, 1995; Fortes, 1994). The latter two waterways and Sukol Creek have a combined average area of 10.25 hectares (Table 1) based on a mean width of 32.5 m (15-50 m) and length of 2 km for Palsabangon River, 20 m (10-30 m) mean width and length of 1.5 km for Nahalinan River and 15 m (10-20 m) mean width and length of 500 m for Sukol Creek (Pinto 1987, Bagarinao 1995).

The Pagbilao Experimental Mangrove Forest had been the subject of various studies on its forest resources and fisheries. These include those by the National Mangrove Committee (1982), Andrada (1983), Tang (1983), Leonardo (1984), Melijan (1984), De la Paz and Aragones (1985), Fortes and Jara (1987), Pinto (1987, 1988), Fortes (1994), Carandang and Padilla (1995) and Bagarinao (1995), among others.

This study is part of a multidisciplinary project assessing various management alternatives for Philippine mangrove forests. The objectives of the fisheries component are:

a. to assess the contributions which mangroves make to supporting fish and shellfish stocks on the basis of available literature;
b. to infer on the degree of dependence of various fishes and crustaceans on the Pagbilao mangroves; and
c. to estimate potential yields of fish and crustaceans as a result of alternative management alternatives for the Pagbilao mangroves.

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[5] Report submitted to the Resources, Environment and Economics Consultants, Inc. (Philippines) and the Institute For Environmental Studies Free University (the Netherlands).

This paper builds on previous studies by the National Mangrove Committee (1982), De la Paz and Aragones (1985), Pinto (1987, 1988), Fortes (1994) and Bagarinao (1995). It also draws on the forestry study on nutrient productivity by Carandang and Padilla (1995). The fisheries data analyzed in this report were based on Bagarinao's sampling at Sukol Creek (Figure 5.1), which is the most recent data collected for this study area. The data are summarized in Appendices 1 and 2.

5.2. Importance of Mangroves as Feeding and Nursery Grounds

From the perspective of aquatic species, notably fish and crustacea, the mangrove habitat maybe defined as the mangrove prop root system and its adjacent muddy bottom areas such as lagoons, creeks, and passages, which are derived from mangrove-induced deposition processes and that would not be there if the mangroves were not (Bagarinao 1995). Several studies in sites other than the Pagbilao mangroves have established a positive correlation between fish and shrimp yields and mangrove area or length of mangrove-lined area (Camacho and Bagarinao 1987; Martosubroto and Naamin 1977; Macnae, 1974; Turner, 1977; Staples *et al.*, 1985). This could be attributed to mangroves' providing food for the support of these stocks and/or acting as a nursery supporting the survival of juveniles (Odum and Heald, 1975; Hatcher *et al.* 1989). These two aspects are discussed briefly in the following sections.

There is ample evidence in the literature that supports the view that mangroves are important feeding and nursery grounds for various fish and crustaceans (see Odum and Heald, 1972, 1975; Macnae, 1974; Martosubroto and Naamin 1977; Turner, 1977; Staples *et al.*, 1985; Camacho and Bagarinao 1987; Hatcher *et al.* 1989) despite views to the contrary (Robertson and Duke, 1987; Stoner and Zimmerman, 1988; Thollot and Kulbicki 1988, Parrish 1989, Salini *et al.* 1990, Thollot *et al.* 1991; Primavera, 1995; Fleming *et al.*, 1990).

Mangrove ecosystems are believed to be highly productive equaling or exceeding the productivity of most terrestrial ecosystems and even cultivated land. Fortes and Jara (1987) have shown that the organic matter production of the four dominant species in the Pagbilao Experimental Mangrove Forest (mean=481.74 gm/m^2/year) is comparable to that of the major cultivated crops (mean=744.5 gm/m^2/year), particularly if one takes into consideration the fact that mangroves grow naturally without external energy subsidies such as fertilizers and other means of yield improvement.

Substantial contributions to primary productivity are also made by mangroves themselves; although other sources include mangrove associates, benthic algae and phytoplankton (Singh *et al.* 1993). Some of this primary production is grazed directly by herbivores, e.g., insects grazing on mangrove leaves, zooplankton grazing on phytoplankton. However, it appears that most of the fixed carbon contributes to the pool of dead organic matter in the sediments under the mangroves. Further contributions to this detritus pool come from suspended and dissolved organic matter in inflowing waters particularly those draining from the catchment. Fortes and

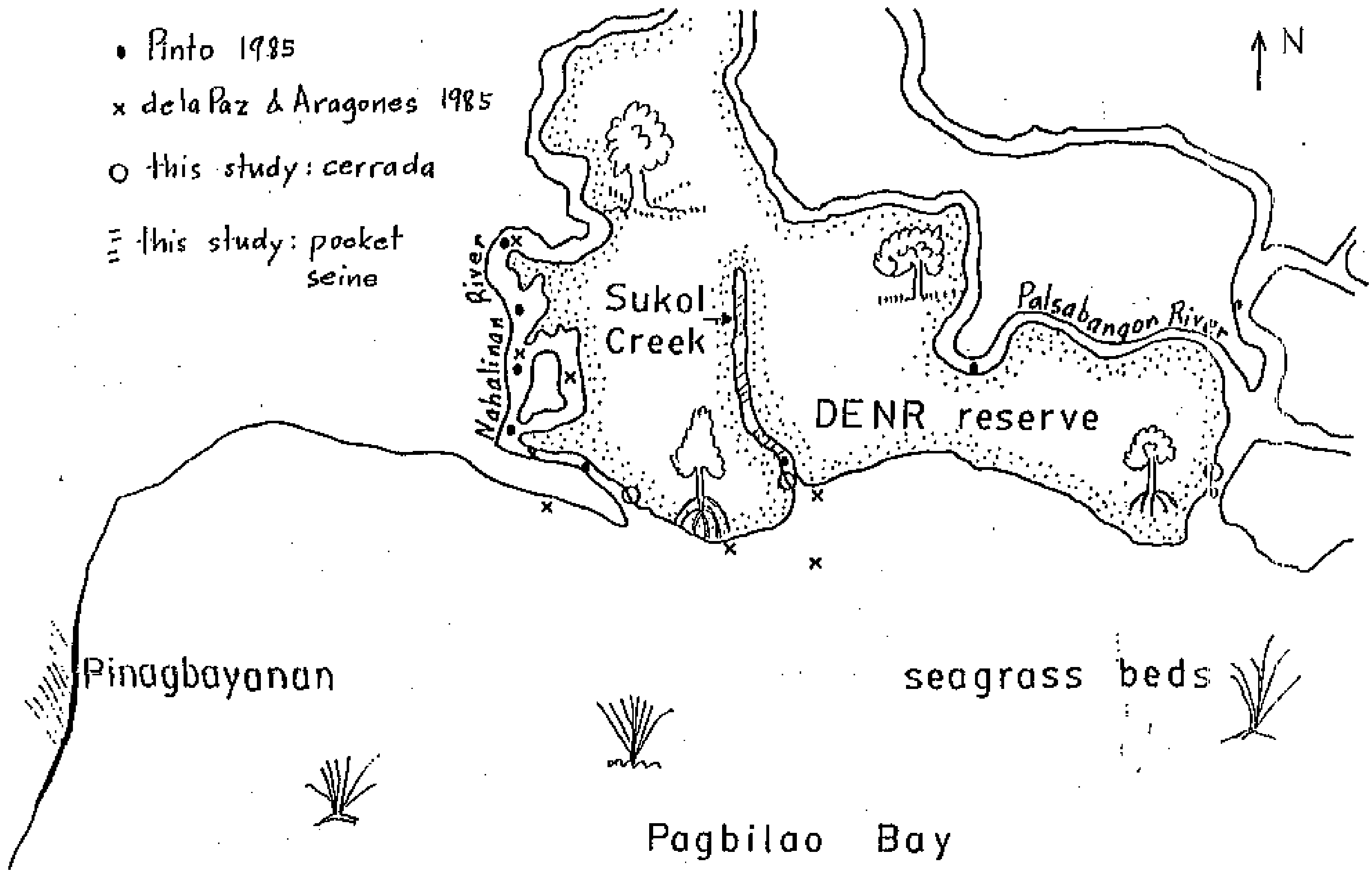

Figure 5.1. The study site in Sukol Creek at the DENR mangrove reserve in Pagbilao, Quezon. Also indicated are the study sites of other studies by Pinto (1985) and Dela Paz and Aragones (1985). Figure from Bagarinao (1995).

Jara (1987) also found that in the Pagbilao Experimental Mangrove Forest there is a higher level of organic matter in undisturbed areas than disturbed areas and that there is a net export of organic matter from the mangroves to the open seas.

Decomposition of detritus by bacteria and fungi results in the concentration of nitrogen, which is voraciously sought by detritivores, and forms the basis for a complex food web (see Figure 5.2). Mangrove ecosystems demonstrate a high secondary productivity and support a large diversity of species (Robertson *et al.* 1988). Not all of these species are permanent residents. For example, there are species which breed in mangrove ecosystems and others which complete their life cycles there. The latter includes juveniles of some fishery species typically found offshore.

In the Pagbilao Experimental Mangrove Forest, several factors interact that provide the physico-chemical environment and food of the juvenile fish and that those factors leading to food abundance are more important for the occurrence of juvenile fish in this environment than those determining the physico-chemical environment (Pinto 1987). Furthermore, Pinto (1987) suggested that environmental factors are only one aspect that determines the occurrence of juvenile fish in the mangroves and biological factors such as population characteristics and predation could further affect the occurrence of juvenile fish in the mangroves.

The macrofauna, the meiofauna, phytoplanktons, zooplanktons and detritus in mangroves provide the major sources of food for fishes and crustaceans (see references in Singh *et al.* 1993, Robertson *et al.* 1988). Chua (1973) established a positive correlation between fish presence and copepod abundance while Odum and Heald (1972, 1975) also showed that mangrove leaf litter provides nutrition for detritivores, particularly shrimps. Of the 128 species of fish species Pinto (1987) identified in the Pagbilao Experimental Mangrove Forest, 39% were benthic, 6% were pelagic, 1% hyponeustonic and 54% benthopelagic. The distribution pattern in the life habits of these fish species indicates the importance of the mangrove river bottom in the life of the mangrove fishes.

Macnae (1974) established a positive correlation between mangrove productivity and finfish and shellfish production (see Singh *et al.* 1993 for other examples of this relationship). Two mechanisms have been postulated to explain the link between fisheries yields and adjacent intertidal areas. These are (1) trophic subsidy through export or outwelling and (2) use as nursery grounds (Boesch and Turner 1984; Robertson and Blaber 1992).

Part of the detritus which accumulates in mangrove ecosystems is thought to be exported towards offshore environments by tides. Many authors stress the contribution which mangrove ecosystems make to productivity in adjacent ecosystems via outwelling, suggesting that the detritus generated and accumulated in mangrove ecosystems could support long food chains ending with open oceans (see Carter 1988). However, care should be taken with this point. Fisilier (1990) argues that scientific evidence for this support of offshore ecosystems is lacking or only a very small percentage of primary production is involved. Studies exist which

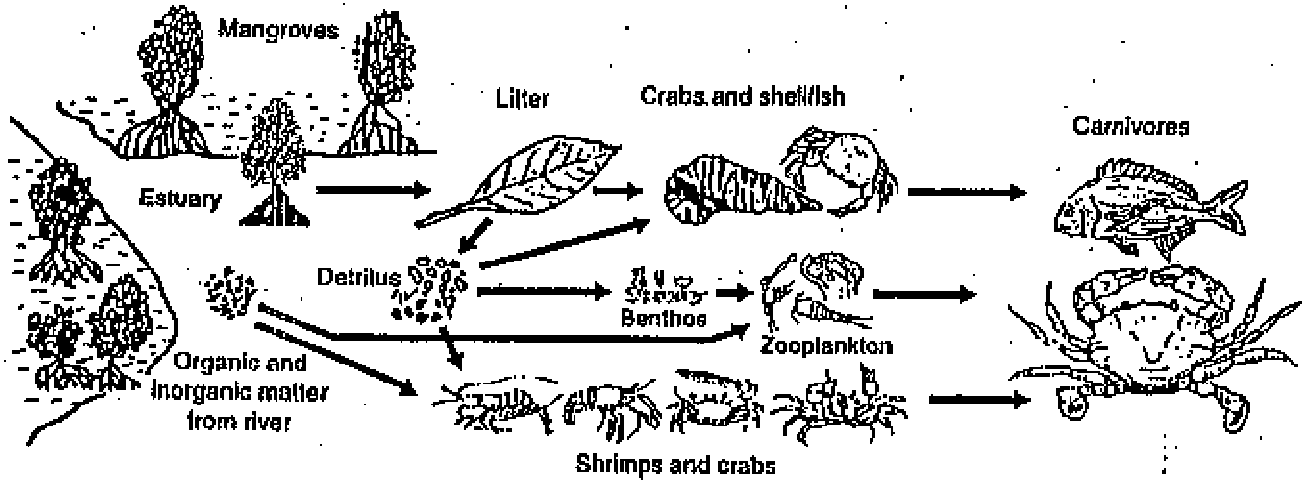

Figure 5.2. Simplified diagram of a food web in the mangroves (adapted by Singh *et al.* 1993 from JICA 1990).

support a view of mangrove ecosystems more as a sink for substances carried by rivers and tides, than a source (Ong 1984 in Fisilier 1990). Finally there is little evidence that exported detritus enhances primary productivity in offshore communities (Lee 1995).

The connection between offshore prawn catches and mangroves may lie in the nursery function rather than the export function (Hatcher *et al.* 1989). Mangrove habitats are potential nursery areas for marine animals, i.e., they provide food, shelter from predation and turbulence, or both. They are also important nursery grounds for some penaeid species such as *Penaeus monodon* and *P. merguiensis* (Primavera 1995). Specifically, mangroves act as penaeid shrimp nurseries by providing food and/or shelter from predation, the latter through physical structures such as roots, turbidity or exclusion of predators (Hatcher *et al.* 1989; Robertson and Blaber 1992; Primavera 1995). Furthermore, mangroves are major nursery grounds for a variety of juvenile fishes and provide important habitats for adult fishes (Robertson and Duke, 1987; Pinto, 1987, 1988; Christensen, 1982; Macnae, 1974). Figures 5.3 and 5.4 show the life cycles of *P. merguiensis* and *Lates calcarifer* and their dependence on the mangroves, respectively.

Herre (1959) reported numerous marine fish species in the Philippines that visit the freshwater or brackish water, entering as juveniles but returning to the sea long before sexual maturity. The most abundant fish group, the glassfish, swim up the Philippine rivers during the dry season and during the rainy season returns to the sea to spawn.

In Pagbilao Bay, peaks in organic matter production in the Pagbilao Experimental Mangrove Forest and its transport to the sea were correlated with peaks in fish abundance (Fortes and Jara, 1987) while total biomass of the catch showed positive correlation with sediment carbon and litterfall although this varied between fish species (Pinto, 1987). To illustrate, the benthic sting fish (*Prosopodasys gorgozae*, Scorpaenidae) showed positive correlation with sediment carbon and salinity while the benthic goby (*Gnatholepis calliurus*) showed positive correlation with nitrate pH and litterfall (Pinto 1987).

Primavera (1995) provided evidence of the importance of the nursery role of the riverine mangrove, e.g., greater juvenile abundance, smaller sizes, and absence of maturing female penaeids in this habitat. In contrast, both transient juveniles and adults penaeids, were present in the island mangrove, at greater sizes and lower densities than in the river. Primavera (1995) also concluded that the requirements of juvenile shrimps are species specific. Juveniles of *Penaeus monodon* need mangrove vegetation while juveniles of *P. merguiensis* need a combination of mangrove vegetation and brackish water conditions; juveniles of *Metapenaues anchistus* need marine waters while juveniles of *M. ensis* need estuarine waters.

Only 12% of the 128 fish species found in the Pagbilao Experimental Mangrove Forest showed maturing gonads, another indication that the Pagbilao mangrove fish community is composed mainly of immature fish (Pinto 1987). Fish caught by Bagarinao (1995) also were in sizes that were considerably smaller than market sizes while fishermen using gears that would have trapped larger fish, also caught small fish, further supporting this observation.

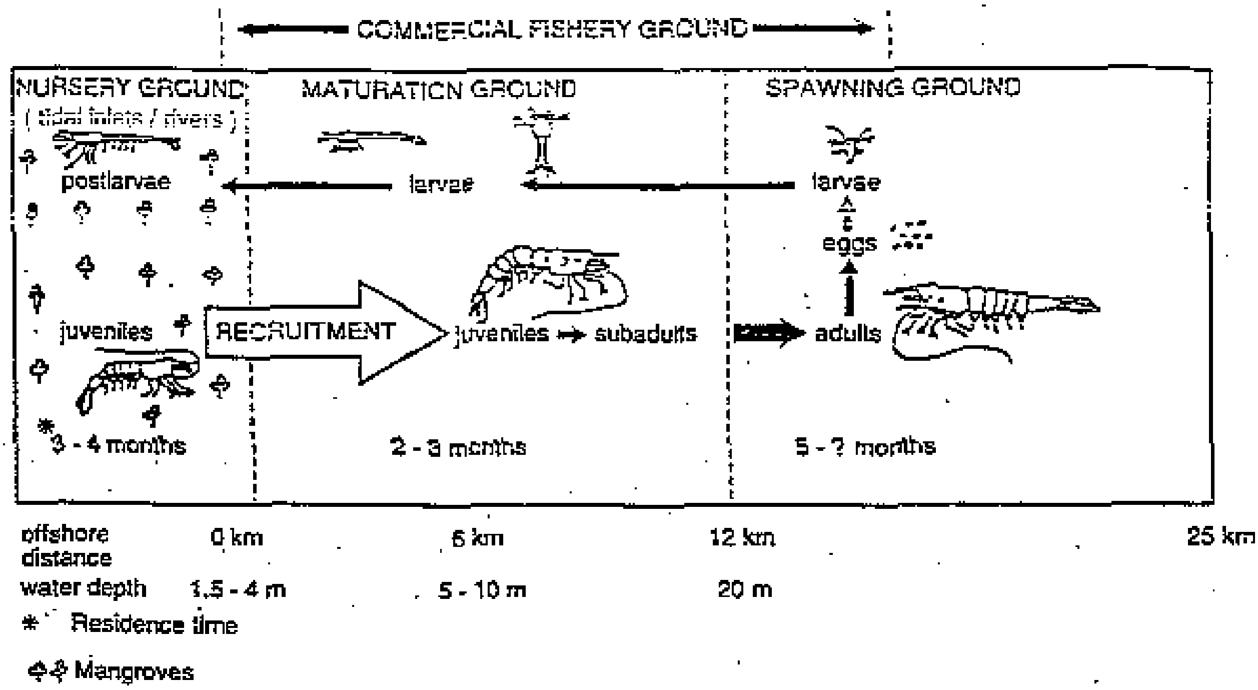

Figure 5.3. Diagrammatic representation of the life cycle, habitat and fishery ground of the white prawn Penaeus merquiensis off the coast of Selangor, Malaysia (adapted by Singh et al. 1993 from Chong 1984).

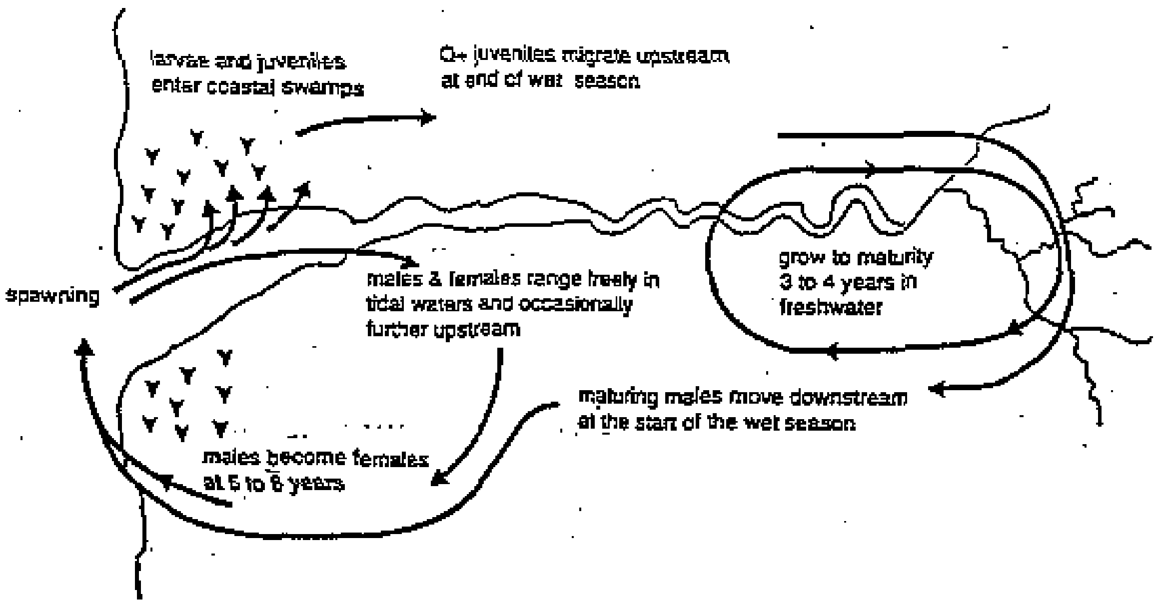

Figure 5.4. Generalised life history of sea bass or barramundi *Lates calcarifer* (adapted by Singh *et al.* 1993 from Grey 1986).

Finally, there is a high mortality rate in the study area, which is typical of populations with very high juvenile population. In contrast, there are very few fish eggs and larvae found in the gut of fish caught in Pagbilao (Melijan, 1984 and Leonardo, 1984). These two observations indicate that the Pagbilao Experimental Mangrove Forest serves a nursery ground function rather than a spawning ground function.

However, several recent studies have challenged the notion that mangrove leaves and detritus provide nutrients for detritivores (Robertson and Duke, 1987; Stoner and Zimmerman, 1988; Thollot and Kulbicki 1988, Parrish 1989, Salini *et al.* 1990, Thollot *et al.* 1991; Primavera, 1995). Mangroves make only a localized contribution to the food chain, such as within the riverine forest (Fleming *et al.* 1990). The nursery function of mangroves may be different for different fishes and shrimps, and may not only be via the detritus pathway (Bagarinao 1995). Furthermore, Primavera (1995) showed experimentally that not all penaeid shrimps are dependent on mangroves. She also demonstrated that mangrove-associated penaeids are not detritivores but instead derive their carbon sources from feeding on phytoplanktons and epiphytic algae through intermediate links such as copepods, polychaetes and gastropods. Nevertheless, these studies do not detract from the feeding ground and nursery ground function of mangroves as the other links in the food chain identified and the habitat quality are dependent on mangroves albeit this maybe through indirect means.

This apparent contradiction regarding the roles and contributions of mangroves to productivity probably stems from the difference between the roles and contributions of mangroves as a species and of mangroves as an ecosystem. To illustrate, if mangrove-associated penaeids are not feeding on detritus derived from mangrove leaves, this does not mean that they are not dependent on the mangrove ecosystem which also provides the phytoplanktons and epiphytic algae that they do feed on. The mangrove ecosystem and its food web is very complex. The degree of dependence of species on the mangroves may not differ between one species which eats dead mangrove leaves, another which eats herbivores which eat algae which grow on mangrove roots, or a third species which breeds among the roots of mangroves. Furthermore, some species are less choosy and in having a broader resources base, range or niche, they reduce their dependence on any one food source, habitat, etc. (personal communication from L. Fernandes and A. Gilbert).

5.3. Fish Diversity in The Pagbilao Experimental Mangrove Forest

The number of fish species caught in the Pagbilao Experimental Mangrove Forest reported by the five studies varied from 26 to 128 (Table 5.2). All studies covered relatively the same sampling sites (in the Palsabangon and Nahalinan Rivers and Sukol Creek). Thus, it appears that the number of species caught is directly proportional to sampling effort (i.e., as sampling effort increased, the number of species caught increased). To illustrate, the lowest number of fish species (=26) recorded by the National Mangrove Committee (1982) sampled only once every month in three different months while the highest number of fish species (=128) recorded by Pinto (1987, 1988) sampled once a month over 18 months. The former study did not indicate the sampling gear used and the timing of sampling while the latter study used an otter trawl net and sampled only at night during high tides.

Among the five studies, only those by Pinto (1987) and by dela Paz and Aragones (1985) were undertaken over prolonged and continuous periods whereas the other three studies were mostly short-term sporadic sampling. It is these two studies that recorded the highest number of fish species caught (110 and 128 species respectively) whereas the last three studies recorded the least number of fish species caught (26, 37 and 46 respectively).

In this respect, Bagarinao's data approximated the number of fishes recorded by the other two short-term studies (National Mangrove Committee, 1982 and Fortes 1994) and were comparable to the results of the other two long term studies (dela Paz and Aragones 1985; Pinto 1987, 1998). It appeared not to underestimate the number of species in the Pagbilao Experimental Mangrove Forest and represented a good cross-section of the species composition of the Pagbilao Experimental Mangrove Forest. Furthermore, the more abundant and/or dominant species caught were similar in these studies. *Ambassis kopsi* was found to consistently dominate the mangrove fish community in Pagbilao (Dela Paz and Aragones, 1985; Pinto, 1988; and Bagarinao, 1995).

5.4. Methods

Based on the abundance (e.g., Glassfish, Slipmouths) and economic importance (e.g., Cardinalfish, Milkfish, Mullets, Groupers and Snappers) of fish collected from the Sukol Creek area, Bagarinao (1995) selected fish groups for inclusion in her analysis and extrapolations of fish standing crop in the Pagbilao Experimental Mangrove Forest (see Appendix 3). Furthermore, Pinto (1988) identified four fish species as residents in the Pagbilao Experimental Mangrove Forest based on their length frequency data which were close to the L_{max} records for these species. From these, Pinto (1988) calculated for:

$Z=F+M$, where Z = total mortality, F= fishing mortality and M= natural mortality; and
$E=F/Z$, where E is the exploitation rate, F and Z are as described as above;

The calculated exploitation rate for the resident species was derived from Pinto's (1988) data. The exploitation rate for species classified as transients by Bagarinao (1995) were derived from available records reported by Ingles and Pauly (1984). For those species classified as residents or transients but where data on their exploitation rate were not available, the exploitation rate was assumed to the mean for each group. A summary of the exploitation rate for residents and transients are presented in Table 5.3.

The mean sizes of the fish groups caught in Sukol Creek were compared to the mean sizes of those being sold at the fish market (Columns A and B of Table 5.4). Using the following formula:

$$W=aL^b$$

where W= weight, L= length and a and b (see Columns C and D) are coefficients based on the International Center for Living Aquatic Resources Management's (ICLARM) computer database called FishBase.

The mean weight of these fish groups was calculated (Columns E and F).

The difference between the weights of fish from Sukol Creek and those sold at the market varied markedly, with those from Sukol Creek consistently being underweight, in some groups being even more than 100 times lighter. This is due to the juvenile stages of the fish caught and confirms the nursery role of the Pagbilao mangroves.

Column G, the estimated total number of individuals per hectare per year, was derived from Appendix 3, which Bagarinao estimated based on the following assumptions:

1. The mean number of fish caught during the three sampling dates was assumed by Bagarinao to represent a cohort, i.e., a group of residents or transients present at any one time. This was then divided by 250 m^2 to arrive at the number of fish per cohort caught on a per hectare basis.
2. Based on a knowledge of their biology, Bagarinao assumed that resident species were capable of producing 10 cohorts per year, while transients produced between 2 and 6 cohorts per year.
3. Estimates of the total population of fish within the Pagbilao mangroves were made assuming temporal and spatial homogeneity: i.e., that the number and species caught by Bagarinao in Sukol Creek is the same throughout the mangrove ecosystem and is independent of the time of the day or of the year.

Using these assumptions, an estimate of the annual standing crop of each fish group in terms of individuals per hectare was calculated.

The projected annual standing crop per hectare per year of the Pagbilao Experimental Mangrove Forest, Column H, was arrived at by multiplying Column F with column G then divided by 1000g/kg. Finally, the projected harvest per hectare per year that is considered sustainable, Column I, was arrived at by multiplying Column H by the exploitation rate presented in Table 5.3 except for the crustaceans, where an exploitation rate of 50% was assumed in the absence of catch and effort data (see Gulland 1971).

5.5. Results and Discussion

Among mangrove residents, the glassfish and the slipmouths are projected to have an annual harvest considered sustainable of more than 79 kg/ha/year (558 kg/ha/year and 79.1 kg/ha/year, respectively), while the gobies and the cardinalfish, are projected to have an annual harvest considered sustainable of less than 10 kg/ha/year (8.8 kg/ha/year and 5.8 kg/ha/year, respectively). Crabs and mudcrabs are projected to have an annual harvest considered sustainable of 535 individuals/ha/year and 750 individuals/ha/year, respectively.

Among mangrove transients, the mullets and the rabbitfish, are projected to have an annual harvest considered sustainable of more than 10 kg/ha/year (40.1 kg/ha/year and 11.6 kg/ha/year, respectively), while the milkfish, snappers and the groupers, are projected to have an annual harvest considered sustainable of less than 3 kg/ha/year (2.5 kg/ha/year, 1.4 kg/ha/year and 0.7 kg/ha/year, respectively). Shrimps are projected to have an annual harvest considered sustainable of 21,639 individuals/ha/year.

Annual Standing Crop Under Various Management Alternatives

The data presented in Column H of Table 5.4 represent the status quo in terms of the projected annual standing crop of important fish groups and crustaceans per hectare per year and presented as such in Table 5.5 (Column A). Since Fortes and Jara (1987) showed that peaks in organic matter production in the Pagbilao Experimental Mangrove Forest and its transport to the sea were correlated with peaks in fish abundance and that the total biomass of the catch showed positive correlation with sediment carbon and litterfall, it was assumed that there is a direct relationship between nutrient productivity and fish and crustacean standing crop. This in turn was correlated with the annual nutrient production (tons/year) of the Pagbilao Experiment Mangrove Forest estimated by Carandang and Padilla (1995). Thus, the annual nutrient productivity in the Pagbilao Experimental Mangrove Forest was assumed to translate directly to the fish and crustacean standing crop estimated for the area. Hence, in the various management alternatives, the reduction in the size of the mangroves results in a reduction in fisheries and crustacean standing crop. Since all management alternatives result in a reduction in the annual nutrient production of the mangroves, the reduced annual fisheries and crustacean standing crop was calculated for each by simple ratio and proportion.

Alternatives 2 and 3 (Column B) result in a 2.7% reduction in nutrient production, alternative 4 (Column C) in a 25% reduction, alternatives 5 and 6 (Column D) in a 86% reduction and alternatives 7 and 8 (Column E) in a 31% reduction. Thus, the fish and crustacean standing crop were reduced by these corresponding levels. Columns D and E present the data on the assumption that the reduction caused by these alternatives were the same as in the other alternatives. However, knowing that there is a minimum area beyond which an ecosystem ceases to function as such, i.e., a massive reduction in the size of an ecosystem can drastically alter if not completely halt its ecological functions, it was further assumed that these lost ecological functions will affect the standing crop, e.g., when a mangrove area is converted to a fishpond and involves massive alteration to the mangroves even when a strip of mangrove is left as a buffer zone, then the effects are also equally devastating on the fish and crustacean fauna, albeit to different degrees to different groups. With these assumption, the effect on fish and crustacean standing crop was recalculated and shown in Columns D^I and E^I.

In Column D^I, the conversion to fishponds was assumed to have a devastating effect on all fish species, thus fish productivity will disappear altogether while there will be a 90% reduction in crab standing crop and a 95% reduction in shrimp standing crop. Based on a knowledge of fish biology and behavior (see Appendix 4), the habitat alteration proposed under these alternatives and the pollution that will be generated by the fishponds will be the *coup de grace* that will definitely drive away and prevent future recolonization by mangrove residents and transients alike. The impact on shrimps is greater than that expected on the crabs as the shrimps are more sensitive to these changes than crabs.

In Column E[1], the conversion of a part of the mangroves to aquaculture will have a less devastating effect on the fish and crustacean fauna than that proposed under alternatives 5 & 6 but this will be only in terms of degree. It is estimated that impact will be more serious to mangrove transients than to mangrove residents since transients can afford to move to other areas in the face of habitat alteration, in the sense that if they were absent in the area when the changes occur, they can move directly to alternative sites where these are available and thus disappear altogether from the damaged area, whereas residents will be forced to stay and confront the altered conditions and make adjustments to the new conditions. It is assumed that under alternatives 7 & 8, the standing crop of all residents will be reduced by 75%, while for transients, the effect will vary. For milkfish, groupers and snappers, they will be immediately be driven out of the area while the remaining group of transients, the rabbitfish and mullets will have a 90% reduction in standing crop while shrimp standing crop will be reduced by 85%.

To sum up, when ecological factors affecting the standing crop are considered once mangroves are converted to fishponds (as in alternatives 5 and 6), the result can be devastating and may even result in local extinctions in the fish fauna, whereas the standing crop of crabs and shrimps will be greatly reduced by as much as 90 and 95%, respectively. Partial conversion (as in alternatives 7 and 8) will have a lesser degree of devastation (a 75% to 100% reduction in standing crop) but a devastation nonetheless.

Projected Potential Standing Crop Under Various Management Alternatives

Over 25 Years

Carandang and Padilla (1995) projected an average annual mean increase in nutrient production (in terms of N, P, K at 7.8%, -0.5% and 1.44%, respectively) of 2.91%. To compute for the projected standing crop over 25 years under status quo, the mean annual rate of increase in nutrient production was used as the basis for estimating the annual fish and crustacean production. This process was repeated for each year with the values of the preceding year as the basis for calculating the production for the succeeding year. Once this was computed, the yearly productivity, in terms of the number of individuals/ha over 25 years and its weight in kg/ha over 25 years, was summed up to arrive at the potential standing crop over 25 years (Table 5.6).

The potential standing crop over 25 years under other management alternatives was estimated by simple ratio and proportion as follows (e.g., alternatives 2 & 3):

The rates of change in Table 5.6 were assumed to be similar to that calculated for the annual standing crop in Table 5.5. As in Table 5.5, Columns D and E of Table 5.6 present the data on the assumption that the reduction caused by these alternatives were the same as in the other alternatives. However, since it was assumed that some of the management alternatives entail different ecological impacts as described in the previous section, the impact on fish and crustacean productivity was recalculated and shown in Columns D[1] and E[1].

The assumptions made earlier in estimating the annual standing crop under each management alternative remain applicable when the potential standing crop over 25 years was estimated, thus when ecological factors affecting the standing crop are taken into consideration once mangroves are converted to fishponds (as in alternatives 5 and 6), the result remain devastating and may even lead to local extinctions in the fish fauna, whereas the standing crop of crabs and shrimps will be greatly reduced by as much as 90 and 95%, respectively. Partial conversion (as in alternatives 7 and 8) will have a lesser degree of devastation (a 75% to 100% reduction in productivity) but a devastation nonetheless.

The management alternative of converting mangroves into aquaculture, whether on a semi-intensive or intensive basis (alternatives 5 and 6), will have the most negative impact on the fisheries of the mangroves. The physical reduction in the size of the mangroves and the resulting pollution that will arise from the operation of the fishponds will ensure that the original fish fauna will be driven away if not killed outright and create conditions that will prevent their future re-colonization (e.g. 25 years from now). Partial conversion (alternatives 7 & 8) will have the same negative impact but only to a slightly lesser degree. Nevertheless, the fish fauna will still be adversely affected and may never recover from it.

Over 50 Years

The projected fish and crustacean standing crop over 50 years were also estimated by extending the 25 year increase into 50 years in terms of number of individuals/ha and in terms of the weight/hectare (Table 5.7). The rate of increase has a compounding effect, thus although the time frame was doubled (i.e., from 25 to 50 years), the standing crop increased nearly three times. Again, as in the estimates made on standing crop over 25 years, the same assumptions were made in projecting the standing crop over 50 years, i.e. there is a direct linear relationship between nutrient productivity and fish standing crop. Thus the rate of change in fish standing crop under various management alternatives was equivalent to the percentage reduction in nutrient productivity, except under Columns D[1] and E[1] where impacts on the ecological function of mangroves were factored in. Thus, the effect on decreasing productivity was greater than when a direct linear relationship was assumed (e.g. Columns D and E).

5.6. Valuation of Fishery-Related Functions

A valuation of the fisheries' standing crop estimates of the mangrove forest under alternative management strategies. With respect to the various management regimes, the focus of valuation is on the current status of the mangroves, as the fisheries survey only collected data assuming no significant changes on the physical characteristics of the mangrove forest. The procedure in estimating productivity for the other management alternatives is followed in the valuation.

Several points need to be considered in the valuation exercise. First is the size of fishes found in the mangrove forest. Using market prices which apply to bigger sizes of fish maybe misleading in attaching values to juveniles. Further, fisheries productivity need to be adjusted to take into account losses from natural mortality. Second is the level of dependence of the various fish species on the mangrove forest. For simplicity, migration of fish to adjacent mangrove sites when the mangrove is converted into other uses is not considered. Thus, the lower fisheries productivity in alternatives involving conversion represents net loss with respect to the experimental mangrove forest. (It could have been that the fish may move to adjacent mangrove strips or in the seagrass beds and coral reefs. Thus, there maybe no net loss when a wider spatial coverage is considered).

The number of fish growing to market size is estimated considering that most of the fish species found in Sukol creek are juveniles (see Columns E and F in Table 5.3). Losses from natural mortality is assumed equivalent to the percentage deviation from the market size of the fish found in the creek. The weight of these juveniles when they reach market size is then computed and shown in Table 5.8. Mangrove residents comprise the bulk of fish production, particularly glassfishes and slipmouths. Transient species production is very minimal. Across management alternatives, the highest production is realized when the mangrove forest is preserved although fisheries productivity under either the sustainable subsistence or commercial forestry alternatives is minimally affected. It is in the conversion alternatives that mangrove-dependent fisheries productivity declined considerably.

Estimated standing crops are converted to monetary equivalents using *in-situ* price of fish. This price is similar to stumpage value in respect of forest products, particularly timber. *In-situ* prices of fish is estimated at 12.25% of the landed price of fish (NSCB 1996). This means that 87.75% of the prices received by fishers cover the costs of catching based from a national survey of fisheries in the country[6]. The value of fisheries production for the study site, Sukol creek in particular, is shown in Table 5.9. The value ranges from about 270 pesos/ha/yr for the full-conversion alternatives to 5,300 pesos/ha/yr in the preservation alternative.

The value of fisheries productivity in Sukol Creek is raised for the entire area considering that waterways such as the creek may contribute more to fisheries production compared to portions of the mangrove forest which are intermittently underwater. The total area of waterways of the experimental forest is estimated at 10.25 ha (see Table 5.1). It is assumed that the relevant area for fisheries production is thrice the area of the waterways. This is then used to multiply the value of fisheries production in Table 5.9 and divided by the total area of the mangrove forest at 110.7 ha (Table 5.10). The values in this table may be interpreted as the lower-bound estimate of fisheries productivity while those in Table 5.9 as the upper bound estimate.

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6 This information is used in the absence of long-term survey data of fishing operations in Pagbilao.

5.7. Conclusion and Recommendations

There are contrary views regarding the importance of mangroves as feeding and nursery grounds for fish and crustaceans. However, the discussion revolves more around the degree of importance, than around the existence or not of these roles. The degree of dependency is not yet quantified and so valuation of the mangroves in terms of their contribution remains very imprecise.

Based on the assumption that among the more important fisheries-related functions of mangrove forests of Pagbilao are its role as a feeding ground and nursery ground, one thing consistently emerged from this analysis: the status quo alternative will provide the highest natural fish productivity while conversion into fishponds will have the most adverse effect including the possibility of local extinctions and prevention of further re-colonization.

This exercise in the valuation of the fisheries-related functions of mangrove forests was severely limited by the lack of solid baseline information. Estimates have been made using a number of assumptions which are tenuous. It is strongly recommended that this gap in knowledge be filled in as soon as practicable. Furthermore, the validity of some of the assumptions needs to be ascertained. These include:

a. Is the relationship between nutrient productivity and fisheries productivity a direct and linear one? If yes, by how much? If not, why and on what are the other factors on which fish productivity rely on?
b. corollary to (1), will the decrease in size of mangrove forests under the various management alternatives result in a decrease in fisheries? If yes, by how much? If not, how does reduction in mangrove forest affect fish productivity?

Other aspects in the study that were not addressed due to lack of reliable data include an analysis into the relationship of the fish productivity and catch per unit effort (CPUE) and the effect of other forms of human activity on fish productivity. These are some of the potential areas of follow-up research identified in this exercise.

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Table 5.1. Size of the waterways directly draining the Pagbilao Experimental Mangrove Forest.

Waterways	Width (range, m)	Length (m)	Mean Size (ha)	Reference
Palsabangon River	32.5 (15-50)	20,000	6.50	Pinto 1988
Nahalinan River	20.0 (10-30)	15,000	3.00	Pinto 1988
Sukol Creek	15.0 (10-20)	500	0.75	Bagarinao 1995
Total			***10.25***	

Table 5.2. Comparison of the number of fish species caught in previous studies *vis a vis* various sampling variables in the Pagbilao Experimental Mangrove Forest.

	A	B	C	D	E
Total Species	26	110	128	32 + 5*	46
Total Genera	25	73	82	27 + 4*	37
Sampling site	Palsabangon Nahalinan, and Lokohin Rivers; Sukol Creek	Nahalinan River and Sukol Creek	Palsabangon and Nahalinan Rivers; Sukol Creek	Nahalinan River; Sukol Creek	Palsabangon and Nahalinan Rivers; Sukol Creek
Sampling Gears	Not mentioned or described	beach seine, gill nets	otter trawl net	Interviews with fishermen who used gill nets and seines; use of motorized bancas	small seine, filter net bag, pocket seine (ps), cerrada (cer), floating gill net
Period Covered	Aug 1981 to Mar 1982	Nov 1982 to Dec 1983	May 1983 to August 1984	July to Oct. 1992	Jan 26-31 and July 10- 14, 1995
Sampling Effort	3 sampling (once each in Aug. Dec. and Mar.)	monthly over 13 months, 3 days per month	monthly over 18 months, once a month	monthly over4 months	3 sampling (twice in Jan and once in Jul.)
Timing of sampling	Not mentioned or described	at night and at low and high tides	at night during high tides	24 hour sampling, no indication of frequency	Low tide at dawn (ps); 7 night-time hours; 7 daytime hours (cer)

*unidentified genera and species.

Legend: A=National Mangrove Committee (1982); B=Dela Paz and Aragones (1985); C=Pinto (1987 1988); D=Fortes (1994); E=Bagarinao (1995).

Table 5.3. Estimated exploitation rates of fish species and fish species related to those found in the mangroves of Pagbilao, Quezon.

Species	F (fishing mortality)	M (natural mortality)	Z (Total mortality)	E=F/ZExploitation rate
A. Residents				
*Ambassis kopsi**	0.91	1.96	2.87	0.3171
*Secutor ruconis**	0.81	2.83	3.64	0.2225
*Leiognathus brevirostris**	0.91	2.75	3.66	0.2486
*Prosopodasys gogorzae**	0.43	1.37	1.80	0.2389
Mean				0.2568
B. Transients				
*Liza subviridis***	1.95	1.25	3.19	0.6100
*Epinephelus sexfasciatus***	0.82	1.14	1.95	0.4200
Mean				0.5150

* derived from Pinto 1988.
**derived from Ingles and Pauly 1984.

Table 5.4. Estimated standing crop of important fish groups and crustaceans per hectare in the Sukol Creek, Pagbilao Experimental Mangrove Forest, Quezon (enclosed in parenthesis are the number of species in each group, from Bagarinao 1995).

	A	B	C	D	E	F	G	H	I
	Mean size (in cm)		Coefficients*		Mean weight** (in gm)		Estimated total number of individuals per hectare per year***	Projected standing crop per hectare per year**** (kg)	Projected allowable sustainable yield per hectare per year***** (kg)
Mangrove Residents	Market	Sukol	(a)	(b)	Market	Sukol			
Slipmouths (3 spp.)	6.0	5.0	0.0268	3.0	5.8	3.4	93,070	316.4	78.7
Cardinalfish (1 sp.)	10.0	7.2	0.0107	3.207	17.2	6.0	3,730	22.4	5.8
Glassfishes (2 spp.)	6.0	5.4	0.0528	2.793	7.9	5.9	295,600	1,744.0	553.0
Gobies (4 spp.)	12.5	9.7	0.00275	3.027	5.8	2.7	12,530	33.8	8.7
Crab (1 sp.))#	7.5	7.5					1,070	1,070	535
Mudcrab (1 sp.)#	15.0						1,500	1,500	750
Mangrove Translents									
Milkfish (1 sp.)	25.0	16.2	0.0348	2.823	307.6	90.4	54	4.9	2.5
Rabbitfishes (2 spp.)	20.0	6.8	0.0120	3.011	99.2	3.9	5,922	23.1	11.9
Mullets (2 spp.)	22.5	10.4	0.0182	2.963	184.8	18.8	4,294	80.7	49.2
Groupers (1 sp.)	35.0	10.0	0.016	3.000	686.0	16.0	80	1.3	0.6
Snappers (3 spp.)	35.0	7.0	0.0212	2.995	892.9	7.2	374	2.7	1.4
Shrimps (4 spp.) #	6.0	2.8					43,278	43,278	21,639

* based on ICLARM's Fish Base.

** derived using the formula: $w = aL^b$ where w is the weight, L is the length, a and b are coefficients based on ICLARM's Fish Base.

*** from last column of Appendix 3.

**** calculated by multiplying column F with G then divided by 1000.

***** calculated by multiplying column H with the exploitation rates arrived at in Table 3, where no data is available the mean for each group, e.g., as residents, was used; data from related species was also used whenever possible.

\# For crabs and shrimps, estimates are for number of individuals, exploitation rate was the mean of the group to which they belonged.

Table 5.5. Estimated standing crop of important fish groups and crustaceans under various management alternatives based on Carandang and Padilla's (1995) annual nutrient production and when lost ecological functions are factored in.

	A	B	C	D	D[1]	E	E[1]
	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
Nutrient production (ton/ha/year)	70.1	68.2	52.7	10.0	10.0	48.6	48.6
A. Number of individuals/ha/year							
AI.Mangrove Residents							
Slipmouths (3)	93,070	90,547.4	69,968.5	13,276.7	0.0	64,525.0	23,267.5
Cardinalfish (1)	3,730	3628.9	2804.2	532.1	0.0	2,586.0	932.5
Glassfishes (2)	295,600	287,588.0	222,227.1	42,168.3	0.0	204,938.1	73,900
Gobies (4)	12,530	12,190.4	9,419.8	1,787.4	0.0	8,687.0	3,132.5
Crabs (1)	1,070	1,041.0	804.4	152.6	107.0	741.8	267.5
Mudcrabs (1)	1,500	1,459.3	1,127.7	214.0	150.0	1,039.9	375.0
AII. Mangrove Transients							
Milkfish (1)	54	52.5	40.6	7.7	0.0	37.4	0.0
Rabbitfishes (2)	5,922	5,761.5	4,452.1	844.8	0.0	4,105.7	592.2
Mullets (2)	4,294	4,177.6	3,228.2	612.6	0.0	2,977.0	429.4
Groupers (1)	80	77.8	60.1	11.4	0.0	55.5	0.0
Snappers (3)	374	363.9	281.2	53.4	0.0	259.3	0.0
Shrimps (4)	43,278	42,105.0	32,535.7	6,173.8	2,163.9	30,004.4	6,491.7
B. Kg/ha/year							
BI.Mangrove Residents							
Slipmouths (3)	316.4	307.8	237.9	45.1	0.0	219.4	79.1
Cardinalfish (1)	22.4	21.8	16.8	3.2	0.0	15.5	5.6
Glassfishes (2)	1,744.0	1,696.7	1,311.1	248.8	0.0	1,209.1	436.0
Gobies (4)	33.8	32.9	25.4	4.8	0.0	23.4	8.5
Crabs (1)#	1,070.0	1,041.0	804.4	152.6	107.0	741.8	267.5
Mudcrabs (1)#	1,500.0	1,459.3	1,127.7	214.0	150.0	1,039.9	375.0

Table 5.5. Continued.

	A	B	C	D	D[1]	E	E[1]
	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
BII. Mangrove Transients							
Milkfish (1)	4.9	4.8	3.7	0.7	0.0	3.4	0.0
Rabbitfishes (2)	23.1	22.5	17.4	3.3	0.0	16.0	2.3
Mullets (2)	80.7	78.5	60.7	11.5	0.0	55.9	8.1
Groupers (1)	1.3	1.3	1.0	0.2	0.0	0.9	0.0
Snappers (3)	2.7	2.6	2.0	0.4	0.0	1.9	0.0
Shrimps (4)#	43,278.0	42,105.0	32,535.7	6,173.8	2,163.9	30,004.4	6,491.7

Legend: PR: Status quo, SF: Sustainable subsistence forestry, CF: Sustainable commercial forestry, AS: Aquasilviculture, SA: Semi-intensive aquaculture, IA: Intensive aquaculture, CF/IA: Commercial forestry and intensive aquaculture, SF/IA: Subsistence forestry and intensive aquaculture.

* alternatives SF and CF, SA and IA, CF/IA and SF/IA assumed to have same effect on mangrove productivity; assuming fishpond conversion will directly reduce nutrient productivity only.

** when lost ecological functions are factored in.

number of individuals/ha/year.

Table 5.6. Potential standing crop of resident and transient fish and crustacean species over 25 years based on Carandang and Padilla's (1995) projected average annual increase in nutrient production (mean=2.91%) under various management alternatives with impacts of lost ecological functions factored in.

	A	B	C	D	D[1]	E	E[1]
	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
Nutrient production (tons)	1,754	1,705	1,318	249	249	1,215	1,215
A. Number of individuals/ha/year							
AI. Mangrove Residents							
Slipmouths (3 spp.)	3,353,451	3,259,769	2,519,868	476,060	0.0	2,322,944	838,363
Cardinalfish (1 sp.)	134,397	130,643	100,990	19,079	0.0	93,097	33,599
Glassfishes (2 spp.)	10,650,909	10,353,364	8,003,363	1,512,016	0.0	7,377,910	2,662,727
Gobies (4 spp.)	451,475	438,862	339,249	64,092	0.0	312,738	112,869
Crab (1 sp.))#	38,554	37,477	28,970	5,473	3,855.4	26,706	9,638
Mudcrab (1 sp.)#	54,047	52,537	40,612	7,673	5,404.7	37,439	13,512
AII. Mangrove Transients							
Milkfish (1 sp.)	1,946	1,891	1,462	276	0.0	1,348	0
Rabbitfishes (2 spp.)	213,379	207,418	160,338	30,291	0.0	147,808	21,3388
Mullets (2 spp.)	154,719	150,397	116,260	21,964	0.0	107,174	15,472
Groupers (1 sp.)	2,883	2,802	2,166	409	0.0	1,997	0
Snappers (3 spp.)	13,476	13,099	10,126	1,913	0.0	9,335	0
Shrimps (4 spp.) #	1,559,371	1,515,808	1,171,751	221,370	77,968.55	1,080,180	233,906
B. Kg/ha/year							
BI. Mangrove Residents							
Slipmouths (3 spp.)	11,400	11,082	8,567	1,618	0	7,897	2,850
Cardinalfish (1 sp.)	807	785	606	115	0	559	202
Glassfishes (2 spp.)	62,839	61,083	47,219	8,921	0	43,529	15,710
Gobies (4 spp.)	1,218	1,184	915	173	0	844	304
Crab (1 sp.))#	38,554	37,477	28,970	5,473	3,855.4	26,706	9,638
Mudcrab (1 sp.)#	54,047	52,537	40,612	7,673	5,404.7	37,439	13,512

Table 5.6. Continued.

	A	B	C	D	D[1]	E	E[1]
	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
BII. Mangrove Transients							
Milkfish (1 sp.)	177	172	133	25	0	122	0
Rabbitfishes (2 spp.)	832	809	625	118	0	577	83
Mullets (2 spp.)	2,908	2,827	2,185	413	0	2,014	291
Groupers (1 sp.)	47	46	35	7	0	32	0
Snappers (3 spp.)	97	95	73	14	0	67	0
Shrimps (4 spp.) #	1,559,371	1,515,808	1,171,751	221,370	77,968.55	1,080,180	233,906

Legend: PR: Status quo, SF: Sustainable subsistence forestry, CF: Sustainable commercial forestry, AS: Aquasilviculture, SA: Semi-intensive aquaculture, IA: Intensiveaquaculture, CF/IA: Commercial forestry and intensive aquaculture, SF/IA: Subsistence forestry and intensive aquaculture.

* alternatives SF and CF, SA and IA, CF/IA and SF/IA assumed to have same effect on mangrove productivity; assuming fishpond conversion will directly reduce nutrient productivity only.

** when lost ecological functions are factored in.

\# number of individuals/ha/year.

Table 5.7. Potential standing crop of resident and transient fish and crustacean species over 50 years based on Carandang and Padilla's (1995) projected average annual increase in nutrient production (mean=2.91%) under various management alternatives with impacts of lost ecological functions factored in.

	A	B	C	D	D[1]	E	E[1]
Nutrient production	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
(tons over 50 years)	3,507	3,409	2,635	498	498	2,430	2,430
A. Number of individuals/ha/year							
AII. Mangrove Residents							
Slipmouths (3 spp.)	10,223,051	9,937,377	7,681,134	1,451,691	0.0	7,083,551	2,555,763
Cardinalfish (1 sp.)	409,713	398,264	307,840	58,180	0.0	283,890	102,428
Glassfishes (2 spp.)	32,469,472	31,562,142	24,396,082	4,610,721	0.0	22,498,095	8,117,368
Gobies (4 spp.)	1,376,328	1,337,868	1,034,110	195,441	0.0	953,657	344,082
Crab (1 sp.))#	117,532	114,247	88,308	16,690	11,753.2	81,438	29,383
Mudcrab (1 sp.)#	164,764	160,160	123,796	23,397	16,476.4	114,165	41,191
Mangrove Transients							
Milkfish (1 sp.)	5,932	5,766	4,457	842	0.0	4,110	0
Rabbitfishes (2 spp.)	650,488	632,311	488,747	92,370	0.0	450,723	65,049
Mullets (2 spp.)	471,664	458,484	354,387	66,977	0.0	326,816	47,166
Groupers (1 sp.)	8,787	8,542	6,602	1,248	0.0	6,089	0
Snappers (3 spp.)	41,081	39,933	308,66	5,834	0.0	28,465	0
Shrimps (4 spp.) #	4,753,768	4,620,928	3,571,765	675,043	475,376.8	3,293,885	713,065
B. Kg/ha/year							
BI. Mangrove Residents							
Slipmouths (3 spp.)	34,754	33,783	26,113	4,935	00	24,081	8,689
Cardinalfish (1 sp.)	2,460	2,392	1,849	349	00	1,705	615
Glassfishes (2 spp.)	191,565	186,212	143,934	27,203	00	132,736	47,891
Gobies (4 spp.)	3,713	3,609	2,790	527	00	2,573	934
Crab (1 sp.))#	117,532	114,247	88,308	16,690	11,753	81,438	29,383
Mudcrab (1 sp.)#	164,764	160,160	123,796	23,397	16,476	114,165	41,191

Table 5.7. Continued.

Nutrient production	A	B	C	D	D[1]	E	E[1]
	PR	SF & CF*	AS	SA & IA*	SA & IA**	CF/IA & SF/IA*	CF/IA & SF/IA**
(tons over 50 years)	3,507	3,409	2,635	498	498	2,430	2,430
BII. Mangrove Transients							
Milkfish (1 sp.)	538	523	404	76	00	373	0
Rabbitfishes (2 spp.)	2,537	2,466	1,906	360	00	1,758	253
Mullets (2 spp.)	8,864	8,617	6,660	1,259	00	6,142	886
Groupers (1 sp.)	143	139	107	20	00	99	0
Snappers (3 spp.)	297	288	223	42	00	205	0
Shrimps (4 spp.) #	4,753,768	4,620,928	3,571,765	675,043	237,688	3,293,885	713,065

Legend: PR: Status quo, SF: Sustainable subsistence forestry, CF: Sustainable commercial forestry, AS: Aquasilviculture, SA: Semi-intensive aquaculture, IA: Intensiveaquaculture, CF/IA: Commercial forestry and intensive aquaculture, SF/IA: Subsistence forestry and intensive aquaculture.

* alternatives SF and CF, SA and IA, CF/IA and SF/IA assumed to have same effect on mangrove productivity; assuming fishpond conversion will directly reduce nutrient productivity only.

** when lost ecological functions are factored in.

\# number of individuals/ha/year.

Table 5.8. Estimates of annual production of market-size fishes taking into account natural mortality of various fish species (kg/ha/yr).

	Management Alternative				
	PR	SF/CF	AS	SA/IA	CF/IA&SF/IA
A. Mangrove Residents					
Slipmouths (3 spp.)	183.1	178.1	137.7	0.0	45.8
Cardinalfish (1 sp.)	7.8	7.6	5.9	0.0	2.0
Glassfishes (2 spp.)	1299.4	1264.2	976.9	0.0	324.9
Gobies (4 spp.)	15.7	15.3	11.8	0.0	3.9
Crabs (1) in #	1070	1041	804	107	268
Mudcrabs (1) in #	1500	1459	1128	150	375
B. Mangrove Transients					
Milkfish (1 sp.)	1.4	1.4	1.1	0.0	0.0
Rabbitfishes (2 spp.)	0.9	0.9	0.7	0.0	0.1
Mullets (2 spp.)	8.2	8.0	6.2	0.0	0.8
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.) in #	4540.0	4417.0	3413.1	227.0	681.0

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Note: Production estimates are adjusted by the percentage deviation of fish sizes caught in Sukol Creek from market sizes. Length measures are first converted to weight. For simplicity, this is assumed to represent losses from natural mortality as the fish grows to market sizes.

Table 5.9. Estimated value of annual production of fishes in mangrove waterways (pesos/ha/yr).

	Management Alternative				
	PR	SF/CF	AS	SA/IA	CF/IA&SF/IA
A. Mangrove Residents					
Slipmouths (3 spp.)	259.6	252.5	195.2	0.0	64.9
Cardinalfish (1 sp.)	6.7	6.5	5.0	0.0	1.7
Glassfishes (2 spp.)	2,372.0	2,307.6	1,783.2	0.0	593.0
Gobies (4 spp.)	17.8	17.4	13.4	0.0	4.4
Crabs (1 sp.)	349.5	340.1	262.8	35.0	87.4
Mudcrabs (1 sp.)	2,296.9	2,234.6	1,726.8	229.7	574.2
Sub-total	5,302.5	5,158.7	3,986.4	264.6	1,325.6
B. Mangrove Transients					
Milkfish (1 sp.)	2.6	2.5	2.0	0.0	0.0
Rabbitfishes (2 spp.)	0.1	0.1	0.1	0.0	0.0
Mullets (2 spp.)	2.0	2.0	1.5	0.0	0.2
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.)	58.3	56.8	43.9	2.9	8.8
Sub-total	63.1	61.4	47.4	2.9	9.0
Total	5,365.6	5,220.0	4,033.8	267.6	1,334.6

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:

1. Value of fish in the water (analogous to stumpage value for timber) is 12.25% of prices received by fishers (NSCB, 1995). Total costs and revenues may be obtained from these figures.
2. Estimates pertain only to waterways, specifically Sukol Creek. These figures should be interpreted as upper bound estimates. Total area of waterways (Sukol Creek, Palsabangon and Nahalinan Rivers) is 10.25 has.

Table 5.10. Computed value of fisheries productivity for the entire experimental mangrove forest (pesos/ha/yr).

	Management Alternative				
	PR	SF/CF	AS	SA/IA	CF/IA&SF/IA
A. Mangrove Residents					
Slipmouths (3 spp.)	72.1	70.2	54.2	0.0	18.0
Cardinalfish (1 sp.)	01.9	01.8	01.4	0.0	0.5
Glassfishes (2 spp.)	658.9	641.0	495.3	0.0	164.7
Gobies (4 spp.)	05.0	04.8	03.7	0.0	01.2
Crabs (1 sp.)	97.1	94.5	73.0	09.7	24.3
Mudcrabs (1 sp.)	638.0	620.7	479.7	63.8	159.5
Sub-total	1,472.9	1,433.0	1,107.3	73.5	368.2
B. Mangrove Transients					
Milkfish (1 sp.)	0.7	0.7	0.5	0.0	0.0
Rabbitfishes (2 spp.)	0.0	0.0	0.0	0.0	0.0
Mullets (2 spp.)	0.6	0.6	0.4	0.0	0.1
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.)	16.2	15.8	12.2	0.8	2.4
Sub-total	17.5	17.0	13.2	0.8	2.5
Total	1,490.4	1,450.0	1,120.5	74.3	370.7

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Appendix

Appendix 5.1a. Fish caught by pocket seine from Sukol Creek in January and July 1995 (from Bagarinao 1995).

Species	Family	Number of Fish Caught			Total	Total length (mm)		
		1/29	1/31	7/11		1/29	1/31	7/11
Chanos chanos	Chanidae	1			1	154		
Epinephelus malabaricus	Serranidae	2	1		3	106-127	60	
Lutjanus johni	Lutjanidae	1	1	6	8	89	110	29-36
Lutjanus argentimaculatus	Lutjanidae	1	2		3	78	90-97	
Lutjanus russelli	Lutjanidae		1		1		81	
Lutjanus fulviflamma	Lutjanidae	1	1		2	70	104	
Siganus guttatus	Siganidae	56	5		61	66-106	54-90	
Siganus javus	Siganidae	4	2		6	70-105	42-51	
Scatophagus argus	Scatophagidae		1		1		40	
Valamugil cunnesius	Mugilidae	79	81		160	40-135	33-90	
Liza tade	Mugilidae			1	1			116
Leiognathus equulus	Leiognathidae	84	135		219	33-79	29-56	
Leiognathus splendens	Leiognathidae		169		169		40-80	
Leiognathus brevirostris	Leiognathidae	240		70	310	40-76		32-55
Cynoglossus abbreviatus	Cynglossidae	3			3	40-74		
Apogon amboinensis	Apogonidae	11	16	1	28	45-87	44-93	91
Gerres Filamentosus	Gerreidae	2		1	3	50-62		38
Sillago sihama	Sillaginidae	1			1	80		
Yongeichthys criniger	Gobiidae	18	61		79	56-76	25-70	
Exyrias puntang	Gobiidae	1	1		2	124	118	
Acentrogobius janthinopterus	Gobiidae	2	1	7	10	104-125	125	91-116
Acentrogobius suluensis	Gobiidae		57	64	121		22-44	25-40
Acentrogobius viganensis	Gobiidae		32	47	79		30-55	35-55
Acentrogobius sp.	Gobiidae	96	103	264	463	23-58	30-60	20-55
Oxyurichthys opthalmonema	Gobiidae	3		1	4	88, 58, 102		135
Redigobius bikolanus	Gobiidae	1		3	4	37		36-39
Cristagobius nonatoea	Gobiidae	1		1	2	46		70
Favonigobius reichei	Gobiidae	4		19	23	30-34		27-70
Brachyamblyopus anotus	Gobiidae	3			3	30-32		
Butis butis	Bleotridae	51	60	61	172	69-109	56-119	49-114

Appendix 5.1a. Continued.

Species	Family	Number of Fish Caught 1/29	1/31	7/11	Total	Total length (mm) 1/29	1/31	7/11
Ambassis kopsi	Ambassidae	50	641	212	1,353	30-85	nd	nd
Ambassis urotaenia	Ambassidae	107	115	642	864	37-65	nd	nd
Ambassis interruptus	Ambassidae	1			1	95		
Zenarchopterus buffonis	Hemiramphidae	144	177	10	331	55-115	69-137	55-10
Gullaphallus mirabilis	Phallostethidae	7	145		152	30-32	28-38	
Hippichthys spicifer	Syngnathidae	10	10	3	23	114-158	125-152	150-166
Prosopodasys gogorzae	Scorpaenidae	54	48	36	138	30-67	29-71	25-62
Arothron reticularis	Tetraodontidae	2	1		3	110-127	104	
Chelonodon patoca	Tetraodontidae	16	3	7	26	30-55	33-41	39-78
Triacanthus indicus	Triacanthidae	1			1	17		
Total		1,508	1,870	1,456	4,834			
No/m^2		6.0	7.5	5.8	6.4			

Appendix 5.1b. Fish caught by cerrada in Sukol Creek in January and July and in Nahalinan (Nahal) and Paisabangon (Palsa) Rivers in July 1995 (from Eugarinao 1995).

Species	Family	Number of Fish Caught						Total Length (mm)				
		01/30 Sukol	01/31 Sukol	07/11 Sukol	07/12 Palsa	07/13 Nahal	Total	01/31 Sukol	01/31 Sukol	07/11 Sukol	07/12 Palsa	07/13 Nahal
*Epinephelus malabaricus**	Serranidae			1			1			140		
*Siganus guttatus**	Siganidae	36		32	56	21	145	45-40		29-33	29-39	27-35
*Scatophagus argus**	Scatophagidae			5	8	5	18			15-31	10-19	10-16
*Liza tade**	Mugilidae	4	1	1			6	138-176	131	67		
*Valamugil cunnesius**	Mugilidae	19	34				53	32-103	33-117			
*Leiognathus brevirostris**	Leiognathidae			17	68	25	110			31-60	19-61	23-62
Sphyraena forsteri	Sphyraenidae					1	1					42
Stolephorus commersoni	Engraulidae				1		1				35	
*Apogon amboinensis**	Apogonidae	22	26	11			59	69-10		65-95		
*Acentrogobius janthinopterus**	Gobiidae		4				4		97-107			
*Oxyurichthys ophthalmonema**	Gobiidae			6			6			80-120		
*Exyrias puntang**	Gobiidae			1			1			69		
*Favonigobius reichei**	Gobiidae			2			2			48-50		
Ophiocara porocephala	Eleotridae			1			1			210		
*Butis butis**	Eleotridae	34	14	24	19	6	97	63-128	60-109	60-112	44-80	76-112
*Ambassis kopsi**	Ambassidae	1,390	592	1,107	660	801	4,550	nd	nd	22-74		60
*Ambassis urotaenia**	Ambassidae	38	122	103	1,560	17	1,840	nd	43-59			
*Ambassis interruptus**	Ambassidae	1					1	66				
*Zenarchopterus buffonis**	Hemiramphidae	128	27	32	107	115	409	74-132	105-150	49-92	69-140	46-110
Pranesus pinguis	Atherinidae	4	1				5	40-68	65			
*Gullaphallus mirabilis**	Phallosthetidae		3	21	17	66	107			25-36	20-30	23-33
*Hippichthys spicifer**	Syngnathidae	4	1	1			6	115-155	130	145		
Megalops cyprinoides	Megalopidae	2					2	170-185				
*Prosopodasys gogorzae**	Scorpaenidae	2		3	2		7	35-60		34-51	32-43	
*Arothron reticularis**	Tetraodontidae	2					2	68-155				
*Chelonodon patoca**	Tetraodontidae	2				1	3	35-38				60
Toxotes jaculator	Toxotidae				1		1				23	
Total		1,688	825	1,368	2,499	1,058	7,438					

*previously caught by pocket seine in Sukol Creek.

Appendix 5.2. Non-fish species collected from Sukol Creek, Nahalinan River, and Palsabangon River (Bagarinao 1995).

A. Crustaceans		
Penaeus monodon	*Orastosquilla nepa*	
Penaeus merguiensis	*Orastosquilla quinquedentata*	
Metapenaeus ensis	*Orastosquilla inornata*	
Acetes sp.	*Thalamita crenata*	
Macrobachium equidens	*Charybdis anisodon*	
Macrobachium sp.	*Metaplax* sp.	
Alpheus sp.	*Pinnotherid crab*	
B. Mollusks picked up or caught by collection gears in Sukol Creek in January 1995.		
Bivalves (11 species)		**Gastropods** (8 species)
Anadara maculosa telescopium		*Telescopium*
Tellina sp.		*Nassarius puellus*
Lopha cristagalli		*Clypeomorous corallium*
Isognomon isognomon		*Chicoreus cappucinus*
Verpricardium multispinosum		*Hexaplex chicoreum*
Pitar affinis		*Vexillum sp.*
Perna viridis		*Terebralia sulcata*
Dosinia troscheli		*Nerita planospira*
Mactra mera		
Crassostrea iredalei		
Circe scripta		
C. Some of the mollusks collected from the outer coralline areas in Paghilao Bay		
Tridacna squamosa		
Amusium pleuronectes		

Appendix 5.3. Estimated catches of important fish groups and crustaceans in the experimental mangrove forest based on sampling by pocket seine (PS) and cerada (Cer) in Sukol Creek in January and July 1995 (from Table 12 of Bagarinao 1995).

Fishes	Species	Market size	Size in Sukol	Sampling		Period	Production		(individuals)[b]
		(mm)[a]	(mm)[a]	01/29	01/31	07/11	Total/ha/cohort[c]	Cohorts/year[d]	Total/year
Residents[e]									
Silpmouths	*Leiognathus* (3 spp.)	40-80	19-80	324	304	70	9,307	10	93,070
Cardinalfish	*Apogon amboinensis*	100	44-100	11	16	1	373	10	3,730
Glassfishes	*Ambassis* (2 spp.)	40-80	22-85	607	756	854	29,560	10	295,60
Gobies	4 species	100-150	69-125	24	63	7	1,253	10	12,530
Crab	*Thalamita crenata*	50-100	50-100	3	3	2	107	10	1,070
Mudcrab[f]	*Scylla serrata*	100-200							1,50
Transients[e]									
Milkfish	*Chanos chanos*	200-300	154-170	1	1	0	27	2	54
Rabbitfishes	*Siganus* (2 spp.)	100-300	29-106	60	7	7	987	6	5,922
Mullets	*Valamugil, Liza*	150-300	32-176	79	81	1	2,147	2	4,294
Groupers	*Epinephelus malabaricus*	200-500	60-140	2	1	0	40	2	80
Snappers	*Lutjanus* (3 spp.)	200-500	29-110	3	5	6	187	2	374
Shrimps	Various penaeids	200-100	05-50	126	39	376	7213	6	43,278

a. Fish sizes are total length, crab sizes are carapace width, and shrimp sizes are carapace length in mm.
b. Production was estimated from the average of the pocket seine catches (over a 250 m^2 sampling transect), extrapolated to the total area of the Sukol Creek waterway.
c. A 'cohort' is taken in the simplistic sense to be a group of residents or transients at any one time.
d. Cohort'/year is the assumed number of spawning cycles per year, probably more frequent in residents than in migratory transients, and more frequent for small-size than large-size species.
e. Residents live their whole lives and spawn in the mangroves; transients are usually juveniles of species that spawn and otherwise live in the open coast.
f. Mudcrab not collected during the survey, production was estimated from the trap fishery in the mangrove forest (catch mostly large juveniles).

Appendix 5.4. Habits and food of selected fish species identified by Bagarainao (1995) as important in the Pagbilao Experimental Mangrove Forest (adapted from Pinto 1987).

Species	Habitat	Habit	Social Groupings	Trophic Level	Food Items
Chanos chanos	E	S, B	Pg, Gr	H	Algae, invertebrates
Epinephelus malabaricus	M	BP	So	C	Fishes, crustaceans
Lutjanus spp.	M	BP	So, Pg	C	Shrimps, fish
Siganus spp.	M	BP	Pg	H	Algae, diatoms
Liza tade, *Valamugil cunnesius*	E	BP	So	H	Algae, diatoms, plant detritus
Leiognathus spp., *Gazza* spp.	M	BP	Gr	C	Copepods, polychaetes, plant detritus
Apogon amboinensis	M	BP	Gr, Pg	C	Shrimps, fish, plant detritus
Gobiidae	R, E	B	So, Pg	C	Amphipods, isopods, nematode, plant detritus
Ambassis spp.	E	BP	Gr	C	Zooplankton, shrimp, plant detritus

Legend: E= estuarine, M= marine, R= riverine; B= benthic, P= pelagic, BP= benthopelagic, S=surface; So= Solitary, Pg= pair, Gr= gregarious; H= herbivorous, C= carnivorous

Appendix 5.5. Cost-benefit estimates of fisheries productivity of the Pagbilao Mangrove Reserves under various management alternatives.

I. Revenues

	Management Alternatives				
	PR	**SF & CF**	**AS**	**SA & IA**	**CF/IA & SF/IA**
A. Mangrove Residents					
Slipmouths (3 spp.)	2,119.2	2,061.6	1,593.4	0.0	529.8
Cardinalfish (1 sp.)	54.5	53.0	40.9	0.0	13.6
Glassfishes (2 spp.)	19,363.1	18,838.0	14,556.8	0.0	4,840.8
Gobies (4 spp.)	145.6	141.7	109.4	0.0	36.2
Crabs (1 sp.)	2,853.3	2,776.0	2,145.1	285.3	713.3
Mudcrabs (1 sp.)	18,750.0	18,241.3	14,096.3	1,875.0	4,687.5
Sub-total	43,285.8	42,111.6	32,541.8	2,160.3	10,821.2
B. Mangrove Transients					
Milkfish (1 sp.)	21.2	20.7	16.0	0.0	0.0
Rabbitfishes (2 spp.)	0.7	0.7	0.5	0.0	0.1
Mullets (2 spp.)	16.7	16.2	12.5	0.0	01.7
Groupers (1 sp.)	0.1	0.1	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.)	476.3	463.4	358.0	23.8	71.4
Sub-total	514.9	501.0	387.1	23.8	73.2
Total	43,80.6	42,612.6	32,928.9	2,184.1	10,894.4

Appendix 5.5. Continued.
II. Costs

	Management Alternatives				
	PR	. SF & CF	AS	SA & IA	CF/IA & SF/IA
A. Mangrove Residents					
Slipmouths (3 spp.)	1,859.6	1,809.1	1,398.2	0.0	464.9
Cardinalfish (1 sp.)	47.8	46.5	35.9	0.0	12.0
Glassfishes (2 spp.)	16,991.1	16,530.3	12,773.5	0.0	4,247.8
Gobies (4 spp.)	127.8	124.4	96.0	0.0	31.8
Crabs (1 sp.)	2,503.8	2,435.9	1,882.3	250.4	626.0
Mudcrabs (1 sp.)	16,453.1	16,06.7	12,369.5	1,645.3	4,113.3
Sub-total	37,983.3	36,952.9	28,555.4	1,895.7	9,495.6
B. Mangrove Transients					
Milkfish (1 sp.)	18.6	18.2	14.0	0.0	0.0
Rabbitfishes (2 spp.)	0.6	0.6	0.5	0.0	0.1
Mullets (2 spp.)	14.6	14.2	11.0	0.0	01.5
Groupers (1 sp.)	0.1	0.1	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.)	417.9	406.6	314.2	20.9	62.7
Sub-total	451.8	439.7	339.7	20.9	64.2
Total	38,435.0	37,392.6	28,895.1	1,916.6	9,559.8

Appendix 5.5. Continued.
III. Net Value of Fish (I minus II)

	Management Alternatives				
	PR	SF & CF	AS	SA & IA	CF/IA & SF/IA
A. Mangrove Residents					
Slipmouths (3 spp.)	259.6	252.5	195.2	0.0	64.9
Cardinalfish (1 sp.)	06.7	06.5	05.0	0.0	1.7
Glassfishes (2 spp.)	2,372.0	2,307.6	1,783.2	0.0	593.0
Gobies (4 spp.)	17.8	17.4	13.4	0.0	04.4
Crabs (1 sp.)	349.5	340.1	262.8	35.0	87.4
Mudcrabs (1 sp.)	2,296.9	2,234.6	1,726.8	229.7	574.2
Sub-total	5,302.5	5,158.7	3,986.4	264.6	1,325.6
B. Mangrove Transients					
Milkfish (1 sp.)	2.6	2.5	2.0	0.0	0.0
Rabbitfishes (2 spp.)	0.1	0.1	0.1	0.0	0.0
Mullets (2 spp.)	2.0	2.0	1.5	0.0	0.2
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.)	58.3	56.8	43.9	2.9	8.8
Sub-total	63.1	61.4	47.4	2.9	9.0
Total	5,365.6	5,220.0	4,033.8	267.6	1,334.6

6. ASSESSMENT OF MILKFISH AND PRAWN CULTURE IN BRACKISH WATER PONDS

Jose E. Padilla and Michael A. Tanael

6.1. Introduction

This study is prompted by the rapid loss of mangrove areas in the Philippines from conversion to aquaculture ponds. Over the years, the time-series data on the remaining mangrove cover and the area of brackishwater fishponds show an inverse relationship (Fig. 6.1). Several aquaculture economic studies have been conducted in the past but even the more recent studies use data collected several years ago. The work by Guerrero et al. (1994) covered 1991 crop year while that of Padilla (1994) evaluated 1989 crop year. A more recent study is needed to assess the performance of aquaculture over the years. In addition to providing a more recent assessment of aquaculture in the Philippines, this study will attempt to incorporate environmental costs of aquaculture in the assessment. This is borne by the fact that in some cases, widespread use of chemicals for maintaining productivity of fishponds have been increasing in recent years.

This study is also important in the light of the potential opening up of more public lands, including mangrove areas, for aquaculture. Conversion of public lands to aquaculture is now allowed under certain circumstances with the passage on February 1995 of the amendment of Republic Act 7881 otherwise known as the Comprehensive Agrarian Reform Law (CARL). The specific provision under section 65-A - Conversion into Fishpond and Prawn Farms reads:

> "No conversion of public agricultural lands into fishponds and prawn farms shall be made except in situations where the provincial government with the concurrence of the Bureau of Fisheries and Aquatic Resources (BFAR) declares a coastal zone as suitable for fishpond development. In such case, the Department of Environment and Natural Resources (DENR) shall allow the lease of and development of such areas: *Provided*, that the declaration shall not apply to environmentally critical projects and areas ... . *Provided, further*, That the approval shall be in accordance with a set of guidelines to be drawn up and promulgated by the Department of Agrarian Reform and BFAR; *Provided, furthermore*, That small-farmer co-operatives and organizations shall be given preference in the award of the Fishpond Lease Agreements (FLAs)."

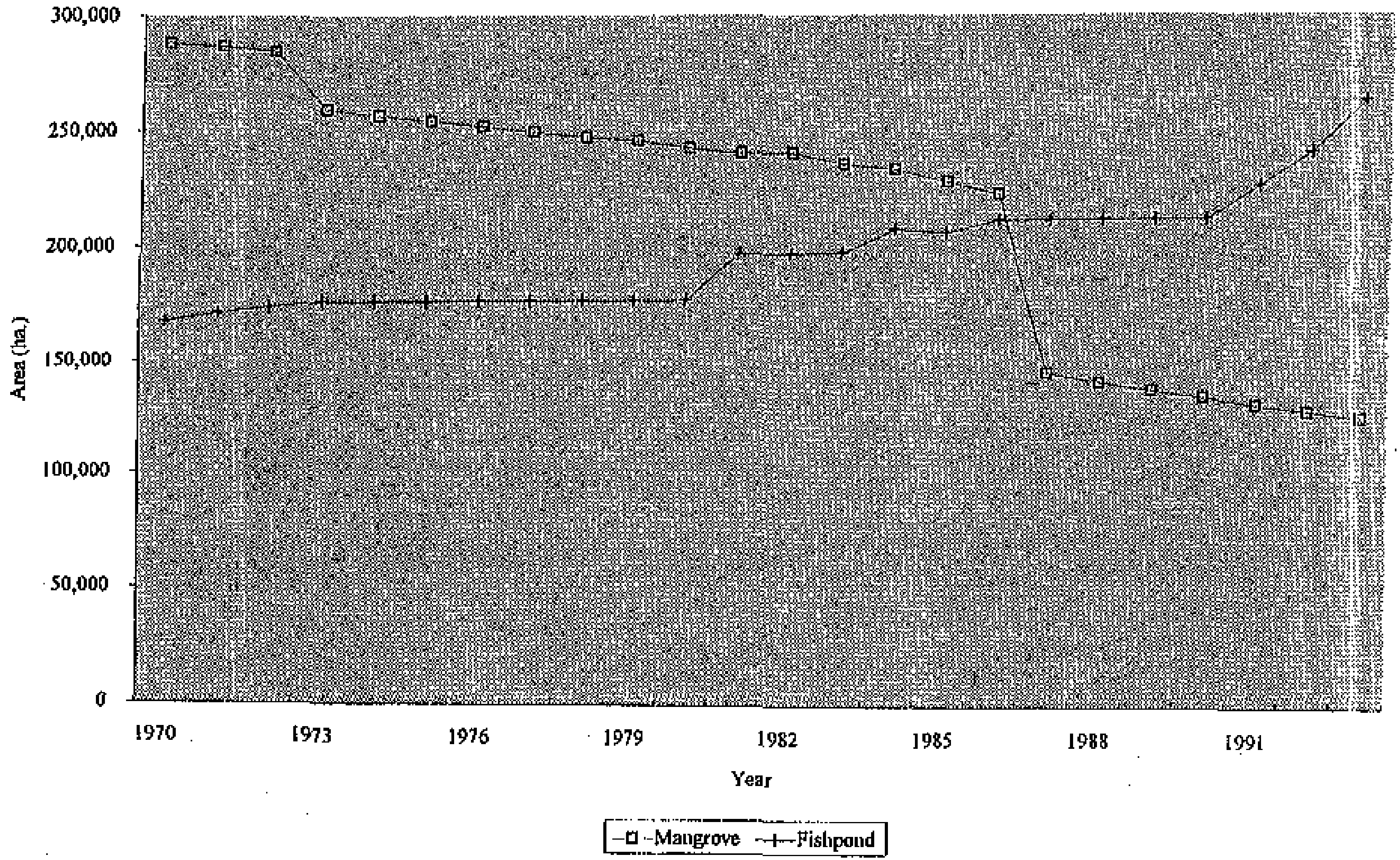

Figure 6.1. Area of Mangrove and Brackishwater Pond.

While the opening up new fishpond areas may be necessary to augment dwindling production from capture fisheries, there are foregone benefits or costs of mangrove conversion. Hence, the possible impact of the provisions of the revised CARL need to be assessed. The primary objectives of this study is to evaluate the conversion of mangroves for aquaculture. Specifically, this study is to assess the performance of aquaculture over the years.

The focus will on the two dominant species cultured in brackishwater fishponds in the Philippines, i.e., milkfish (*Chanos chanos*) and prawn (primarily *Penaeus monodon* sp.). Table 6.1 shows aquaculture production for the entire country for the last 10 years. Total aquaculture production increased by almost 300,000 mt or by 62% for the entire period. Milkfish production increased gradually from 1984 to 1991 but dropped drastically to 124,500 mt in 1993. Prawn production, on the other hand, has been increasing with production in 1993 reaching 86,000 mt equivalent to 227% increase from 1984 production.

This paper is divided into three parts. The first presents the results of a survey of fishfarms which was conducted purposely for this study. The survey methodology, profile of respondents and fish farms and the culture technologies are described in relative detail. This part informs the unfamiliar reader of the aquaculture technologies currently employed in the Philippines. The performance of fish farms is assessed using a simple costs and earnings analysis. The second part compares the performance of milkfish and prawn aquaculture over the years using several studies. Inferences are made on the future performance of aquaculture in the Philippines. The third part looks into the environmental aspects of aquaculture.

Part 1: Assessment of Fishpond Aquaculture Using 1994 Data

A survey of fishponds was conducted in February to March in 1995. The province of Pangasinan was selected for its accessibility and the large number of FLAs and private aquaculture farms. Nine municipalities of Pangasinan were covered by the survey. These are Agno, Alaminos, Anda, Bani, Binmaley, Dagupan City, Labrador, Lingayen and San Fabian (Fig. 6.2). A purposive sampling was done where farms practising semi-intensive and intensive culture technologies were selected as may be indicated by extent of pond development, stocking density and cropping frequency. The reference period of the survey was the 1994 crop year, i.e., January-December 1994. The survey covered twenty-four milkfish farms and ten prawn farms.

6.2. Production and Revenue

The average cropping frequency in milkfish farming in 1994 was 4.08 with culture period of 71 days per crop or 290 days per year. Production for the sample was roughly 686 kg/ha/crop equivalent to 2,797 kg/ha/year which is almost three times the average national production. Only one milkfish farmer in the survey employed intensive technology with average stocking density of 15,000 pieces/ha/crop in the rearing pond. Average production in intensive farming was 4,700 kg/ha/crop or 23,500 kg/ha/yr. The rest were semi-intensive farmers with average production of 642 kg/ha/crop or 2,594 kg/ha/yr. Cropping frequency in prawn farming was 1.8 and harvesting was done after 150 days after stocking. Production reached 1,841 kg/ha/crop equivalent to 3,314 kg/ha/year. Incidental harvest primarily of tilapia, gobbies and other competitors was observed but only in milkfish farming. Such amounted to 14 kg/ha/crop or 56 kg/ha/yr. Based on the stocking density, the technology employed by prawn farms in the sample is semi-intensive. The intensive prawn farms in the country are the big corporate farms not covered by the survey.

For milkfish crops, usual harvest size was 4 pieces/kg and the average price was P62 /kg. For prawn. Average size of prawn reached 34 pieces/kg and price ranged from P110 to P215 with an average of P185 /kg. Price varies according to size, season, and supply-demand situation. Average revenue in milkfish farming was P46,075 /ha/crop or P187,984 /ha/yr. For the intensive milkfish farmer, revenue reached P250,500 /ha/crop or P1.252 million/ha/yr. For the semi-intensive milkfish farmer, average revenue was P43,878 /ha/crop and P177,268 /ha/yr. Average revenue in prawn farming reached P343,641 /ha/crop and P618,554 /ha/year. The revenues figures cited exclude the value of the incidental harvests.

6.3. Costs of Production

Material costs are grouped into stocking material, feeds, fertilizers, lime, and pesticides/additives. Average cost of material inputs in growing milkfish on a per ha basis for about 4 times a year was P53,992. Feeds, commercial feeds in particular, were the biggest expense item at 46% of total or P24,925 /ha/year. Stocking materials involved an outlay of about P18,231 /ha/year. Fertilizers accounted for 20% of the total cost with organic fertilizer at P3,703 /ha/year and inorganic fertilizer at P6,922 /ha/year. The cost of pesticides and other chemical and biological products was 0.4 % of the total cost at an average of P211 /ha/year. Prawn monoculture was about 5 times more expensive than milkfish monoculture with average total cost reaching P246,964 /ha/year. The biggest (83%) expense item was feeds at P204,038 /ha/year or 83% of total costs which is typical of semi-intensive and intensive prawn culture. The cost of stocking material (12%) followed at P29,589 /ha/year. The cost of fertilizer was minimal at 2%, lime at 1%, pesticides and other related inputs at 3% of total costs.

Considering that milkfish farming is less labour intensive than prawn farming, average labour expenses in the former was lower at P4,581/ha/crop or P18,687/ha/yr compared to P28,495 /ha/crop or P51,291 /ha/yr in the latter. A large portion of this amount went to pay permanent employees at 77% in milkfish farming and 84.3% in prawn farming. As the cost figures are averages for the sample not for the reporting respondents, these figures should be interpreted with caution. In some farms, for instance, some of the farm activities were done by the permanent employees, hence the breakdown by activity may not be meaningful. Unskilled and semi-skilled laborers are usually hired from communities adjacent to aquaculture farms. Skilled workers, primarily technicians and office personnel, do not necessarily come from the area. Hence, the benefits that accrue to adjacent communities may be represented by the payments to unskilled and semi-skilled labor.

Sixty three percent of milkfish farmers and twenty percent of prawn farmers had loans outstanding which were used for fishpond development, for purchase of inputs and for working capital. The primary sources were formal lending institutions like banks and co-operatives. Private individuals (primarily the farmer's relatives) also extended loans at lower interest rates. Collateral asked from respondents included fishpond, farm, residential and commercial lots. The annual average amount of loans of milkfish farmers was P292,000 compared to prawn farmers at P625,000. The interest rate of loans availed by prawn farmers was relatively higher (28%) compared to those for milkfish farmers (17%). Average annual interest expense amounted to P59,036 and P262,750 for milkfish and prawn farmers, respectively. Depreciation is computed by dividing the average acquisition or the initial cost by the average economic life which assumes zero salvage value for the asset. On a per ha, per year basis, total depreciation rate was slightly higher for prawn farms (P29,239) compared to milkfish farms (P24,682).

6.4. Profits and Rents

The difference between total revenue and total variable costs is the estimated gross profits while the difference between the gross profit and fixed costs is the net profit. Milkfish and prawn farming were profitable with annual gross profit of P115,595 /ha/year and P320,299 /ha/year, respectively (Table 6.2). Taking into account fixed costs, milkfish and prawn farming are still attractive investment activities. Return on investments (ROI) (with working capital included in investments) was 5.6% per annum in milkfish farming and 9.8% in prawn farming. The difference in ROI may explain the shift to prawn farming by traditional milkfish monoculturists although the ROIs for both are still below the yields of alternative financial investments.

To obtain an estimate of rents accruing from aquaculture, the opportunity costs of factors of production are deducted from net profits. Three production factors are considered: capital, labor (including management), and land. The opportunity cost of capital is the amount of interest earned by investing the expenses (working capital, i.e., material inputs and labor costs) in the bank. An annual interest rate of 10% was used which is applicable to time deposits. This is equivalent to P7,270 for milkfish farms and P29,825 for prawn farms. As far as management is concerned, if the operator is an absentee or farm management is delegated to the caretaker, then opportunity cost is zero. For the sample, 54% among milkfish operators were part-time and the remaining 46% full-time. All prawn farm operators were working part-time with time input of 50%. Average time involvement in aquaculture is computed for both milkfish and prawn farms which is multiplied by the monthly minimum wage. This represents the opportunity cost which is equivalent to P2,295 per month or a daily wage of P76.50 in the study area in 1994. The foregone income for operators of milkfish farms is estimated at P18,934 /year and in prawn farms at P13,770 /year. With average farm sizes of 4.76 and 4.67 has for both farms, the net opportunity cost is about P3,978 /ha./year and P2,949 /ha./year for milkfish and prawn farms, respectively.

The residual from net profits after deducting the opportunity costs of labor and capital accrues partly to the other input, land. The net profit for milkfish and prawn farms are P84,195 and P279,808, respectively, while total opportunity costs of capital and labor are P11,248 and P32,774. The residual is about P72,947 /ha./year and P247,034 /ha/year (for milkfish and prawn, respectively) which represent the rents accruing to land input. On all counts of financial indicators, prawn culture is superior to milkfish culture based on the 1994 survey data in Pangasinan.

Part 2: Comparative Assessment of Brackishwater Aquaculture

We evaluate the performance of milkfish monoculture and prawn monoculture over time by comparing several studies. The bases for comparison are five cost and earnings studies in milkfish farming (Table 6.3) and three studies in prawn farming (Table 6.4). Although a different set of sample farms in various locations in the country was utilized in each study, the performance indicators would give an inference into the status of milkfish and prawn farming over time. We attempt to factor out the differences in technology and sample farms in the 5 studies to make them comparable. On the input side, stocking density is assumed to be the indicator of technology which is then used to divide production, costs and revenue to obtain the standardized or normalized figures. On the output side, production per unit area may also be an indicator of technology as it provides inference on the efficiency the aquaculture production process. The two standardized or normalized figures are reflected in the tables.

Milkfish monoculture

The studies in milkfish farming cover 5 crop years from 1979 to 1994 (Table 6.3). Stocking density ranges from about 900 pieces per ha per crop to over 6,400 pieces which indicate that semi-intensive and intensive farms were covered by the studies. The 1991 study concentrated on the more intensive farms, perhaps the outliers in these studies, hence in discussing trends this study may not be included. Increases in production in milkfish farming were achieved in two ways, higher stocking for each crop and more frequent cropping. Average production per crop went up from 444 kg/ha in 1979 to 686 kg/ha in 1994. On an annual basis, it went up from 1,164 kg/ha to 2,797 kg/ha. However, normalized production went up from 1979 to 1984 but went down to about 0.2 kg; the in yield-per-fingerling (or fry) stocked is declining. This may be attributed to several factors such as declining pond productivity and higher mortality due to changes in natural and environmental conditions. (A discussion of environmental factors in the succeeding section will clarify this matter).

Nominal costs, revenue and profits are expressed in real terms, i.e., adjusted by the implicit price index for the fishery sector. On a per cropping basis, the farming costs of milkfish have been increasing. This may be attributed to higher stocking and the increasing price of fry due to its increasing scarcity. The normalized cost, however, does not show a marked increase. The cost of growing a unit fingerling of milkfish in 1979 was P2.33 and P2.96 in 1994 equivalent to an average annual increase of about 2%. On a per kg basis, costs have increased much higher which may attributed to several factors such as those mentioned earlier. Total revenue per crop per ha increased from P7,467 to P23,259 in 1994 mainly from the increase in production and from the continuing increase in the real price of milkfish from P16.8 per kg in 1979 to P33.9 per kg in 1994 equivalent to 6.8% per annum. The trend in the revenue-per-fingerling (normalized revenue) which depends on the average size of harvested fish is erratic. Given the changes in prices and costs, profits have likewise increased in real terms on both measures, per kg of production and per fingerling stocked.

The ratio of gross profit and variable cost may be interpreted as the return on variable costs. This is quite high at over 100 percent for all studies except in 1984. This indicates that milkfish monoculture remains a very attractive investment. It may be expected then that with the investment potential of milkfish aquaculture, there would be pressure from the aquaculture industry for government to open more areas for aquaculture.

Prawn monoculture

Three studies in prawn monoculture covering 1989, 1991 and 1994 crop years are compared (Table 6.4). Stocking density has been increasing over time -- from extensive to semi-intensive. Intensive farms with stocking rate of at least 200,000 /ha/crop were not covered for lack of access to these corporate farms. The reported number of croppings for the sample farms has been decreasing. This may indicate that higher stocking require longer growing periods thus smaller number of crops. It could have been also due to crop rotation reported by a farm technician interviewed for the 1994 study. It appeared that milkfish performed better than prawn when salinity is high in the summer months. (Refer to the section environmental factors for more discussion.) The three-fold increase in production was due to higher stocking considering that the yield-per-fry decreased down from 0.03 kg to 0.01 kg from 1989 to 1994.

The (variable) costs of production per unit area has been increasing in real terms. However, with production moving in the same direction, the cost per unit output (or unit fry stocked) has actually declined from P72 per kg to P47 per kg (or from P1.83 per fry to P0.61 per fry). Total revenue per ha should move in the same direction as production. However, the trend in real price of prawn, which is affected by international supply and demand conditions, was erratic. Price per kg first went up then went down. With unit costs going down and unit revenue rather erratic, unit profits was also erratic. Gross profit per unit area, however, increased more than ten-fold.

Return to variable costs from prawn monoculture is reasonable at over 100% in crop years 1991 and 1994 whereas it the 1989 crop year it was about 15%. The returns are lower compared to milkfish monoculture and even lower when fixed costs are included considering that prawn monoculture is more capital intensive. The attractiveness of prawn monoculture, however, is the higher absolute gross profits compared to milkfish monoculture per unit area and per unit time.

Part 3: The Environmental Aspects of Aquaculture

This section briefly describes the environmental impact of coastal aquaculture in the Philippines and presents estimates of the environmental costs of intensive prawn aquaculture. We identify the environmental impacts of fish farming starting from the development of aquaculture farm to actual operation.

Identification of Environmental Impacts

The conversion of intertidal areas, particularly wetlands, is the first step in the destruction of the environment. Conversion is a relatively irreversible alteration of a rich ecosystem representing loss of about 70% of the estimated mangrove cover in the Philippines. Mangrove forests is an integral part of the coastal ecosystem which offer multifarious benefits.

Mangroves are important in nutrient cycling, as a source of nutrients and as breeding ground, nursery and grow-out area for different kinds of species. These impacts are detrimental to aquaculture itself. For instance, the availability of broodstock and wild shrimp postlarvae associated with mangrove degradation and conversion resulted in the shortage of seed for stocking (Phillips et al. 1993). Mangrove conversion also endangers endemic species, destroys their habitats and affects the foodchain of the estuarine ecosystem and the habitats of wildlife. In addition, conversion also entails losses of products derived from timber resources which are used for construction, fuelwood, charcoal, food, medicine, dye, etc. Other functions of mangroves such as the prevention of coastal erosion and buffering are also lost with conversion.

Mangroves have acid sulphate soils which may encourage the break-up of fish diseases in shrimps such as soft-shell syndrome, red disease and blue shrimps (Nash et al. 1988; Baticados et al. 1990). Acidic soils are not suitable for fish culture and studies (e.g., Kapetsky 1986) show decreasing fisheries production and eventual abandonment of fishponds from poor financial returns. The application of lime to increase soil pH is a necessity not only in newly constructed fishponds but also in most fishponds (both for milkfish and prawn culture) in the 1994 study. The environmental impact of liming is the discharge of very acidic effluents from the fishpond.

Milkfish and prawn aquaculture in the Philippines has progressively become more intensive as shown by higher stocking density and more frequent cropping. Pullin (1993) indicated that intensive aquaculture poses much greater threats to the environment than does extensive and semi-intensive aquaculture. Extensive aquaculture is characterized by low stocking densities and minimal usage of chemical products such as fertilizers, insecticides and pesticides. Thus, the system is unlikely to worsen nutrient loadings or organic matter in nearby aquatic system. Intensive culture, on the other hand, requires higher dosages of chemical inputs for various reasons and more feeding to supplement naturally available food in the pond. These include anaesthetics, disinfectants, biocides, antibiotics, food additives, and organic and inorganic fertilizers.

The use of antibiotics and other chemicals (refer to Table 6.5 for a list of these inputs as used in the 1994 survey) for disease management, disinfection, growth promotion and pest control may have far-reaching consequences. These inputs may create and expand antibiotic resistant strains of potentially harmful pathogens which may, in turn, affect human health, quality of the produce and the environment in general. With continuous use, antibiotics may transfer pathogens to wild fish, and if ingested by humans, may develop drug-resistant human pathogens. In terms of effect on aquaculture, the overexposure of larvae to antibiotics in hatcheries resulted in high mortalities of *P. monodon* in grow-out ponds (Chen 1990). In the Philippines, drug resistant strains of the luminous vibrios are believed to exist due to widespread use of chemicals/antibiotics and by frequent intermixing of effluent and influent water in highly congested areas (Sorgeloos 1990).

Pollution of waterways results from the discharge of aquaculture wastes. These include fecal materials, excess feeds, other organic inputs, dissolved metabolites which require very high biological oxygen demand (BOD). Increased sedimentation may also result which may affect natural decomposition that leads to some changes in productivity, benthic community structures and possible siltation (Phillips et al. 1993). Aquaculture wastes also cause eutrophication that change the composition and abundance of phytoplankton populations. As aquaculture is a source of coastal pollution, it may have also encouraged toxic algal blooms or red tides, which are associated with coastal pollution (Maclean 1993; Hallegraeff 1990). The impact of red tides on the fishing industry is quite enormous. In Manila Bay, the value of sales lost from infected mussel in 1988 amounted to US$950,000 over three months (Maclean 1989).

Pollution from aquaculture has also affected itself -- a case of self-pollution. Nutrients and organic solids hasten the excessive growth of bacteria, phytoplankton, and zooplankton. Feed wastes affect sediment quality and the health of fishes and interfere with harvesting. When accumulated, hydrogen sulfide and methane may cause stress specially to shrimp species (Boyd 1989). Long-term use of lime to neutralize acid sulfate soils are believed to harden pond sediments that make ponds unfit for aquaculture (Poernomo and Singh 1982). In a study by Baticados et al. (1986), it was found that the use of organotin mulluscicides by prawn farmers in the Philippines caused soft-shell syndrome. Chemotherapeutants such as formalin are both toxic to algae and certain types of shrimps and other fishes at certain concentration levels. Hazards also arise from introduction and transfer of species which may serve as the medium for transfer of pathogens.

Valuation of Environmental Costs of Aquaculture

From the preceding discussion, the negative environmental impacts associated with aquaculture after mangrove conversion are more pronounced with intensive aquaculture, particularly of prawn. A recent and comprehensive study (Auburn University 1993) of the Philippine prawn industry recommends crop rotation to reduce negative environmental impacts of intensive aquaculture and to increase unit production. The description of the recommended technology below is largely lifted from the report. Crop rotation has been practised based on personal communications with an aquaculture technician during the 1994 survey in the province of Pangasinan. It was reported that crop rotation was prompted by high rates of prawn postlarvae mortality during the summer months.

The specific recommendation is to rotate semi-intensive prawn and milkfish monoculture. From May to October after sufficient pond preparation (as described in the first part of this report) for two months, the pond is used for prawn culture. No scraping of black mud is done during pond preparation. After water conditioning, prawn PL is stocked at 15-18/sq.m. and reared to harvestable size using semi-intensive technology. Prawn is harvested at 31-35 gm size at 4.2 tons/ha in the (one prawn crop per year. Incidence of disease is minimized although it may occur with poor water management.

Milkfish is stocked into the pond (without pond preparation) immediately after harvesting the prawn crop. Milkfish is grown from November to March when salinity is high and more conducive to milkfish farming. The recommended stocking rate is extensive at 1,500- 2,000 pcs per ha of fingerling of 100-gram size. The bigger size milkfish is believed to be more efficient in grazing/filtering *lablab*/plankton in the pond. No artificial feed should be given (so as not to add organic load) and no fertilizer is applied to induce algal growth. On harvest, the milkfish are 300 to 500 gm in size with a total harvest of about 500 gm.

We now compute the returns from the recommended technology utilizing the data collected from the 1994 crop-year survey. The comparative returns from the recommended technology and prawn monoculture are given in Table 6.6. The difference in gross profit between prawn monoculture and crop rotation is about P55,780 per ha per year or about 36% of the gross profit in prawn monoculture. With average farm size of prawn monoculturists at about 6 ha, the foregone profits per farm is over P300,000 per year. This is quite substantial although it may be incurred only in the short-run as the expectation is for lower profitability of intensive prawn monoculture over time. The short-run reduction in profits with the recommended technology may be interpreted as the costs of minimizing the environmental costs of intensive prawn aquaculture.

Part 4: Quantifying Costs and Benefits of Aquaculture Alternatives for the Pagbilao Mangrove Forest

This section uses parts 1-3 of this paper in assessing the various management alternatives for the Pagbilao mangrove forest. Four alternatives requiring the conversion of portions of the Pagbilao mangrove forest into fishponds are identified. These are enumerated in the table below.

In quantifying the benefits and costs of aquaculture for the 4 management alternatives for the Pagbilao mangrove forest, several studies are being used. For semi-intensive aquaculture which is the monoculture of milkfish, the study by Guerrero (1991) is used. For intensive aquaculture, the intensive prawn farming in Pangasinan is adopted. This is where the survey of aquaculture farms in Pangasinan becomes useful considering that intensive prawn farming is not currently practised in Pagbilao. Estimated annual aquaculture production for the various management alternatives are listed in Table 6.6 and for the 50-year period in Table 6.7.

Additional assumptions are made aside from those indicated at the bottom of each table. For semi-intensive aquaculture, the 1991 crop year survey of Guerrero is used. The average production from the Pagbilao fishponds is over six-fold the national average. Guerrero attributed this to better management in the proper application of inputs in older ponds such as those in Pagbilao in addition to higher stocking densities and more frequent cropping frequency. In addition to these factors, Padilla (1995), using a bigger data set but only covered leased fishponds from the government, found that milkfish productivity tends to be higher in highly-developed farms and in larger farms. In these respects, the fishfarms of Pagbilao are larger and more developed. More importantly, perhaps, is that some of the fishfarms in

Pagbilao are operated by commercial concerns including foreign (Taiwanese) and local conglomerates such as San Miguel and Ayala (PRRM 1993).

For intensive aquaculture, the recommended technology of rotating intensive prawn crop with extensive milkfish culture is adopted. This scenario is used considering the difficulty of projecting future production in intensive prawn aquaculture over a longer period. If the recommended technology is adopted it can simply be assumed that current production may be sustained over time.

The annual figures show that on a per ha basis, the first alternative of semi-intensive aquaculture would produce better results compared to intensive aquaculture (Table 6.7). The difference in total revenue in each alternative is negligible. This is due to higher production of milkfish in semi-intensive aquaculture offsetting the higher price prawn in intensive aquaculture. With lower variable costs in milkfish monoculture compared to crop rotation of prawn and milkfish, gross profit is much higher for the former.

Gross profits are adjusted by the amount of development costs in Table 6.8. The planning horizon assumed is 25 years which coincides with the length of a fishpond lease agreement (FLA) which should be adopted in the event that the mangrove forest is opened for conversion. A risk factor is also included by assuming one crop failure every five years, which means that revenues are reduced by 50 percent every five years (indicating an average of 2 crops per year) with the costs remaining the same. The present value of gross profits realized over 25 years is computed using a discount rate of 15 percent. This is adjusted by the development costs which are incurred at the start of the project. The prevent value figures show that semi-intensive aquaculture is superior to intensive aquaculture. This can be attributed to three factors, namely: lower prices of prawn compared to previous years; higher investment cost in intensive aquaculture compared to semi-intensive culture; and the recommended rotation of prawn and milkfish which deviates from the normal straight prawn monoculture in the early years of prawn farming. It should be emphasized, however, that the performance of prawn crops is quite sensitive to world prices of the product. Currently, Philippine prawn prices are considered depressed, hence profitability of intensive aquaculture will improve with the increase in world prawn prices.

Management Alternative	Type and Description of Aquaculture Technology
1. Conversion to semi-intensive aquaculture	Area allocation Semi-intensive fishponds : 95.2 ha Forest (buffer zone only) : 15.5 ha Semi-intensive aquaculture is defined as milkfish monoculture with stocking densities following that for the average farm in the 1991 crop-year survey in Pagbilao, Quezon.
2. Conversion to intensive aquaculture	Area allocation: Intensive fishponds : 95.2 ha Forest (buffer zone only) : 15.5 ha The recommended sustainable intensive aquaculture practice is the rotation of intensive prawn farming and extensive to semi-intensive milkfish farming. Intensive prawn farming is that practised in Pangasinan while the semi-intensive milkfish crop that is grown after harvesting the prawn is the recommended technology in the assessment of the Philippine prawn industry (Auburn University 1993).
3. Conversion to commercial forestry and intensive aquaculture	Area allocation: Intensive fishponds : 35.0 ha Forest (including buffer zone) : 75.7 ha Intensive aquaculture is as defined in B but over a smaller area of 35.0 ha.
4. Conversion to subsistence forestry and intensive aquaculture	Area allocation: Intensive fishponds : 35.0 ha Forest (including buffer zone) : 75.7 ha Intensive aquaculture is as defined in B but over a smaller area of 35.0 ha.

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Table 6.1. Production of Milkfish, Prawn and Total Production from Aquaculture (mt).

Year	Milkfish Monoculture		Prawn Monoculture		Total	
	Quantity	Growth Rate	Quantity	Growth Rate	Quantity	Growth Rate
1984	155,709		26,357		477,887	
1985	155,344	-0.23	26,357	0.00	494,742	3.53
1986	158,621	2.11	27,980	6.16	470,893	-4.82
1987	179,791	13.35	32,380	15.73	560,970	19.13
1988	175,935	-2.14	41,548	28.31	599,554	6.88
1989	181,197	2.99	43,539	4.79	629,345	4.97
1990	191,878	5.89	47,591	9.31	671,116	6.64
1991	213,674	11.36	45,740	-3.89	692,401	3.17
1992	145,554	-31.88	75,996	66.15	736,381	6.35
1993	124,510	-14.46	86,096	13.29	772,082	4.85
Total (1984-93)	1,682,213		453,584		6,105,371	
Percent of Total	28		7			
Average		-1.45		15.54		5.63

Sources: Bureau of Agricultural Statistics (BAS).

Table 6.2. Estimate of Net Profit (Per Hectare, Per Year).

Item	Milkfish Monoculture	Prawn Monoculture
Total Revenue	188,274	618,554
Total Variable Cost	72,679	298,255
Material Inputs	53,992	246,964
Labor Cost	18,687	51,291
Gross Revenue	115,595	320,299
Fixed Cost	31,400	40,492
Interest Expense	6,718	11,253
Depreciation	24,682	29,239
Net Revenue	84,195	279,808
Opportunity Cost	11,248	32,774
OC of Capital	7,270	29,825
OC of Labor	3,978	2,949
Economic Profit	72,947	247,034

Table 6.3. Data Comparison of Different Studies for Milkfish Monoculture.

Item	Study 1a 1979	Study 2b 1984	Study 3c 1989	Study 4d 1991	Study 5e 1994
Stocking Density (fingerlings)					
pcs/ha/crop	1,411	908	2,183	6,415	3,311
pcs/ha/year	3,400	3,206	6,440	25,658	13,509
Number of Croppings/year	2.41	3.53	2.95	4.00	4.08
Average Farm Size	17.52	15.66	8.07	21.24	4.76
Production					
kg/ha/crop	444	364	431	1,568	686
kg/ha/year	1,164	1,359	1,271	6,273	2,797
Pesos/fingerling	0.31	0.40	0.20	0.24	0.21
Costs (Total Variable Costs)					
Pesos/ha/crop	3,288	4,082	5,032	17,888	9,808
Pesos/ha/year	8,614	15,222	14,844	71,553	40,019
Pesos/kg	7.41	11.21	11.68	11.41	14.30
Pesos/fingerling	2.33	4.49	2.31	2.79	2.96
Total Revenue					
Pesos/ha/crop	7,467	7,284	10,808	44,919	23,259
Pesos/ha/year	19,577	27,165	31,884	179,675	94,896
Pesos/kg	16.82	20.01	25.09	28.64	33.91
Pesos/fingerling	5.29	8.02	4.95	7.00	7.02

Table 6.3. Continued

Item	Study 1a	Study 2b	Study 3c	Study 4d	Study 5c
	1979	1984	1989	1991	1994
Gross Profit					
Pesos/ha/crop	4,178	3,202	5,776	27,031	13,450
Pesos/ha/year	10,962	11,943	17,040	108,122	54,878
Pesos/kg	9.41	8.80	13.41	17.24	30.29
Pesos/fingerling	2.96	3.53	2.65	4.21	4.06

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Table 6.4. Data Comparison of Different Studies for Prawn Monoculture.

Item	Study 1a	Study 2b	Study 3c
	1989	1991	1994
Stocking Density (Fry)			
pcs/ha/crop	17,985	25,043	142,409
pcs/ha/year	39,926	50,086	256,336
Number of Croppings/year	2.22	2.00	1.80
Average Farm Size	8.42	13.12	4.67
Production			
kg/ha/crop	459	853	1,841
kg/ha/year	1,019	1,707	3,314
kg/fry	0.03	0.03	0.01
Total Variable Costs (Real)			
Pesos/ha/crop	32,991	33,332	86,668
Pesos/ha/year	73,239	66,664	156,002
Pesos/kg	71.87	39.06	47.08
Pesos/fry	1.83	1.33	0.61
Total Revenue (Real)			
Pesos/ha/crop	38,597.59	98,085.53	173,206.15
Pesos/ha/year	85,686.66	196,171.06	311,771.17
Pesos/kg	84.09	114.93	94.08
Pesos/fry	2.15	3.92	1.22

Table 6.4. Continued.

Item	Study 1a	Study 2b	Study 3c
	1989	1991	1994
Gross Profit (Real)			
Pesos/ha/crop	5,607.02	64,753.31	86,538.42
Pesos/ha/year	12,447.59	129,506.61	155,769.15
Pesos/kg	12.22	75.87	47.01
Pesos/fry	0.31	2.59	0.61
Implicit Price Index for Fishery	123.06	147.73	198.40
(1985=100)			

Real figures are derived by dividing nominal figures by the Implicit Price Index

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Table 6.5. Chemical and Biological Products Used in Milkfish and Prawn Monoculture in 1994 Survey in Pangasinan, Philippines.

Product/Category	Use and Active Ingredients	Remarks
A. Plankton Growth Promoters		
Organic Fertilizers	Induce algal growth and for soil conditioning.	
Chicken Manure		Traditional pond input
Cow Manure		Traditional pond input
Tobacco Dust	(*nicotine*)	Fertilizer-cum-pesticide
Inorganic Fertilizers	Induce algal growth and for soil conditioning.	Traditional pond input
Urea (45-0-0)		May be combined with organic fertilizers
16-20-0	(*monoammonium phosphate*)	
14-14-14	(*NPK*) complete	
18-46-0	(*diammonium phosphate*)	
B. Soil and Water Treatment		
Agricultural Lime	Increases pH; pond disinfectant (*$CaCO_3$, Dolomite*)	Traditional pond input. Also used as disinfectant
Zeolite	Absorbs toxic gases (*clinoptilolite*)	For water quality maintenance
C. Pesticides, Algicide, etc.		
Aquatin	Fungicide (*fentin chloride*)	Effective on snails and worms
Bayslucide	Molluscicide (*niclosomide*)	Eradicate snails and worms
Brodan	(*BPMC*)	Originally an insecticide but accepted for general use
Cococide	Germicide (*Natural based Quaternary Ammonium Compound*)	Has superior biodegrability and also used as disinfectant
Gusathion	For control of pests, predators and competitors	Poisonous to Tilapia, gobbies and wild fishes
Protocide	Anti-microbial (*$C_{23}H_{41}ClN$, $C_{23}H_{25}ClN$, C_2H_5OH, inert ingredients*)	Has superior biodegrability and also used as disinfectant
Malathion	Pesticides, fungicides (*diethyl succinate, diethyl butanedioate, diethyl mercaptosuccinate, phosphorodithioate*)	Toxic to auxilliary arthropods and fish
Teaseed Powder/Cake	Piscicide (*saponin*)	Selective toxicant for the eradication of predatory and competitive species.
Thiodan	Used as Piscicide (*endosulfan*)	Not allowed to use in fishponds
D. Feed Additives		
Ascorbic Acid		May be combined with other products
Vitapolebe		

For a more exhaustive listing, refer to Primavera (1993).

Table 6.6. Comparative Analysis: Recommended Crop Rotation and Prawn Monoculture.

Item	Prawn Monoculture (A)	Crop Rotation			Difference (D-A)	
		Milkfish Crop (B)	Prawn Crop (C)	All Crops (D)	Amount	Percent
Stocking Density (fingerling/fry)	150,000 (approx.)	3,000 (approx.)	150,000 (approx.)	n.a.		
Number of crops per year	1.8	1	1	2		
Production (kg/yr)	3,314	686	1,841	2,527	-787	-23.75
Total Revenue (pesos/yr)	311,771	23,259	173,206	196,465	-115,306	-36.98
Variable Costs (pesos/yr)	156,002	9,808	86,668	96,476	-59,526	-38.16
Gross Profit	155,769	13,451	86,538	99,989	-55,780	-35.81

The values are taken from the 1994 survey; refer to last columns of Tables 16 and 17. The recommended crop rotation when actually implemented may yield different results. For simplicity, the results from the 1994 survey were used.

Table 6.7. Annual Aquaculture Production, Revenues and Costs for each Management Alternative.

Item	Management Alternative (a)									
	SA	IA			CF/IA			SF/IA		
	Milkfish	Milkfish	Prawn	Total	Milkfish	Prawn	Total	Milkfish	Prawn	Total
Production (tons)										
Per ha per year	6.27	0.69	1.84	2.53	0.69	1.84	2.53	0.69	1.84	2.53
Entire area	596.90	65.69	175.17	240.86	24.15	64.40	88.55	24.15	64.40	88.55
Average Price (P/kg)(b)	60	60	185		60	185		60	185	
Revenue (P'000)										
Per ha per year	376	41	340	382	41	340	382	41	340	382
Entire area	35,814	3,941	32,406	36,347	1,449	11,914	13,363	1,449	11,914	13,363
Variable Costs (P'000)(c)										
Per ha per year	96			156			156			156
Entire area	9,148			14,851			5,460			5,460
Gross Profit (P'000)										
Per ha per year	280			226			226			226
Entire area	26,666			21,496			7,903			7,903

Notes:

a. For description of management alternatives, see text.

b. Average milkfish price in Pagbilao is P45/kg in 1991 which is equivalent to about P60/kg in 1994. This is close to prices., to prices in Pangasinan. For local prawn prices which are sensitive to international prices, the average price in 1994 for Pangasian is used.

c. Variable costs do not include pond development costs. On top of the development costs are other capital investments. Variable costs for alternative I are taken from Guerrero (1991).

Table 6.8. Computation of Present Value of Net Profits for Each Management Alternative over 25 Years.

	Management Alternative			
	Semi-Intensive Aquaculture: Milkfish	Intensive Aquaculture: Crop Rotation	Intensive Aquaculture & Commercial Forestry	Intensive Aquaculture & Subsistence Forestry
Gross Profit (P'000)				
Per ha per year	280	226	226	226
Entire area per year	26,666	21,496	7,903	7,903
Less: Development Costs ('000)				
Per ha	450	900	900	900
Entire area		85,680	31,500	42,84031,500
Present Value of Net Profits over 25 years (mil. pesos)				
Entire area	112.36	35.85	13.18	13.18
Per ha.	1.18	0.38	0.38	0.38
Average Annual Profit (pesos/ha)	47,212	15,063	15,063	15,063

Notes:

- NPV of gross profits is adjusted for one crop failure every 5 years. Revenues are 50% less every five years.
- Development costs for intensive aquaculture are estimated at P400,000 per ha when exchange rate is P11/US$
- It is assumed that development costs moved with the exchange rate, hence, it is estimated now at P900,000 per ha when exchange rate is at P25/US$.
- Development costs for semi-intensive NPV is computed using a discount rate of 15 percent.

7. EVALUATION OF INTEGRATED AQUACULTURE AND SILVICULTURE

Jose E. Padilla and Micheal A. Tanael

7.1. Introduction

Integrated aquaculture-silviculture (aquasilviculture) is a multiple-use system that promotes harmonious coexistence between fishery species and mangrove tree species in a semi-enclosed system while providing coastal protection and maintenance to the ecosystem (PCARRD 1991). Aquasilviculture provides harvestable resources such as fish and timber and other natural products while maintaining the natural function of the mangrove ecosystem with minimal disturbance. Hence, it provides a compromise to the many competing users and beneficiaries of mangrove resources, namely: fishfarmers, capture fishers, wood gatherers and the local community as a whole.

Aquasilviculture is also aimed at rehabilitating degraded areas towards sustainable coastal zone development and management. It is an alternative use for abandoned and unproductive fishponds. In the Philippines, this technology is fairly recent and is currently on an experimental stage. Aquasilviculture in the country is very similar to the *tambak tumpang* technology in Indonesia although in the Philippines, the higher-value fish species are cultured while in Indonesia, mostly native fish populations are grown to marketable sizes (Baconguis 1993).

The general objective of this study is the evaluation of aquasilviculture as an alternative to mangrove preservation. Specific objectives include the following: a) identification and valuation of goods and services in aquasilviculture; and b) assessment of interactions between aquaculture and silviculture.

7.2. Analytical Approach

Aquasilviculture is practised in several experimental farms in the Philippines. There are two known sites in Luzon, one is in Catanauan, Quezon and the other in Mindoro island. The site selected for this study is Catanauan due to its relative accessibility and plant species cultured are *Rhizophora*. The site in Mindoro, *nipa* palms (*Nypa fruticans*) were planted instead of tree species. Tree species are the dominant plant species in old growth mangrove forests. An interview of the caretaker of the pilot farm was conducted on January 10, 1995 with a callback on January 22 to verify some of the data collected. Farm data pertain to aquaculture operations for calendar year 1994 and silviculture activities since the initiation of the project.

One of the objectives of the survey is the assessment of the performance of the entire farm. The focus is on aquaculture as the production cycle is shorter than in silviculture; direct benefits derived from the tree species may be realized only after several years. The possible complementation between the concurrent culture of fishes and mangrove tree species in a semi-controlled environment is evaluated indirectly through the aquacultural practices adopted in the farm.

For this study, the approach is to treat aquaculture and silviculture as separate activities although ideally, the two activities should be treated as one economic activity, i.e., aquasilviculture, producing two broad categories of products, namely: forest and fish products. However, in the absence of scientific information on the nature and degree of interactions between the two activities, the approach in this report of treating them separately and as joint (not one) activities may be justified.

7.3. Description of Technology

The aquasilviculture technology in the site was described in detail in Baconguis (1993) from which this section was based. The Ecosystems Research and Development Bureau of the Department of Environment and Natural Resources established an aquasilviculture research farm in Catanauan, Quezon on a privately-owned 8,000 sq.m. pond. About 5,000 sq.m. in the center of the pond (see Fig. 7.1) is planted with *Rhizophora* propagules at 1 m by 1 m interval in 1990. The silviculture area is almost level with the normal water level. Two species were used: *bakauan lalake (Rhizophora apiculata* Blume) and *bakauan babae (Rhizophora mucronata* Lam.) These two species are suitable for use as poles, posts, fences, mine timber, rafts, furniture, firewood, flooring, charcoal, tool handles, tannin, pulp and paper. The propagules of *Rhizophora* are eaten in some countries. Two other species sprouted around the farm after several years: *tabau (Lumnitzera littorea)* and *pototan lalake (Bruguiera cylindrica)*. The experimental farm is constructed with sufficient buffer zone of denuded and degraded mangroves.

The remaining area of 3,000 sq.m. from silviculture is used for aquaculture. The fishpond area is dug to about 0.6 m. with dikes in the perimeter of the farm built up to 1.5 m. above normal water level although erosion of the dikes over time raised the pond bottom. Two small fish nurseries are also constructed at the sides of the farm which permit more frequent cropping with the bigger pond area used solely for fish grow-out. A farm house was constructed for use of government researchers who supervised the project until end 1994. Capital investments amounted to about 30,000 pesos in 1990. Construction of the farm house accounted for over 30 percent of capital investments. Pond development which included the construction of dikes, gates and canals cost P13,500 or about 45 percent of total. The cost of propagule is a minor expense at 1,800 pesos.

7.4. Assessment of Aquasilviculture Operations

7.4.1. Aquaculture

Two crops were grown in 1994. The first crop was between March and June while the second crop was between August to November (Table 7.1). Milkfish was stocked although several wild species that enter the pond were allowed to grow. The total harvest for the cultured species, milkfish, for the first and second crops was 120 kg per cropping. The contribution of wild species was substantial at 50.5 kg and 46.5 kg for the first and second crops, respectively. These are equivalent to about 27.9 to 29.6 percent of total harvests. Combined harvest of cultured and wild species was 336.5 kg per year and is equivalent to about 1, 122 kg per ha per year. For the cultured species alone, the harvest is equivalent to 800 kg per ha per year. The harvest of milkfish in the pilot farm is less than the average milkfish monoculture production in 1988-89 crop year for three regions in the Philippines of about 1,271 kg per ha per year (Padilla 1995).

Total revenues amounted to 8,450 pesos for the first crop and 7,970 pesos for the second crop with the total for the year at 16,420 pesos. Milkfish accounted for 73 percent of total revenues for the year with the wild species sharing the rest. The more valuable species are shrimps and crabs. The large shrimps were sold at 120 pesos/kg while the small shrimps and crabs fetched the same price as milkfish at 50 pesos/kg. The other wild fish species were sold at much lower prices. The incidental or wild species harvested were actually consumed by the caretaker but the price it would have earned in the market was used to impute value.

Aquaculture technology adopted in the farm is extensive with stocking density at 0.17 fingerling per sq.m. The variable expenses incurred amounted to almost 6,940 pesos and 3,640 pesos for the first and second crops, respectively with total for the year at 10,580 pesos. The largest expense is labor followed by artificial feeds and stocking materials. The cost of producing a kg of fish from the farm is about 31 pesos which is equivalent to 17.5 pesos in 1989 (using an deflation factor of 1.77[7]). The unit cost of production in the aquasilviculture farm is much higher than the 10.2 pesos/kg reported by Padilla (1995) for three regions for crop year 1989.

Aquaculture operations in the pilot farm registered positive gross profits of 5,840 pesos per year or equivalent to about 19,500 pesos per ha per year (Table 7.2). Factoring in the fixed costs, aquaculture recorded a loss of 5,109 pesos per year. Fixed costs for those utilized or jointly incurred by the two activities such as salary of caretaker, depreciation of farm house, gates, canals, etc. are allocated to aquaculture and silviculture operations according to area[8] utilized. Aquaculture shares 37.5 percent of these costs or 10,949 pesos for the entire year.

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[7] CPI for 1989 and 1994 are, respectively, 112.2 and 198.2 with 1988 as base year. The deflation factor is the ratio of 198.2 and 112.2 which is equal to 1.77.

[8] This assumption is made in the absence of information on actual time spent by the caretaker in aquaculture and silviculture operations. During farm establishment, it is conceivable that more time is spent by the caretaker tending the trees. Once the trees have grown, most of the time is spent in fish culture.

The loss in aquaculture operations may be attributed to the nonpayment of fixed costs, particularly the salary of the caretaker from fish revenues. If aquaculture is to be sustained over time, revenues should at least cover variable and fixed costs. We perform a sensitivity analysis of aquaculture operations and determine impact on profitability. There are two ways of increasing profits: more frequent cropping and higher stocking density. The first alternative, while feasible, will not considerably increase profits as production and revenue move in the same direction. Hence, we focus on changing stocking density which may be doubled or tripled without requiring change in aquaculture technology. It is assumed that fish production increases linearly with stocking density as long as technology is semi-intensive and this is observed in the sensitivity analysis whereby stocking density still remaining extensive.

The results of three levels of increase in stocking density are given in Table 7.3. Scenario 1 doubles stocking density but economic surplus is still negative. The break-even point is attained when stocking density is increased by about 150%. An increase of 200% in stocking density gives a net surplus of almost 2,000 pesos/yr. We use the break-even scenario in projecting income from aquaculture over time.

7.4.2. Silviculture

A total of 5000 propagules were initially planted in 1990, 2000 of *R. apiculata* and 3000 of *R. mucronata*. The survival rate was about 80 percent for both species (Table 7.4). With replanting, the total number of propagules planted was 6000. The cost of a propagule in 1990 was 0.30 peso but the current price in 1994 in Pagbilao, Quezon increased to 1.00 to 1.50. The average height of the mangrove tree species planted in 1990 reached 1.5 meters for *R. apiculata* and 2.0 m. for *R. mucronata*. The average annual growth rate was, respectively, 0.375 m and 0.50 m. The trees started to flower in 15 to 18 months. In natural regeneration, trees bear propagules three years after planting. So far, three hundred propagules have been harvested with about 1,000 more remaining unharvested. The harvested propagules were germinated for future planting. No timber has been harvested from the trees so far.

Part of the value of silviculture is in the standing trees. The volume of wood is computed for the silviculture area over 50 years. The equation relating wood volume to age of trees and site index is estimated from empirical data for several mangrove plantation sites in the Philippines. Considering the growth of trees in the aquasilviculture farm, a site index of 3.5 may be assumed. For the 3,000 sq.m. plot, wood volume is approximately 9.0 cu.m. and is projected to increase to 15.5 cu.m. on the 10th year and further to 58.7 cu.m. on the 50th year. Valuation of standing trees is presented in succeeding sections.

7.4.3. Interactions between Aquaculture and Silviculture

So far, we have treated aquasilviculture as a case of one activity where fish and timber are produced. The quantities of fish harvested and the wood volume of the standing trees are estimated over time. Benefits are also derived in the production of fish and timber. Specifically, litter fall from the trees is a source of nutrients that enrich pond soil and water which augur well in the growth of fish and trees.

The quantity of litterfall is first estimated and then nutrient production (nitrogen - N, phosphorus - P, potassium - P) is, in turn, estimated from the amount of litterfall. An important assumption here is that there is no cutting of branches is done which may reduce the size of tree canopy and thus litterfall. The regression equations used in estimating litterfall and nutrients and the raw data are listed in Table 7.5. Litterfall is a function of tree canopy which is proxied by stand age. The data on the quantities of N, P and K is expressed in percent of litterfall. The raw data show that the nutrient content of litterfall changes over time which may indicate changing chemical composition of plant leaf over time. Hence, percent nutrient production is regressed with stand age. The r-squared for the regression equations are acceptable except for the phosphorus equation. Using these equations, litterfall, N, P, and K production are estimated over a 50-year period assuming there is no cutting of trees. Potassium accounts for the largest share of nutrients and phosphorus production is minimal.

The implementation of aquasilviculture in the Philippines is aimed at minimizing environmental and socioeconomic stresses on the mangrove ecosystem as mentioned in Baconguis (1993). The environmental benefits are as follows: (i) stabilization of coastal areas and protection from storms, etc., with the rehabilitation of denuded mangrove and mudflat areas; (ii) return of wildlife with the re-establishment of the mangrove forest; (iii) non-formation of acid-sulfate soils common in inadequately-designed fishponds. The socioeconomic benefits include the following: (i) provides an equitable compromise among the competing users of the mangrove resources especially when the project is managed by the community; (ii) increase in income with the joint production of both forest and fish products; (iii) promotes community awareness of sustainable utilization of coastal areas.

The perceived benefits from aquasilviculture as mentioned above were not directly evaluated for the pilot farm although from the configuration of the pond, some of these benefits are not realized. Coastal protection from wave action is only possible when the farm is not enclosed. Enclosing the pond, however, is necessary to prevent fish from escaping the pond. With pond enclosure, the benefits accrue only to the owners of the farm. As correctly pointed out by Baconguis, equitable distribution is achieved only when the farm is operated by the community itself or by a cooperative.

We focus on the interactions between aquaculture and silviculture which there maybe several indicators. First, the contribution of the litter fall from the trees to the productivity of the pond is insufficient to support growth of natural food and this is shown by the application of fertilizers. Artificial feeding also indicate that natural food that is grown is not enough to sustain the fish until harvest. Artificial feeding was also done to accelerate growth of milkfish to increase production. Artificial feeding coupled with the relatively low stocking density contributed to the high cost of fish production in aquasilviculture compared to pure aquaculture farms.

7.4.4. Valuation of Benefits from Aquasilviculture

We now attempt to estimate the value of the benefits of aquasilviculture, which include fish, wood and nutrients. The quantities of these goods may be estimated using empirical data generated by this study and the mangroves study conducted by the Philippine Institute for Development Studies (PIDS). *The discussion of the valuation of other ecological functions which will rely on completed studies elsewhere may be found in the integrative report of this study.* The interactions between aquaculture and silviculture activities will be considered in the valuation process. Valuation covers 50 years which is the planning period in assessing alternative uses of mangrove forests.

The total value of aquaculture operations may be indicated by the value of fish which goes to pay factors of production, labor, capital and management. In the years when surplus is negative, the value of fish is the cost of production. The value of wood from silviculture is the stumpage value using 1994 figures. The stumpage value represents the value of the standing trees. It is derived by subtracting from the market price of wood the extraction costs and normal returns to investments. The volume and value of standing trees are given in Table 6 with the assumption that no cutting is allowed. The difference between the volume of fuelwood and timber is not significant but with the latter valued much higher, the difference in value is significant.

The valuation of nutrients is performed to obtain an estimate of the importance of the linkage between silviculture and aquaculture. Prices of commercially available fertilizers which are adjusted by the proportion of active ingredients. Inclusion of the value of the nutrients to the value of goods and services from aquasilviculture represents double-counting as it is an intermediate product which serves as an input in the production of fish and wood. Its value is captured already in the value of fish and wood. Nonetheless, we estimate the value as it is assumed that these nutrients reduce fertilizer inputs over time. Nutrient value, however, is excluded in the computation of the gross value of aquasilviculture. The estimates are listed in Table 7.7. Potassium accounts for the largest value followed by nitrogen and phosphorus. Total value of nutrients increases from P435 in the first year to P2,881 on the 50th year using 1994 prices over the period.

The gross value of goods from aquasilviculture is the sum of the values of fish and wood. These are summarized in Table 7.8. Fish has market value while wood is potentially marketed. Fish accounts for a larger share in the early years of operation and this is consistent with the financial justification of aquasilviculture; fish provides for the cash requirements of the farm while wood supplements income in subsequent years when harvesting may be done. The share of fish to total value decreases over time as the volume, and, hence the value, of wood increases. The total value of fish and wood increases from P38,474 on the first year to P82,564 on the 50th year and based on this sum, the cost of establishing the aquasilviculture farm (P29,950) is exceeded on the first year. If the net value (revenues less expenses in aquaculture) of goods is considered, however, investment may be recovered only on the 22nd year when net value would have been P3,290. (This does not adjust investments and future revenues for inflation.) The results show that recovery of investments considering the low intensity of aquaculture activities in the Catanauan farm would take at least 22 years.

7.5. Application to Pagbilao Mangrove Forest

We now apply the results of the study to quantify the costs and benefits of aquasilviculture alternative for the Pagbilao mangrove forest. Several questions need to be resolved, however. The first is whether the aquasilviculture alternative is to be recommended or not. Second, if it is an alternative, what specific aquasilviculture technology (aquaculture and silviculture) will be adopted.

For the first question, the economic analysis of aquasilviculture as practised in Catanauan, Quezon is inferior in terms of its aquaculture component. This points to the fact that better aquasilviculture technologies need to be developed to make it a feasible alternative for mangrove forest management. Nonetheless, an aquasilviculture alternative is considered for the Pagbilao mangrove forest to allow for comparison with other alternatives.

A modified aquasilviculture technology is, however, recommended. Aquaculture technology is semi-intensive milkfish monoculture which is a more sustainable technology than intensive prawn culture. The allocation of the area, however is still maintained at 62.5% for silviculture and 37.5% for aquaculture in the absence of any basis for an alternative allocation. Including buffer zone of 15.5 ha, forest cover would increase to 74% or 82.1 ha while fispond area is 28.6 ha. The conversion of the forest to aquasilviculture will not entail the planting of trees but only the clearing of areas designated for fishponds and the construction of dikes, canals and water gates. In a sense, the management alternative does not involve silviculture. It is conceivable that the entire area may be subdivided into smaller ponds although such would have no bearing on the allocation of the entire area into either forest and fishpond. The value of goods and services derived from aquasilviculture are summarized in Table 7.15. For aquaculture, the figures correspond to alternative 1 in Padilla and Tanael while for the forest goods and services, the values are derived in Carandang and Padilla corresponding to the aquasilviculture management alternative. The summary in Table 7.15 shows that aquaculture is the major source of income from this alternative.

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Table 7.1. Aquaculture operations for 1994.

	Crop Number		
	1	2	All crops
Species cultured	**Milkfish**	**Milkfish**	
Culture period	**March 25 - June 20 (87 days)**	**Aug. 15 - Nov. 27 (104 days)**	
Area utilized (sq.m.)	3,000	3,000	3,000
Percent of total area	37.5	37.5	37.5
Harvests (kg)			
Cultured: milkfish	120	120	240
Incidental	50.5	46.5	97
Large shrimps	7	3	10
Small shrimps	10	10	20
Crabs	2.5	2.5	5
Bagaong	20	20	40
Other fishes	11	11	22
Total	170.5	166.5	337

Table 7.2. Costs and earnings of aquaculture operations.

	Crop Number		
	1	2	All crops
Revenues (pesos)	8,450	7,970	16,420
Variable costs (pesos)	6,940	3,640	10,580
Stocking materials	1,500	1,500	3,000
Fertilizer	320	320	640
Artificial feeds	3,300	0	3,300
Labor	1,820	1,820	3,640
Gross profit	1,510	4,330	5,840
Fixed costs	5,474	5,474	10,949
Salary of caretaker	4,500	4,500	9,000
Depreciation: farm house	362	362	724
Depreciation: gates, etc.	113	113	225
Repair/depreciation: net	500	500	1,000
Net profit (loss)	-3,964	-1,144	-5,109
Opportunity costs: capital	562	562	1,123
Net economic surplus (loss)	-4,526	-1,706	-6,232

Assumptions:

- Depreciation of farm house at 20% per annum; depreciation of water gates and canals at 10% per annum; depreciation/repair of nets at 20% per annum.
- Opportunity costs of capital is computed at 10 per cent per annum.
- Salary of caretaker, depreciation of farm structures and opportunity costs are allocated to aquaculture and silviculture based on areas utilized with the former accounting for 37,5 per cent. Repair/depreciation of nets is fully attributed to aquaculture.

Table 7.3. Sensitivity analyses: changes in stocking rate.

	Crop Number		
	1	2	All crops
Scenario 1: 100% increase			
Revenues (pesos)	14,450	13,970	28,420
Variable costs (pesos)	12,340	5,740	18,080
Gross profit	2,110	8,230	10,340
Fixed costs	5,474	5,474	10,949
Net profit (loss)	-3,364	2,756	-609
Opportunity costs: invested capital	562	562	1,123
Net economic surplus (loss)	-3,926	2,194	-1,732
Scenario 2: 150% increase			
Revenues (pesos)	17,450	16,970	34,420
Variable costs (pesos)	14,970	6,720	21,690
Gross profit	2,480	10,250	12,730
Fixed costs	5,474	5,474	10,949
Net profit (loss)	-2,994	4,776	1,781
Opportunity costs: invested capital	562	562	1,123
Net economic surplus (loss)	-3,556	4,214	658
Scenario 3: 200% increase			
Revenues (pesos)	20,450	19,970	40,420
Variable costs (pesos)	17,600	7,700	25,300
Gross profit	2,850	12,270	15,120
Fixed costs	9,340	2,740	12,080
Net profit (loss)	-6,490	9,530	3,040
Opportunity costs: invested capital	562	562	1,123
Net economic surplus (loss)	-7,052	8,968	1,917

Assumptions:

- Production (hence, revenue) and variable costs are assumed to change by the dame proportion.
- Fixed costs and opportunity costs are assumed to remain constant.

Table 7.4. Silvicultural practices and status of mangrove stand.

	Bakawan Lalake	Bakawan Babae
Planting material	Propagule	Propagule
Quantity (pcs)	2000	2000
Spacing (m)	1 by 1	1 by 1
Year planted	1990	1990
Height of trees in 1994 (m)	1.5	2
Year of propagule bearing	1993	1993
Survival rate (%)	80	80
Replanted?	Yes	Yes

Table 7.5. Estimated equations and raw data used.

1. Litterfall (LF in gm/yr/ha) on stand age (A in years)

   LF = 3712014 + 189298 A; R-squared = 0.85

2. Nitrogen Content (N in percent of LF) on stand age (A in years)

   N = 3.7342 + 0.1158 A; R-squared = 0.61

3. Phosphorus Content (P in percent of LF) on stand age (A in years)

   P = 0.6036 - 0.00188 A; R-squared = 0.08

4. Potassium Content (K in percent of LF) on stand age (A in years)

   K = 8.471 + 0.1695 A; R-squared = 0.88

Data Used in Estimation

Age (A) (year)	Litterfall (LF) (gm/yr/ha)	Nitrogen Content (N) (% of LF)	Phosphorus Content (P) (% of LF)	Potassium Content (K) (% of LF)
1	2,622,679	2.72	0.48	.7.82
3	3,133,487	3.52	0.58	.8.32
3	4,653,848	4.24	0.60	.8.56
3	4,666,641	3.34	0.64	.9.44
5	5,343,307	5.12	0.68	10.02
7	5,616,792	6.46	0.64	9.98
10	6,742,393	5.4	0.60	11.16
20	7,211,972	5.28	0.54	11.24
23	7,666,985	5.92	0.48	12.68
29	9,149,085	7.38	0.60	13.12

Source of raw data: Balangue et al. (1995).

Table 7.6. Volume and value of mangrove stand, Area = 3,000 sq.m. and SI = 3.5.

Age (year)	Wood Volume (cu.m.)			Value (pesos)		
	Total	Fuelwood	Timber	Fuelwood	Timber	Total
1	5.75	2.74	3.01	216	3,495	3,711
2	6.83	3.25	3.58	257	4,153	4,409
3	7.91	3.77	4.14	297	4,810	5,108
4	8.99	4.28	4.71	338	5,468	5,806
5	10.07	4.79	5.28	379	6,125	6,504
6	11.15	5.31	5.84	419	6,783	7,202
7	12.23	5.82	6.41	460	7,440	7,900
8	13.31	6.34	6.97	501	8,097	8,598
9	14.39	6.85	7.54	541	8,755	9,296
10	15.47	7.37	8.11	582	9,412	9,994
11	16.56	7.88	8.67	623	10,070	10,693
12	17.64	8.40	9.24	663	10,727	11,391
13	18.72	8.91	9.81	704	11,385	12,089
14	19.80	9.43	10.37	745	12,042	12,787
15	20.88	9.94	10.94	785	12,700	13,485
16	21.96	10.46	11.50	826	13,357	14,183
17	23.04	10.97	12.07	867	14,015	14,881
18	24.12	11.48	12.64	907	14,672	15,580
19	25.20	12.00	13.20	948	15,330	16,278
20	26.28	12.51	13.77	989	15,987	16,976
21	27.36	13.03	14.34	1,029	16,645	17,674
22	28.45	13.54	14.90	1,070	17,302	18,372
23	29.53	14.06	15.47	1,111	17,960	19,070
24	30.61	14.57	16.04	1,151	18,617	19,768
25	31.69	15.09	16.60	1,192	19,275	20,466
26	32.77	15.60	17.17	1,233	19,932	21,165
27	33.85	16.12	17.73	1,273	20,589	21,863
28	34.93	16.63	18.30	1,314	21,247	22,561
29	36.01	17.15	18.87	1,354	21,904	23,259

Table 7.6. Continued.

Age	Wood Volume (cu.m.)			Value (pesos)		
(year)	Total	Fuelwood	Timber	Fuelwood	Timber	Total
30	37.09	17.66	19.43	1,395	22,562	23,957
31	38.17	18.17	20.00	1,436	23,219	24,655
32	39.26	18.69	20.57	1,476	23,877	25,353
33	40.34	19.20	21.13	1,517	24,534	26,051
34	41.42	19.72	21.70	1,558	25,192	26,750
35	42.50	20.23	22.26	1,598	25,849	27,448
36	43.58	20.75	22.83	1,639	26,507	28,146
37	44.66	21.26	23.40	1,680	27,164	28,844
38	45.74	21.78	23.96	1,720	27,822	29,542
39	46.82	22.29	24.53	1,761	28,479	30,240
40	47.90	22.81	25.10	1,802	29,137	30,938
41	48.98	23.32	25.66	1,842	29,794	31,636
42	50.06	23.84	26.23	1,883	30,452	32,335
43	51.15	24.35	26.80	1,924	31,109	33,033
44	52.23	24.86	27.36	1,964	31,767	33,731
45	53.31	25.38	27.93	2,005	32,424	34,429
46	54.39	25.89	28.49	2,046	33,081	35,127
47	55.47	26.41	29.06	2,086	33,739	35,825
48	56.55	26.92	29.63	2,127	34,396	36,523
49	57.63	27.44	30.19	2,168	35,054	37,222
50	58.71	27.95	30.76	2,208	35,711	37,920

Assumption:

- Stumpage used are for 1994, which values are P79 for fuelwood and P1,161 for timber.

Table 7.7. Estimates of the value of nutrients for the 3,000 sq.m. silviculture plot.

Year	Nutrient Production (kg/yr)			Imputed Value (pesos/year)				
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	Total	Cumulative
1	45.06	7.04	101.13	173	37	435	645	645
2	48.67	7.36	108.12	187	38	465	691	1,335
3	52.40	7.68	115.30	202	40	496	737	2,073
4	56.27	7.99	122.67	217	42	527	786	2,859
5	60.28	8.30	130.23	232	43	560	835	3,694
6	64.41	8.61	137.99	248	45	593	886	4,580
7	68.67	8.92	145.94	264	46	628	938	5,518
8	73.07	9.23	154.08	281	48	663	992	6,510
9	77.60	9.53	162.42	299	50	698	1,047	7,557
10	82.25	9.83	170.94	317	51	735	1,103	8,660
11	87.04	10.13	179.66	335	53	773	1,160	9,820
12	91.97	10.43	188.58	354	54	811	1,219	11,039
13	97.02	10.72	197.68	374	56	850	1,279	12,319
14	102.20	11.02	206.98	393	57	890	1,341	13,659
15	107.52	11.31	216.47	414	59	931	1,404	15,063
16	112.97	11.60	226.15	435	60	972	1,468	16,531
17	118.55	11.88	236.03	456	62	1,015	1,533	18,064
18	124.26	12.17	246.09	478	63	1,058	1,600	19,664
19	130.10	12.45	256.35	501	65	1,102	1,668	21,332
20	136.07	12.73	266.81	524	66	1,147	1,737	23,069
21	142.18	13.01	277.45	547	68	1,193	1,808	24,877
22	148.41	13.28	288.29	571	69	1,240	1,880	26,757
23	154.78	13.56	299.32	596	70	1,287	1,953	28,710
24	161.28	13.83	310.54	621	72	1,335	2,028	30,739
25	167.91	14.10	321.96	646	73	1,384	2,104	32,843
26	174.67	14.37	333.56	672	75	1,434	2,182	35,024
27	181.57	14.63	345.36	699	76	1,485	2,260	37,285
28	188.59	14.89	357.36	726	77	1,537	2,340	39,625

Table 7.7. Continued.

Year	Nutrient Production (kg/yr)			Imputed Value (pesos/year)				
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	Total	Cumulative
29	195.75	15.15	369.54	754	79	1,589	2,421	42,046
30	203.04	15.41	381.92	782	80	1,642	2,504	44,550
31	210.46	15.67	394.49	810	81	1,696	2,588	47,138
32	218.01	15.92	407.25	839	83	1,751	2,673	49,812
33	225.69	16.18	420.21	869	84	1,807	2,760	52,571
34	233.50	16.43	433.35	899	85	1,863	2,848	55,419
35	241.45	16.68	446.69	930	87	1,921	2,937	58,356
36	249.53	16.92	460.23	961	88	1,979	3,028	61,384
37	257.73	17.16	473.95	992	89	2,038	3,120	64,504
38	266.07	17.41	487.87	1,024	91	2,098	3,213	67,716
39	274.55	17.65	501.98	1,057	92	2,159	3,307	71,024
40	283.15	17.88	516.28	1,090	93	2,220	3,403	74,427
41	291.88	18.12	530.78	1,124	94	2,282	3,500	77,927
42	300.75	18.35	545.47	1,158	95	2,346	3,599	81,526
43	309.75	18.58	560.35	1,193	97	2,409	3,699	85,224
44	318.87	18.81	575.42	1,228	98	2,474	3,800	89,024
45	328.13	19.04	590.68	1,263	99	2,540	3,902	92,927
46	337.53	19.26	606.14	1,299	100	2,606	4,006	96,933
47	347.05	19.49	621.79	1,336	101	2,674	4,111	101,044
48	356.70	19.71	637.64	1,373	102	2,742	4,218	105,261
49	366.49	19.92	653.67	1,411	104	2,811	4,325	109,587
50	376.41	20.14	669.90	1,449	105	2,881	4,434	114,021
Total	9,248	700	17,389	35,606	3,643	74,773	114,021	

Prices of fertilizers (pesos/kg) in 1994: Urea = P7.7/kg; Solophus = P10.4/kg; Potash = P8.6/kg.
Active ingredients are N in Urea; P in Solophus and P is Potash and per cent active ingredients in each is 50%, hence the value of active ingredients is half the actual price.

Table 7.8. Estimates of the value of products for the 3,000 sq.m. silviculture plot.

Year	Value (pesos)				Total
	Fish	%	Wood	%	
1	33,762	87.8	4,712	12.2	38,474
2	33,762	85.8	5,598	14.2	39,360
3	33,762	83.9	6,485	16.1	40,247
4	33,762	82.1	7,371	17.9	41,133
5	34,420	80.7	8,258	19.3	42,678
6	34,420	79.0	9,144	21.0	43,564
7	34,420	77.4	10,030	22.6	44,450
8	34,420	75.9	10,917	24.1	45,337
9	34,420	74.5	11,803	25.5	46,223
10	34,420	73.1	12,689	26.9	47,109
11	34,420	71.7	13,576	28.3	47,996
12	34,420	70.4	14,462	29.6	48,882
13	34,420	69.2	15,349	30.8	49,769
14	34,420	68.0	16,235	32.0	50,655
15	34,420	66.8	17,121	33.2	51,541
16	34,420	65.7	18,008	34.3	52,428
17	34,420	64.6	18,894	35.4	53,314
18	34,420	63.5	19,780	36.5	54,200
19	34,420	62.5	20,667	37.5	55,087
20	34,420	61.5	21,553	38.5	55,973
21	34,420	60.5	22,439	39.5	56,859
22	34,420	59.6	23,326	40.4	57,746
23	34,420	58.7	24,212	41.3	58,632
24	34,420	57.8	25,099	42.2	59,519
25	34,420	57.0	25,985	43.0	60,405
26	34,420	56.2	26,871	43.8	61,291
27	34,420	55.4	27,758	44.6	62,178
28	34,420	54.6	28,644	45.4	63,064
29	34,420	53.8	29,530	46.2	63,950

Table 7.8. Continued.

Year	Value (pesos)				Total
	Fish	%	Wood	%	
30	34,420	53.1	30,417	46.9	64,837
31	34,420	52.4	31,303	47.6	65,723
32	34,420	51.7	32,190	48.3	66,610
33	34,420	51.0	33,076	49.0	67,496
34	34,420	50.3	33,962	49.7	68,382
35	34,420	49.7	34,849	50.3	69,269
36	34,420	49.1	35,735	50.9	70,155
37	34,420	48.5	36,621	51.5	71,041
38	34,420	47.9	37,508	52.1	71,928
39	34,420	47.3	38,394	52.7	72,814
40	34,420	46.7	39,281	53.3	73,701
41	34,420	46.1	40,167	53.9	74,587
42	34,420	45.6	41,053	54.4	75,473
43	34,420	45.1	41,940	54.9	76,360
44	34,420	44.6	42,826	55.4	77,246
45	34,420	44.1	43,712	55.9	78,132
46	34,420	43.6	44,599	56.4	79,019
47	34,420	43.1	45,485	56.9	79,905
48	34,420	42.6	46,372	57.4	80,792
49	34,420	42.1	47,258	57.9	81,678
50	34,420	41.7	48,144	58.3	82,564
Total	1,718,368	56.5	1,321,408	43.5	3,039,776

The value of this fish is the total revenue for years when surplus is positive and the total cost when surplus is negative. Nutrients do not form part of gross value.

Table 7.9. Valuation of goods and services to be derived from aquasilviculture.

	Quantity		Estimated Values	
Forest Products (per year; 66.6 ha.)				
Commercial fuelwood	42.3	cu.m.	8,037	pesos
Commercial timber	134.1	cu.m.	209,732	
Charcoal	0.0		0	
Sub-total	176.4		217,769	
Aquaculture fish (per year; 28.6 ha.)				
Production/Revenue	179.32	m.t.	10.759	million
Variable costs			2.750	pesos
Gross profit			8.009	
Pond development costs (one-time exp.)			12.870	
Present value of net profits: 25 years			38.131	

Note:
Present value of net profit assumes *10%* reduction in net revenues from one crop failure, failure every *10* crops which covers *5* years.
Discount rate used is 15%.

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