Occasional Papers
of the
East–West
Environment
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Institute

1988

Paper No. 7

Logging Versus Fisheries and Tourism in Palawan

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Center

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An Environmental and Economic Analysis

by

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CONTENTS

FIGURES AND TABLES

Figures

Tables

ACKNOWLEDGMENTS

A project of this type requires the help of many individuals and institutions to whom we are indebted. Thanks is given to the following individuals and organizations for their special contributions: Dr. Edgardo D. Gomez, Director, Marine Sciences Institute, University of the Philippines, for the generous provision of facilities, staff and logistic support; Ms. Rea F. Yamsuan, President, Ten Knots Philippines, Inc., for extensive logistic support; Mr. and Mrs. Elis Lim for their kind hospitality in El Nido; Dr. Kent Carpenter, Mr. Franklyn Tan Te, Ms. Ming Zhou, and Mr. Sofronio "Jun" Invento for indispensable help with fieldwork; Dr. Stan Western, Hunting Technical Services, for arranging the loan of hydrological equipment; ex-Director Benjamin V. Gaon, Cecile Tuparan, and other staff of PIADP, Manila and Puerto Princesa, for supplying information, logistics, and helping design and build the gaging station; Porfirio G. Castañeda, Natural Resources Management Center, for suggesting the study site; ex-Governor Salvador Socrates and Saling Acosta, Palawan Governor's Office, for logistic support; Mr. James R. Seery, Vice-President, Production, ALCORN Philippines, Inc., and the staff of Aerolift, Inc., for air transportation; ex-Director Edmundo V. Cortes and Julie Gorospe, Social Forestry Division, Bureau of Forest Development, for technical support; Dr. Roger N. Concepcion, Agricultural Land Management and Evaluation Division, Dr. Modesto Recel, Chief of Soil Research, Mrs. Belen Pajarito, Senior Soil Technician, Bureau of Soils, for technical support; Jose C. Alvarez, PTPI, for logistic support and maps; Renato Lapitan, UPLB College of Forestry, for design of the erosion plots; ex-Director Felix Gonzales, Ramon Miclat, and Coral Reef Project Staff, Bureau of Fisheries and Aquatic Resources, for logistic support and advice.

We would like to thank the following people for helpful discussions, critical review of manuscripts or advice:

Drs. Robert A. Kinzie III, Leonard A. Freed, Christopher Womersley, Michael Hadfield, Stephen R. Palumbi, Zoology Department, University of Hawaii; Dr. Richard Grigg, Hawaii Institute of Marine Biology; Dr. Paul Ekern, Water Resources Research Center, University of Hawaii; Dr. Raymond M. Rice, Redwood Sciences Laboratory; Drs. Lawrence Hamilton, Robert Ziemer (U.S. Forest Service), David Harper, Maynard M. Hufschmidt, Toufiq Siddiqi, Kirk Smith, and Norton Ginsburg, Environment and Policy Institute, East-West Center.

We also thank East-West Center staff members Mrs. Rose Nakamura and Jeanne Hamasaki for supporting the project from the beginning, Regina Gregory for word processing assistance, April Kam and Laurel Lynn Indalecio for drafting the figures, Joy Teraoka for formatting and layout, and Helen Takeuchi for editing.

This material is based on work supported by the National Science Foundation under Grant No. INT-8421225, by the East-West Center, and by a National Resource Fellowship (Center for Asian and Pacific Studies, University of Hawaii) to the first author.

ABSTRACT

The pollution of rivers, lakes, and sea by sedimentation is a growing problem throughout the world. Sedimentation pollution of coastal marine areas is especially serious in Southeast Asia where fish harvested from coastal waters serve both as a major source of protein for human consumption and a significant source of foreign exchange through exports. One major cause of sedimentation is logging.

In 1985 a logging operation was begun in the watershed bordering Bacuit Bay (El Nido), Palawan, Philippines. Bacuit Bay is also an important resource for two other foreign exchange earning industries--tourism and marine fisheries. The effects of logging-induced sedimentation on the bay's previously pristine marine environment were the subject of a 1-year ecological study. By the end of the study, only 11 percent of the available commercial forest had been logged, but high rates of accelerated erosion due to logging had already resulted in dramatic increases of sediment transport and discharge into the bay. Sedimentation damage to bay coral reefs and associated fisheries was rapid and severe.

In order to examine the economic effects of sedimentation pollution on tourism and marine fisheries, predictions of future revenue production based on two development alternatives are presented. The development options are (1) to ban logging in the bay's watershed or (2) to allow logging to continue as planned. The first option would prevent further damage to the bay's ecosystem due to logging-induced sedimentation and thus the tourism and marine fisheries dependent on it. The second option would maximize logging revenue but reduce revenue from the other industries.

The results of the economic analysis are striking and project a reduction in gross revenue of more than $40 million over a 10-year period with continued logging of the Bacuit Bay

watershed as compared with gross revenue given implementation of a logging ban. The difference is due to projected losses from tourism and fisheries. Present value analysis was performed using both a 10 and 15 percent discount rate. Even with the higher discount rate, the present value of lost revenue exceeds $11 million under Option 2--continued logging. Sensitivity analysis shows that significant deviation from predicted effects of sedimentation damage do not alter the conclusion. In addition to these quantitative results, consideration of qualitative factors reveals that the social, economic, and environmental benefits of fisheries and tourism outweigh those of logging in this location.

The study demonstrates that the combined use of ecological and economic analyses can provide useful information for government planners seeking to maximize net economic benefits while minimizing social and environmental costs. Recommendations are made regarding application of these results to similar resource conflicts in other regions.

INTRODUCTION

Not long ago, environmental impact analysis in both the government and private sectors was the domain of the natural scientist, while economic feasibility studies were the separate concern of financial planners and economists. In economic analyses of projects planned for developing countries, if potential environmental changes were considered at all, they were treated as qualitative externalities. The jargon of the respective final reports reflected their inherent biases. This tended to exclude the results of environmental studies from the decision-making process. Government policymakers are familiar with the language of economics and often make decisions based in part on predicted economic returns, not abstract natural science concepts such as the ecological value of a "keystone species." Not surprisingly, therefore, the often "vague predictions" (Martin 1985) of environmental impact reports were frequently ignored, and projects were initiated based largely on predicted economic or political returns. As a result, there are numerous examples of development projects worldwide that show reduced economic returns due to a lack of consideration of environmental factors (Goodland and Ledec 1986).

Economic analysis of planned or ongoing development projects should take into account the impact of potential environmental changes (Carpenter 1981; Goodland and Ledec 1986). That is, economic analysis of proposed projects should consider the economic impact of potential changes in the target ecosystem ecology caused by project implementation. This marriage of economic and ecological theory (environmental economics, bioeconomics, or ecologinomics; Carpenter and Dixon 1985) has yielded new methods by which such ecosystem changes (damage, restoration, or enrichment) can be translated into economic terms (Kahn and Kemp 1985). (For a fuller discussion of the theory and methodology involved, see such texts as Crocker and

Rogers 1971, Seneca and Taussig 1974, Nijkamp 1977, Sinden and Worrell 1979, Hufschmidt et al. 1983, and Dixon and Hufschmidt 1986.)

Despite these advances, two characteristics of ecosystems--dynamics and linkages--have often been neglected in environmental economic studies and development project planning. Temporal and spatial fluctuations in ecological parameters of ecosystems (e.g., species distribution and abundance) are now known to be the rule rather than the exception and should be accounted for in the planning process. In lieu of long-term studies, extrapolations based on short-term work should be accompanied by appropriate caveats. The second characteristic of ecosystems that should be considered as part of the planning process is their linkages. Despite the large amount of work that has been associated with documenting the effects of pollution on aquatic ecosystems, the prevailing view has been predominantly uni-ecosystemic. For example, one study may investigate pollution effects in a particular river ecosystem while another study may examine how pollution degrades the marine ecosystem, but the obvious ecological links between these adjacent ecosystems have usually been ignored. Recently, there has been wide publicity concerning the economic import of ecosystem linkages through the atmosphere. For example, air pollution in the United States has been linked with acid rain and sterile lakes in Canada; fluorocarbon pollution produced by industrialized nations has been linked to depletion of the ozone layer, which may result in increased rates of skin cancer in humans. The potential economic impacts of such linkages are of obvious importance.

In practice, economic analysis of potential ecosystem changes is often complicated by competition among different private or government groups for use of resources within one ecosystem or multiple-linked ecosystems. One area where multiple-linked ecosystems are found is the coastal zone. Tropical coastal zones often consist of two major regions:

(1) the terrestrial region including coastal forest, mangrove, rivers and streams, and offshore island ecosystems; and
(2) a marine region consisting of coral reef, seagrass, sand flat ecosystems, and offshore submarine shelves rich in fisheries resources.

This paper evaluates alternative development plans for a coastal zone in Southeast Asia where tourism and marine fisheries compete with the logging industry for resource use. In particular, the ecological effects of coastal logging on terrestrial and marine ecosystems at a study site in the Philippines are examined, and then projected revenues from the three industries over a 10-year period are compared using two possible development options: (1) a complete stop to logging in the Bacuit Bay watershed, or (2) continued logging of the watershed with resulting damage to marine fisheries and tourism. This situation, an example of minimal direct competition caused by crucial ecosystem linkages, is of special interest. Erosion from coastal logging in the terrestrial ecosystem produces a negative impact on the marine ecosystem through sedimentation.

The detrimental side-effects of logging on watersheds have been well documented throughout the world (Suparto 1978; U.S. Department of State 1980; Hamilton and King 1983; Tucker and Richards 1983) and include damage to young trees through unplanned felling, soil degradation, and soil loss through increased soil exposure to wind and rain. Although tree-cutting exposes underlying soil to the direct effects of wind and rain by removing protective layers of leaf canopy (Herwitz 1987), the major cause of erosion due to logging operations has been shown to be road-building (O'Loughlin 1985). A major component of logging operations is the construction of an extensive road and skid-trail network to allow for log removal. Erosion resulting from such road and skid-trail networks is the primary cause of high levels of suspended sediment load in streams and rivers, leading to reduced fish and invertebrate biomass and diversity (Cordone 1956; Graynoth 1979; Newbold et al. 1980; Erman and

Mahoney 1983). In addition, silt deposited in dams and reservoirs results in reduced economic returns (Hamilton and King 1983; Goodland and Ledec 1986). Long-term and possibly irreversible changes to watersheds may occur when logging is followed by slash-and-burn agriculture. Eventually, the forest community may be replaced by an economically unproductive grassland.

Although the connections linking watershed erosion, silt-laden rivers, and siltation of the coastal marine environment appear obvious, they have received relatively little scientific attention despite the high economic value of coastal marine life. Terrestrial ecologists have often failed to look beyond the freshwater systems affected by erosion. In the few cases where marine scientists have studied siltation damage to tropical coastal marine species, the origin of the silt has rarely been documented. Often, the cause of siltation has been attributed to a variety of sources associated with development (Mergner 1982; Sudara 1982; Kuhlmann 1985). Without specific documentation of sediment production sources, however, it is difficult to devise cost-effective remedial measures to reduce soil erosion and resultant sedimentation or to make an economic analysis of the costs and benefits of alternative development strategies to the country.

Siltation of coastal marine areas occurs throughout the world and may result from logging, agricultural development, dredging, construction, and other human activities that expose previously protected soils to the erosive action of wind and rain (Gomez et al. 1982; White 1987; Salvat 1987). Coastal marine pollution is especially serious in developing countries such as the Philippines where the rapidly expanding population depends heavily on marine fisheries to meet protein requirements. The pathway of eroded soil from the forest to the sea is shown in Figure 1. (Note the stages along the pathway wherein sediment can be temporarily stored and later returned to the transport process.) If sediment reaches the sea where coral reefs are

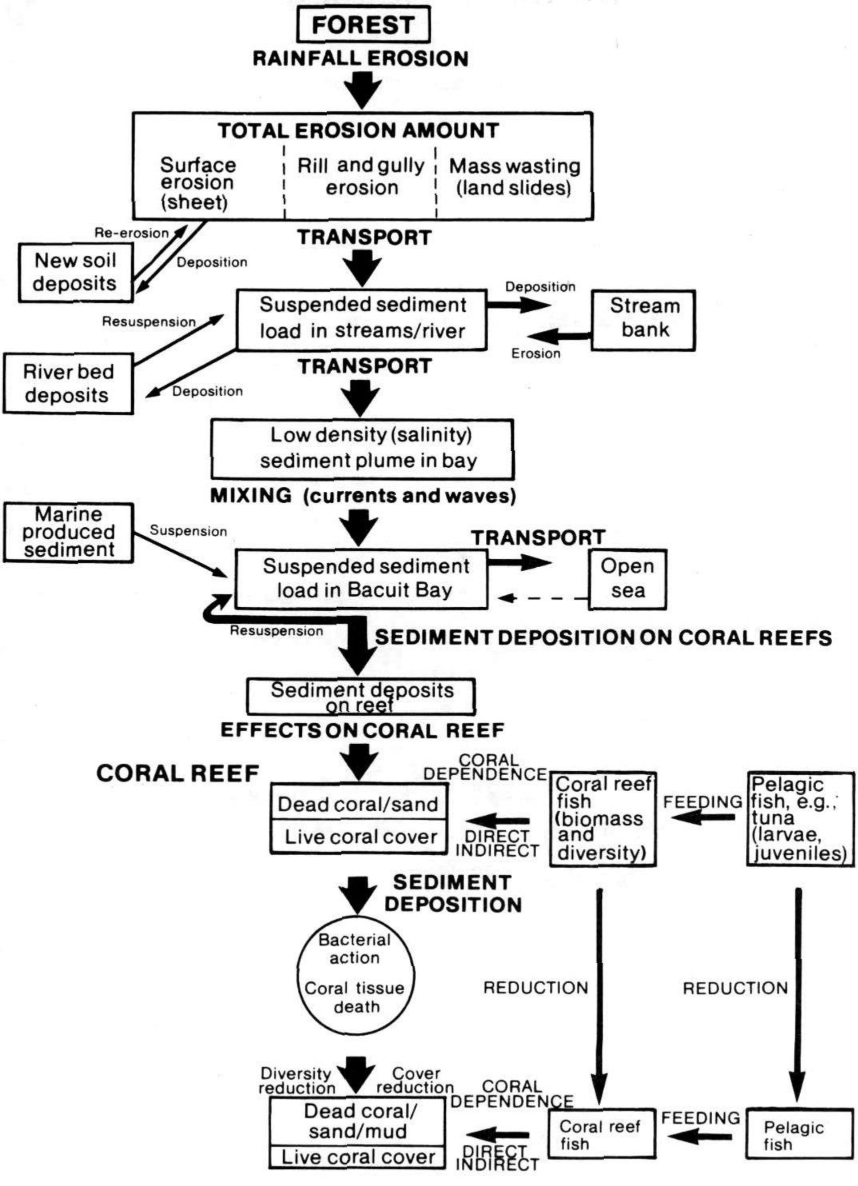

Figure 1. The predicted pathway of soil eroded from the forest floor as it passes to the sea. Note the many locations where soil can be temporarily stored and then later rejoin the transport process. Upon reaching the sea, sediment settles to the bottom. If coral reefs are present, the living corals may be damaged by sediment deposition. Since fisheries are linked to the coral directly and indirectly, they will be reduced by losses of living coral cover.

present, sediment deposition may kill some corals. (Details concerning the manner by which sediment damages living coral and how this may affect fish stocks will be presented later). A general model of the effects of sedimentation on live coral cover and fish biomass is also shown in Figure 1.

Observed reductions of marine fish stocks in Southeast Asia are partially due to overfishing (FAO 1987). However, marine pollution such as siltation may also explain a significant percentage of the reported reduction in fish catch in many areas. The negative effects of siltation on fish stocks need not be direct. For example, increased silt load could act indirectly on a tuna fishery by killing planktonic larvae of coral reef fish upon which tuna feed (Brook 1985). In this case the resulting decrease in tuna catch would not be reported until long after the sedimentation event, when the affected year-class of tuna matured and fishermen noticed a reduced catch. Unfortunately, the intricate nature of marine food webs makes it difficult to demonstrate conclusively a specific cause-and-effect relationship (Jones 1982).

Before beginning the analysis, it is helpful to briefly review the present patterns of resource use in Bacuit Bay, the biophysical interactions within and among ecosystems, and the economic implications of these interactions and effects. The data presented here were collected during an 18-month-long ecological study of the effects of logging on marine resources in Bacuit Bay (Hodgson, in prep.).

PHYSICAL SETTING AND RESOURCE USE IN BACUIT BAY

The study site--Bacuit Bay, El Nido--is located on the west coast near the northern tip of Palawan Island (11°N, 119°E) in the southwest Philippines (Figure 2). Palawan's 12,000 km^2 form a thin, 425-km-long island bounded on the east by the Sulu Sea

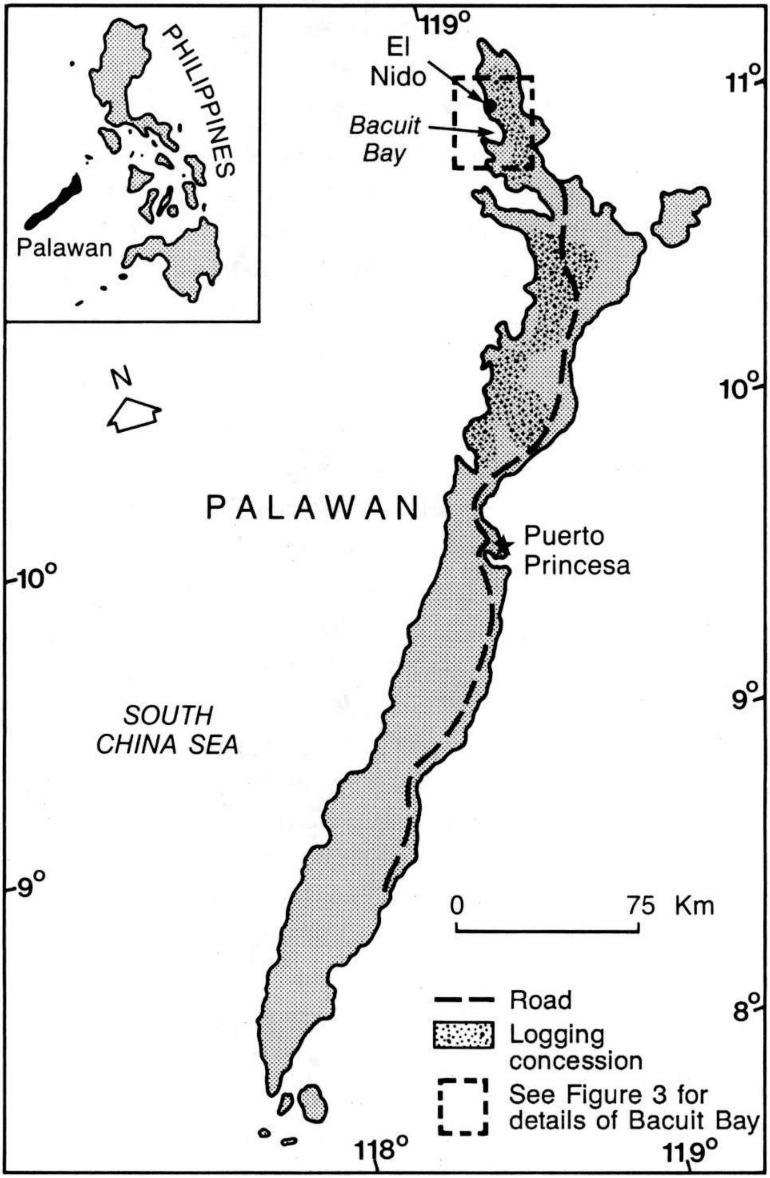

Figure 2. The Philippines (inset) and Palawan Island showing location of the logging concession and the study site, Bacuit Bay, El Nido (see Figure 3 for details of Bacuit Bay).

and on the west by the South China Sea. The island is bisected by a central mountain range, leaving only a narrow coastal margin of cultivable land that accounts for about 20 percent of the total land area (Bureau of Soils 1980). The weather pattern in Palawan is monsoonal. Northern Palawan receives from 2,000 to 4,000 mm of rain each year (PIADP 1985); however, it is not located on a high frequency typhoon track (PAGASA 1957-87). El Nido has not been hit by a typhoon during the past 30 years.

Ten years ago, Palawan was considered one of the last unspoiled regions in the Philippines, with virgin timber stands and plentiful marine resources, numerous endemic species of plants and animals, and a relatively low population density. More recently, rapid population growth, combined with industrial expansion in mining and logging, has drastically reduced the size of Palawan's remaining wilderness areas. Part of the reason for this expansion is that by the late 1960s, natural resources in the southern Luzon and Visayas regions had been depleted by a rapidly growing population, so that government and private interests turned to Palawan to supply their needs. In addition, migration to Palawan has accelerated due to increases in civil strife in rural areas of other provinces. Half of the nearly 5 percent annual population increase in Palawan is estimated to result from in-migration (PIADP 1985).

Palawan's timber and fisheries resources may soon prove inadequate to cope with the demand for them. In 1968, for example, almost 92 percent of Palawan's land area was forested. Poorly controlled logging and slash-and-burn agriculture resulted in a decrease in forest area to 70 percent by 1980 (Pido 1986) and perhaps 50 percent by 1987. Present forest consumption is estimated to be 200 km^2/yr, just more than 3 percent of the 1987 forested area.

Fish are another important resource for Palawan. The seas surrounding Palawan have been identified as one of four major spawning grounds for yellowfin and skipjack tuna in the Philippines (Wade 1950 in Aprieto 1981). A high percentage of the total Philippine fish catch is estimated to be taken from the waters surrounding Palawan (Pido 1986). The total Philippine catch of many demersal (nonpelagic) fish species, however, has been declining in recent years (FAO 1987). Previously pristine, the coastal marine environment of Palawan has begun to follow the trend seen in most other areas of the Philippines and is now being subjected to intense fishing pressure, illegal fishing (dynamite; poison; small mesh net; coral damaging, weighted-scareline or muro ami fishing), siltation, and heavy metal pollution from mine tailings. Due to lack of data, it is unknown whether this level of fishing effort has reached a degree that should be considered "overfishing" of the available stocks. Because of its remote location, the lack of roads, port facilities, or other infrastructure, northern Palawan has been a last hold-out to this onslaught of intense fishing pressure.

Bacuit Bay (Figure 3) encompasses 120 km^2, contains 5 islands, and has 9 islands located on its seaward shelf. The bay floor descends seaward in a series of three submarine terraces. The nearshore submarine terrace is 0.5 km wide and 8 m below sea level. The second submarine terrace is located at 18 m depth and is 2 km wide; the third terrace extends out to the bay entrance at 40 m depth. Depths near the outer islands reach 65 m. Flourishing coral reefs fringe each island and form a continuous band along the bay coastline interrupted only by river passes. Four small rivers and several continuous and seasonal streams enter the bay. The town of El Nido is located close to the northern bay entrance (Figure 3). It is the largest population center in the area (population 2,000). Three small villages border the bay on the north, east, and south coasts. Outside of these villages, the population is widely dispersed.

The terrestrial ecosystem of interest in this study encompasses all land surrounding and draining into Bacuit Bay, which will be termed the "Bacuit Bay drainage basin." The Bacuit Bay drainage basin covers 78.3 km^2 and extends inland to the central Palawan dividing range. Prior to the initiation of

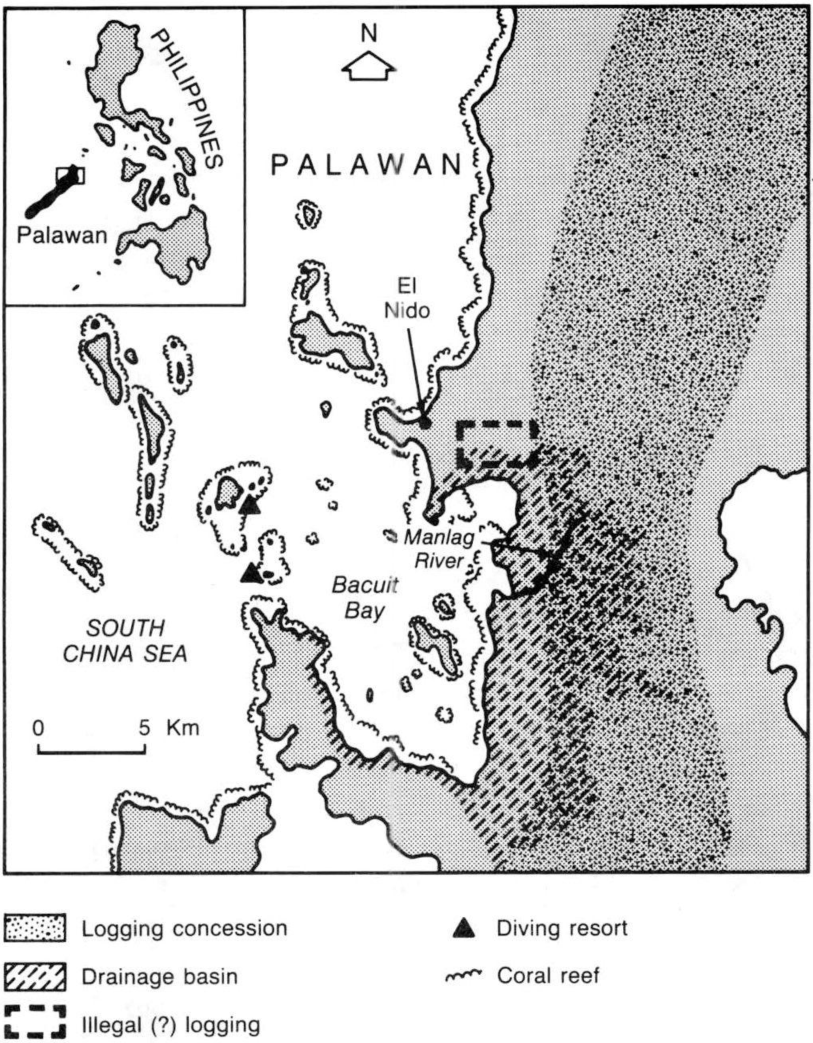

Figure 3. The study area showing Bacuit Bay, El Nido village; the overlap of the drainage basin with the logging concession area; and the location of the tourist resorts. The Manlag River drains about 70 percent of the basin.

Table 1. Land use in the Bacuit Bay drainage basin (1986)

Land use	Area (km2)	Total (%)
Forest		
Primary dipterocarp forest	37.0	47.3
Scrub, secondary forest	27.1	34.6
Logged forest	4.8	6.1
Mangrove forest	3.9	5.0
Subtotal	72.8	93.0
Agriculture		
Swidden/cashew	3.6	4.6
Rice paddy	1.1	1.4
Coconut plantation	0.8	1.0
Subtotal	5.5	7.0
Total	78.3	100.0

logging in 1985, 53 percent of the basin was composed of primary forest. Most of this forestland is now included within a large logging concession, encompassing most of northern Palawan. A breakdown of the 1986 land use in the Bacuit Bay drainage basin is listed in Table 1.

Agricultural production in the region is growing, and export products such as unprocessed cashew nuts show potential of becoming important foreign exchange earners in the future. The percentage of land devoted to agricultural use is low, however (Table 1). The absence of a high percentage of agricultural land use was one of the desirable characteristics sought during the site selection process for this study. Three primary industries compete for resource use in the Bacuit Bay region: logging, marine fisheries, and tourism. The following three sections provide an overview of these primary industries.

Table 2. PTPI logging concession, northern Palawan

Operator	Pagdanan Timber Products Inc. (PTPI)
Area	969.25 km^2
Allowable cut	200,000 m^3/yr
Method	High grade, mechanized
Timber rotation	85 years
Cutting cycle	42 years
Harvestable logs	60 cm Dbh (diameter at breast height) and larger

Logging

The logging operation bordering Bacuit Bay is part of a large concession, which extends to the north and south encompassing most of the remaining primary forest in northern Palawan (Figures 2 and 3). Logging operations in the area bordering Bacuit Bay commenced in January 1985 and were temporarily suspended by the logging company in January 1986 for 1 year. Details of the concession are listed in Table 2.

Philippine law requires that three trees be planted for each tree harvested. This level of planting, combined with diameter limits and selective logging practices that remove approximately half the number of harvestable classes of trees, will theoretically allow a sustainable yield operation with two harvesting cycles during the 85-year timber rotation (tree-growth cycle). Unfortunately, lack of tree planting, overcutting in low-volume timber stands, and excessive felling damage have already been cited as threats to the sustainability of the PTPI concession (PIADP 1985).

In order to facilitate logging operations at Bacuit Bay, three construction projects that contributed to accelerated erosion were undertaken. First, a 100,000 m^3 earthen pier (known as a "logpond" in the industry) was constructed (Figure 4). The pier is used to offload heavy equipment such as trucks and skidders shipped in by barge, as a log storage area, and for loading logs onto a barge for transport to the sawmill. The Philippine mahogany (<u>Dipterocarpus</u> spp., locally called <u>apitong</u>) logs from this region do not float due to a high resin content and must be transported to a sawmill by barge. In order to construct the pier, approximately 100,000 m^3 of soil was pushed down into the bay from an adjacent hillside. With only a bare minimum of protective log pilings, the pier erodes rapidly due to wave action and runoff. The second construction job was to clear 200 m^2 for the logging camp, which is used for housing, equipment storage, and repair. The camp, located about 3 km inland, was cleared almost entirely of vegetation and left bare (Figure 5). The third and largest construction project was road-building.

The Bacuit Bay drainage basin terrain is steep (30 percent mean slope), and the land is classified in the "severe erosion hazard" category (Bureau of Soils 1980). Road construction within the hilly drainage basin is generally done by cutting into the hillsides leaving an exposed vertical face on the uphill side (Figure 6). On the opposite, downslope side the extra clay soil is pushed over the edge of the road, spilling down in a wide swath called a sidecast fill slope. Both the uphill and downhill slopes are destabilized by this type of road construction, increasing the potential for accelerated erosion.

Irrespective of environmental considerations, careful design and construction of logging roads may be financially cost-effective by reducing costly road and equipment repairs and production slowdowns (Figure 7). In an Indonesian study, transportation costs consisting primarily of road-building and maintenance comprised 72 percent of the total cost of logging (Suparto 1977). Despite this well-known relationship, road-building practices in Philippine logging concessions have been slow to change. Three aspects of the design and

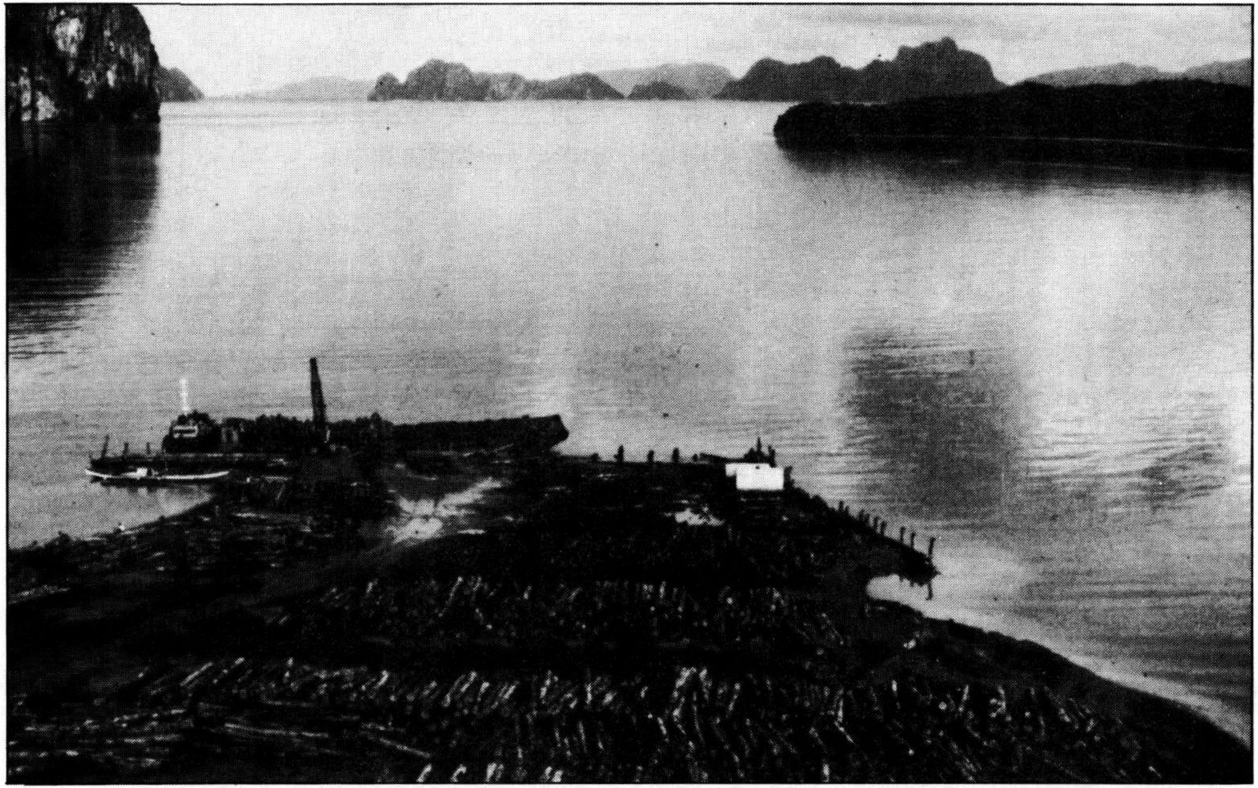

Figure 4. A view of the logging company loading pier (logpond). Logs are loaded onto the barge for transport to the PTPI mill, several hours to the south. Resort islands are in the background.

Figure 5. Aerial view of Manlag logging camp. The upper Manlag River passes (horizontally) through the center of the picture. Note the large areas of cut-and-fill where roads have been cut into steep slopes.

Figure 6. A typical primary logging road in the Bacuit Bay drainage basin. Note small-scale soil slumping at the base of the cut slope.

Figure 7. A log skidder stuck up to its axles on the soft shoulder of this primary logging road.

Table 3. Logging road area by type (1986)

Type	Width (m)	Length (km)	Area (km^2)
Primary access (with gravel)	12	16.7	0.20
Secondary	6	20.7	0.12
Tertiary and skid trails	5	18.4	0.09
Total	23	55.8	0.41

construction of PTPI concession logging roads that could contribute to increased road failure (small landslides) were cited by PIADP (1985): lack of drainage canals, lack of culverts, and excessive road slope angle. During the 1985 rainy season, numerous landslides from cuts above logging roads often halted operations by blocking roads. Such slides were also common during the 1986 rainy season.

Categories of road types comprising the PTPI logging road network are listed in Table 3.

Primary access roads are used daily (e.g., to transport logs to the log pier) and are usually gravel surfaced. Secondary roads are built to service specific logging zones within the concession and are used only while those areas are productive. Tertiary roads connect secondary roads to the skid trails. Skid trails are the paths cut into hillslopes by a bulldozer (Caterpillar tractor) to allow skidders access to specific tree stands. Following tree felling by chainsaw, the skidder transports each log to the log truck onto which it is loaded. Skid trails are normally used for only a few days and then abandoned. In this concession they were designed and built perpendicular to the land contours, thus allowing the greatest possible erosion by maximizing the slope angle for the full length of each skid trail. When fully loaded, log trucks transport logs to the log pier where they are stacked. When a sufficient volume is collected, the logs are loaded onto a barge for transport to the sawmill and veneer plants located 30 km to the south. This modern wood-processing facility is wholly owned by PTPI. The sawmill and veneer plants have capacities of 120 m^3 and 300 m^3 per day, respectively--sufficient capacity to process up to 100,000 m^3 logs per year (PIADP 1985). Regarding timber exports, Philippine law allows only 25 percent of logs harvested from each concession to be exported whole; the remainder must be processed into products such as sawn wood, veneer, and poles prior to export. (A detailed list of PTPI concession production is presented in the economic analysis section.)

Marine Fisheries

Fishing is a year-round, labor-intensive occupation. Bacuit Bay and its seaward shelf are used by commercial fishing operators, as well as by local artisanal (municipal) fishermen using paddle, sail, and motorized outrigger boats (Figure 8). The rich fishing grounds associated with Bacuit Bay attract commercial fishing vessels from provinces such as Panay, Zamboanga, and Batangas several hundred kilometers distant. Foreign fishing vessels are not allowed to fish in the Philippines without obtaining special licenses. Boats from Taiwan, Japan, and South Korea have been apprehended for illegal fishing in these waters (Aprieto 1981). A wide variety of fishing methods are practiced in this area to catch a diverse array of species (Figures 9a and b). The operations considered in this study are listed in Table 4.

Many of the species exploited in the Philippines have seasonal peaks, but the best fishing season is generally during the warm months from March through July, the poorest catches are made during the northeast monsoon period, October through January (Fox 1986). The latter period also coincides with dangerously rough sea conditions along the west coast of Palawan that often

Figure 8. A large number and variety of fishing craft are based at El Nido village (refer to Table 4).

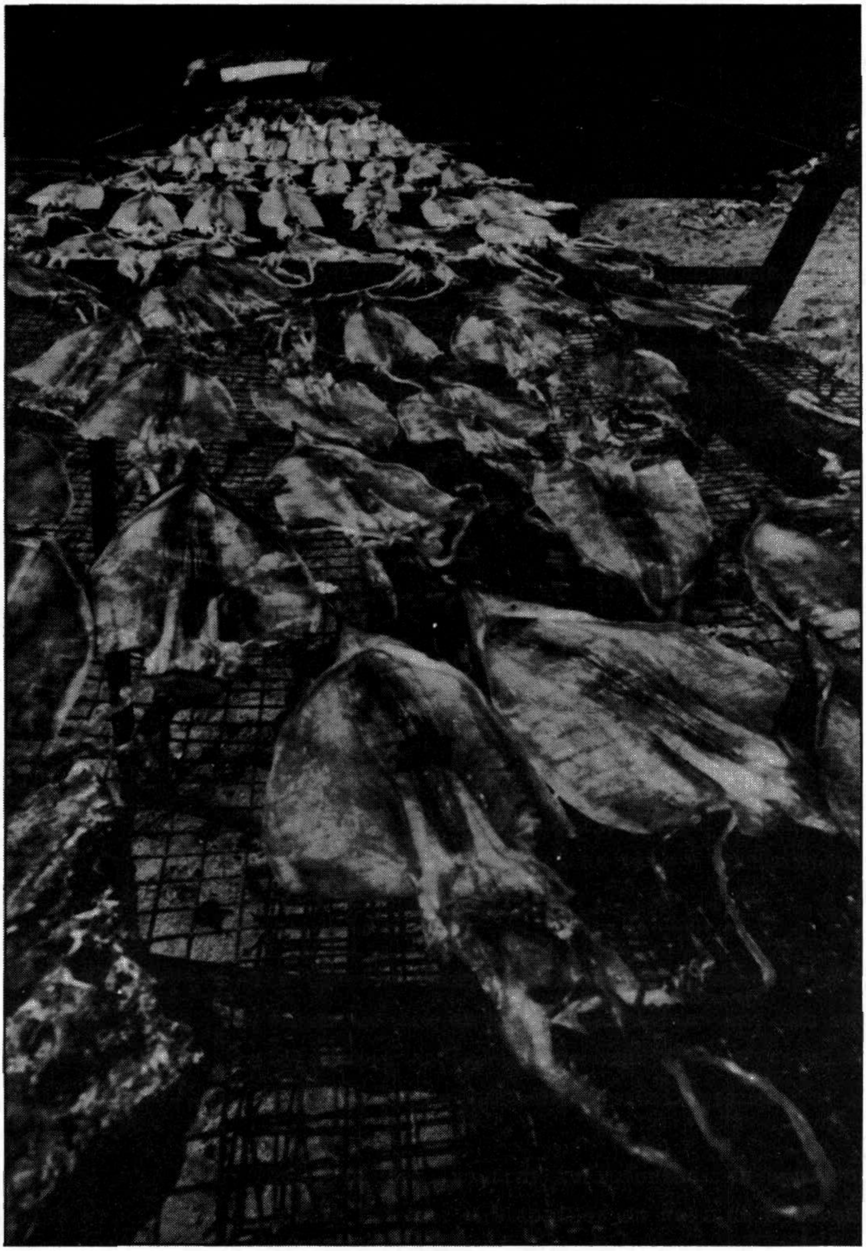

Figure 9a. Dried squid is a seasonal, high-value export product of the region.

Figure 9b. Dried fish is produced all year.

Table 4. Major fishing methods used in and around Bacuit Bay

Method	Number of boats	Fishing time in or around Bacuit Bay (%)
Commercial		
Trawler	5	50[a]
Purse-seine	20	20[a]
Lobster hookah	10	100
Bagnet (basnig)[b]	15	100
Anchovies (net)	5	100
Artisanal (includes handline, gill net, and pot-type traps)		
Motorized outrigger	170	100
Nonmotorized	110	100

[a]Data obtained from interviews with boat captains.

[b]A basnig is a locally built, wooden fishing boat with about 20 mt capacity, which can be used for a variety of fishing techniques, especially bagnet.

limit all categories of commercial fishing. Seasonally unfavorable fishing conditions may help limit the possibility of overfishing off the west coast.

Tourism

Tourism is relatively new to Palawan, and prior to 1979, there was essentially none in the Bacuit Bay/El Nido region. In 1979, a Philippine-Japanese joint venture company (Ten Knots, Inc.) chose the islands at the entrance to Bacuit Bay to set up a scuba diving resort; the El Nido Resort opened on Miniloc Island in 1982. The resort's strategy is to rely on group tours from Japanese diving clubs for the bulk of their business while filling in with local and other foreign individual and group divers during the off season. Despite several previous attempts, Palawan had proven to be too remote to support a flourishing organized tourist trade such as is found in other regions of the Philippines (e.g., Cebu). Reports of rampant malaria (Centers for Disease Control 1983) probably kept many local and foreign tourism entrepreneurs from investing in the region. Following the widely publicized success of Ten Knots, a second diving resort was established on an adjacent island (Pangolacion) by a different company in 1984.

Prior to the start of full-scale logging in 1985, the lack of roads to El Nido allowed the area to remain in a near pristine condition. It is still only accessible by boat from Manila (36 h), by boat from central Palawan (18 h), and by small chartered airplane (1 to 2 h) from either location. The El Nido Resort management realized that the value of Bacuit Bay to foreign scuba divers lay in its undisturbed nature. Any degradation of the natural beauty of the underwater or terrestrial environment would make their investment less profitable. They drew up a list of their own conservation regulations to be followed by their tourist divers. These rules include no spearfishing and no collecting of any kind. In addition they arranged to provide food, accommodation, and patrol boats for the appropriate law enforcement agency personnel to patrol and enforce Philippine fishery regulations. The result has been that Bacuit Bay is one of the few areas in the Philippines where fishery laws are strictly enforced.

The foreign dive trade to the Bacuit Bay/El Nido resorts has flourished as word of the excellent diving and remarkable above-water scenery became known internationally. The view of the bay is dominated by massive limestone islands, which jut straight up to a height of as much as 500 m (Figure 10). The rocky slopes of these islands descend beneath the water surface

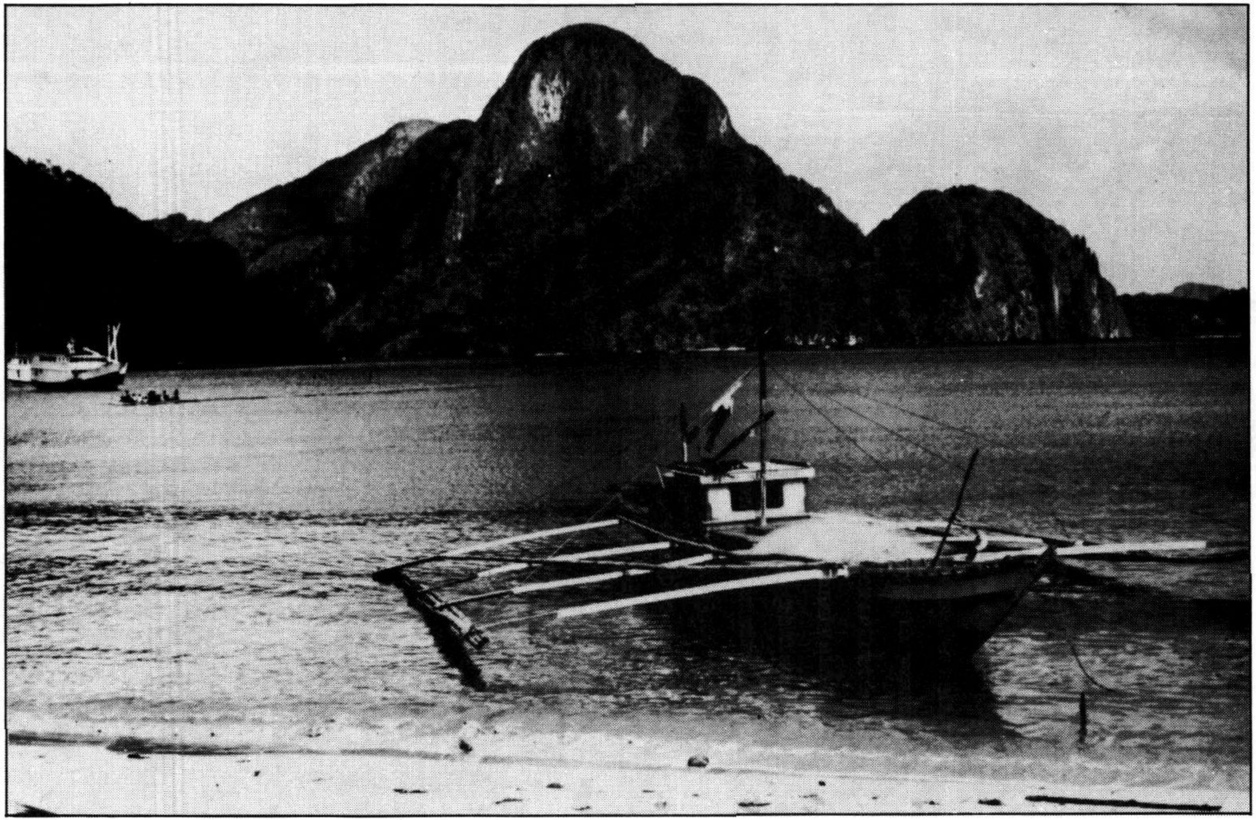

Figure 10. Cadlao Island (height 500 m) is located at the northern entrance to Bacuit Bay. A medium-sized fishing vessel from Batangas Province is in the foreground.

where they provide solid substrate for almost 500 species of corals, which in turn serve as habitat for thousands of species of fish and other marine organisms. Careful mosquito control procedures such as fogging have removed the malaria problem from the resort islands. Much of the remaining Philippine endemic fauna and rare species are found in the El Nido area. These include the dugong (sea cow), crocodile, pangolin (scaly anteater), river otter, mouse deer, Philippine monkey, Philippine eagle, squirrel, and Palawan bearcat. These species are not likely to survive if specific habitat areas are not set aside as preserves. Such preserves would be an added attraction for a developing tourism industry.

So far, tourism development has not had an adverse impact on the terrestrial or marine ecosystems. For example, careful planning and implementation of waste management procedures are a priority at each resort. Since environmental preservation is consistent with continued growth of this industry, tourism development may continue to expand in its role as a foreign exchange producer and environmental conservator.

ENVIRONMENTAL IMPACTS OF DEVELOPMENT OPTIONS

In order to determine the potential economic impact of development options in El Nido, it is necessary to examine their environmental impact. Two alternative development options based on the scale and location of logging have been chosen.

Development Options for Bacuit Bay Drainage Basin

Option 1: Logging continues in northern Palawan but is banned in the remaining Bacuit Bay drainage basin forest areas.

Option 2: Logging continues in northern Palawan, including the area within the Bacuit Bay drainage basin.

These options are considered realistic alternatives for the future development of El Nido. The predicted impacts of logging operations on the terrestrial and marine environments over the next 10 years are then calculated for each of the alternative options. Given the inherent uncertainty in predicting the future size of multispecies fish stocks, the time horizon is limited to 10 years. From both an ecological and economic perspective, this time horizon is considered conservative; yet, it is long enough to allow trends in ecosystem changes to be clearly developed. Although prohibiting further logging throughout all of northern Palawan would guarantee elimination of further environmental degradation from this cause, it is not considered a politically viable alternative and so is not considered further.

An intermediate development option would be to require the logging company to institute modern road-building and logging practices that would reduce potential environmental damage. Unfortunately, although PTPI was cited for poor logging practices by PIADP (1985), there has been little evidence of improvement. It also appears that PTPI has been logging outside of the designated logging concession shown in Figure 3. Even if the logging methods were patterned after those used in the United States, there is no guarantee that soil erosion would be less of a problem. Evidence from potentially less sensitive, temperate ecosystems indicates that significant damage to the forest, soil, and adjacent riparian environments may still occur even if the best controlled logging practices are used (Erman and Mahoney 1983). Given the uncertainty associated with this alternative and the past performance of the logging company, it is not considered viable or realistic.

Environmental Impact of Option 1. The implementation of Option 1 would prevent any further damage to the Bacuit Bay drainage basin due to new commercial logging and slow the damage to the coral reef resources already in progress. Lack of access to this area would not affect operations in other locations. The remaining commercial forest located within the Bacuit Bay drainage basin comprises less than 4 percent of the total concession area of PTPI in Palawan; therefore, banning logging in this area should not be a financial hardship for PTPI.

Environmental Impact of Option 2. The implementation of Option 2 would mean a continuation of the logging operations in all areas of the concession including the Bacuit Bay drainage area.

Forest Cutting

The logging company normally carries out operations at several locations within the concession. The results of a PTPI survey of 20 percent of the concession area give an estimated standing volume of 8300 m^3/km^2 (83 m^3/ha) of timber within the 37 km^2 of remaining primary forest within the Bacuit Bay drainage basin. In order to convert the standing volume into an estimate of harvestable volume, a selective logging formula is used (PIADP 1985). To ensure that sufficient seed trees will remain after cutting, standing volume is reduced by 30 percent. This figure is reduced by a further 25 percent to account for unrecoverable standing volume yielding an estimate of harvestable volume of about 4300 m^3/km^2 (8300 x 0.70 x 0.75 = 4357).

One estimate of the minimum time required to cut and remove all allowable commercial grade logs from the Bacuit Bay drainage basin can be made based on the operations plans reported to the Bureau of Forestry Development (BFD). The minimum time to cut the remaining forest area within the Bacuit Bay drainage basin can be calculated from a reported manifested production of about 88 percent annual allowable cut (AAC = 175,825 m^3; PIADP 1985) and the expected harvestable volume of 4300 m^3/km^2. The minimum time would be about 1 year (37 x 4300/175,825 = 0.9). This minimum time does not match the 1985 record of operations, however, and is considered unrealistic. A slower harvest rate may be due to many factors such as high rainfall creating impassable roads and equipment breakdowns. More important, the widely dispersed distribution of harvestable tree classes slows timber extraction. In 1985, 11.5 percent of the drainage basin was logged; therefore, a more realistic prediction of the time necessary to log the entire basin would be 5 years. This takes into account the delay in the first year due to one-time set-up work, such as building the logpond and logging camp, and agrees with the operations manager's estimate.

To predict the environmental impact of Option 2 over a 10-year time horizon, the effects of the initial year of El Nido logging operations (1985) can be extrapolated. These continuing effects were measured during 1986 (Hodgson, in prep.). Since logging operations were temporarily suspended precisely during the period when quantitative data were being collected by the first author (January 1 to December 31, 1986), the results are a conservative estimate of the deleterious environmental effects of active logging operations. These effects included accelerated soil erosion, high levels of suspended sediment load, sediment discharge, and sediment deposition in Bacuit Bay.

Erosion

The results of erosion plot studies (see Appendix A) show that sheet erosion per kilometer of logged area (roads and cut forest) was about 240 times greater than from primary (uncut) forest plots. The sheet erosion for the logging area lying within the Bacuit Bay drainage basin was calculated by extrapolating the erosion plot results (see Table 5). These total sheet erosion values do not include other forms of erosion such as gully or rill erosion and mass wasting.

The estimate of logging road area, 0.41 km^2, is 8.5 percent of the cut forest area and is within the range measured in

Table 5. Sheet erosion in logging concession area within the Bacuit Bay drainage basin, 1986

Area type	Area (km^2)	Erosion (mt/km^2)	Total (1000 mt)
Roads	0.41x(3)[a]	14,130	17.4
Cut forest	4.80	260	1.2
Uncut forest	37.00	60	2.1
Total	42.21	14,450	20.7

[a]Measured area multiplied by 3 to account for cut-and-fill slopes.

concessions in Malaysia and other tropical regions (Gilmour 1977; O'Loughlin 1985). When considering erosion from roads, however, the entire area of soil disturbance, not just the width and length of the road surface, must be taken into account. Erosion from sidecasts along logging roads in Malaysia was found to contribute up to 1.5 times the road surface erosion (O'Loughlin 1985). Field measurements and aerial photograph analysis revealed that cut-and-fill increases effective road width by a factor of 3. Using this factor, the total effective road area is 1.23 km^2. Roads thus make up 3 percent of the drainage basin area but account for 84 percent of the surface erosion due to logging (Figure 11). This finding is in agreement with most previous work on the contribution of road-building to total erosion in logging areas (Brown and Krygier 1971).

No attempt was made to measure rill and gully erosion or mass wasting within logged over or undisturbed forest. Therefore, the quantitative contribution of these erosion processes to a total erosion budget for the Bacuit Bay drainage basin is unknown. Sediment from these sources in the cut forest is probably reflected in the high suspended sediment load measured in the major river draining the area (see following section). Along logging roads and near the earthen log pier, landslides of various scales were commonly observed. Rill

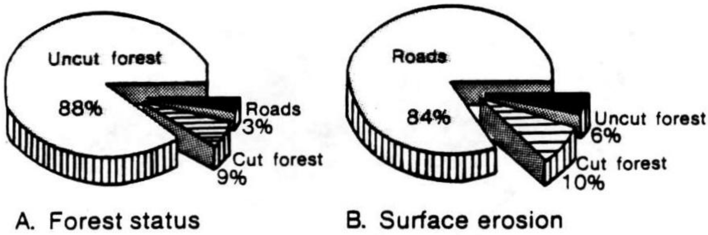

Figure 11. The contribution of roads, cut and uncut (primary) forest areas to the 42.21 km^2 logging concession area lying within the Bacuit Bay drainage basin in 1986 (A). The contribution of each of these areas to surface erosion (about 21,000 mt) estimated from erosion plot measurements in 1986 (B).

development on most exposed, sloping surfaces, and meter-deep gullies on steep roads (Figure 12) made it clear that these processes would contribute a significant amount of soil to a total erosion budget. Colonization and growth of grasses and weeds on level and low-slope road surfaces occurred within 1 year, especially if only a thin strip of land was cleared of vegetation on either side of the road. Steeply sloped roads bordered by 10 m wide cleared areas showed no plant recolonization 2 years after abandonment and may continue to erode for decades to come.

Sediment Delivery (Manlag River)

Although accelerated surface erosion was documented within the logging concession and thus established a potential sediment pollution source, it is important to estimate what proportion of eroded soil is actually carried out of the drainage basin by rivers and streams and into Bacuit Bay. This proportion is normally termed the "sediment delivery ratio." From Table 5, the sheet erosion from the Bacuit Bay drainage basin during 1986 was estimated to be 20,700 metric tons (mt). This figure can be compared with the total 1986 sediment discharge from the

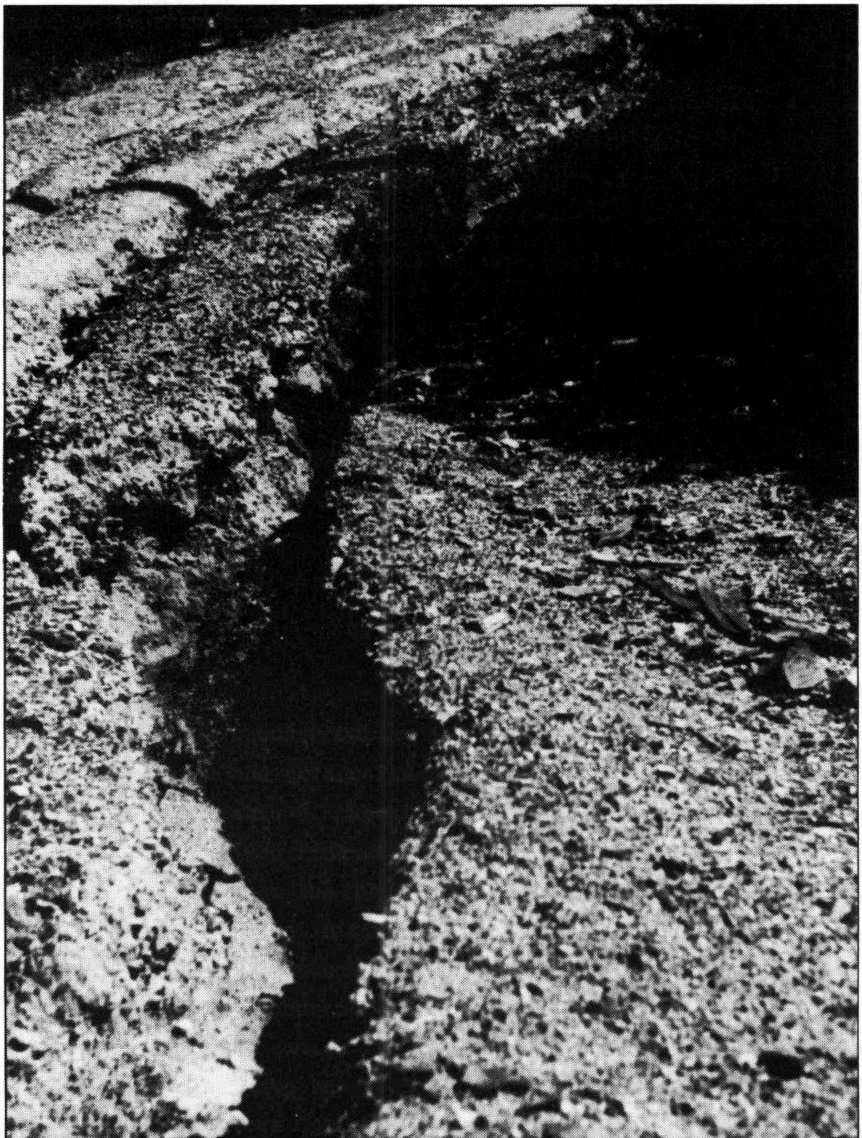

Figure 12. A 50 cm deep gully on a secondary logging road 6 months after abandonment. Rapid gully erosion on steeply sloped roads tends to prevent plant recolonization.

Manlag River, which drains approximately two-thirds of the Bacuit Bay drainage basin (Figure 3). The river gaging station was located just past the point where the river passes out of the logging concession. River height, current velocity, and suspended sediment concentration were measured in order to calculate daily sediment discharge (see Appendix A for details). The sediment discharge summed over the 1986 rainy season amounted to about 35,000 mt. This figure does not include bed load, the heavier material that is washed along the river bottom. Bed load is not considered further since it is not expected to be carried far enough into the bay to significantly affect marine resources.

In order to estimate sediment discharge from accelerated erosion due to logging for the entire Bacuit Bay drainage basin, the measured discharge from the Manlag River needs to be adjusted to account for the concession area not draining into the Manlag River and also for the surface erosion component contributed by natural erosion from the uncut forest. These adjustments yield an estimate of about 41,000 mt, which is more than 2 times the sheet erosion due to logging. With a logged area (plus roads) of 5.2 km^2, this equals nearly 8000 mt/km^2 in annual sediment yield. In comparison, annual sediment yields reported from various logging operations in the United States range from about 300 to 20,000 mt/km^2 (reviewed in Brown and Krygier 1971).

The sediment discharge estimate is expected to be larger than the surface erosion figure since sheet erosion is only one component of total erosion. Because an estimate of total erosion is not available, the sediment delivery ratio cannot be calculated. It is of interest, however, to consider potential causes of the difference. Several factors, especially gully erosion and mass wasting, have been shown to produce a significant proportion of total erosion in some logging areas (Guy and Norman 1970; Reid et al. 1981). Nonforestland comprises only 7 percent of the total drainage basin; therefore, it would not be expected to contribute greatly to total erosion. Measurements of suspended sediment load made simultaneously at the Manlag River and at an adjacent control river (Balangoyan) passing through all land-use types except logging supported the assumption that agricultural areas including swidden fields did not contribute significantly to the total erosion and sediment discharge. Suspended sediment load samples from the Manlag River were often more than 1000 mg/l (maximum 3000 mg/l), while simultaneous samples from the control river rarely exceeded 10 mg/l (maximum 30 mg/l) (Hodgson, in prep.). During storm-flow periods, there was a striking difference in the appearance of the two rivers; water in the control river was clear or slightly milky, whereas water in the Manlag River was almost chocolate brown. Additional factors affecting sediment delivery to Bacuit Bay include river bank erosion and sediment deposition in river channel storage compartments. In 1986 the banks of the Manlag River appeared relatively stable. The lack of obvious river bank slumping may be due to bank stabilization by a variety of plants in the upland areas and by nipa palm and mangroves near the entrance to the bay.

The lower portion of the river is influenced by tidal changes. During the dry season, river flow (and sediment load) is minimal; therefore, high tides may slow or temporarily block river discharge allowing suspended sediment to be deposited in river storage compartments. Due to the short length of the river and swift currents during the rainy season, long-term sediment storage is not expected to be a major factor in determining annual sediment discharge into Bacuit Bay. This assumption is reinforced by results of particle size analysis of concession soils. The clay and silt fraction comprises between 70 to 80 percent of the soil weight (particles smaller than 0.05 mm). Given this soil particle size distribution, Stokes Law (Guy 1969) predicts that a high percentage of eroded soil will settle relatively slowly. Clay and silt particles will also be resuspended by weak currents, allowing transport to the bay.

Sediment Deposition in Bacuit Bay

The high level of sediment discharge measured from the Manlag River during 1986 indicates that vast amounts of soil eroded due to logging operations in the drainage basin are transported to the river and carried to Bacuit Bay. It is necessary to document what proportion of this sediment is deposited in the bay as opposed to being transported out to the open sea by currents.

Many factors such as wind and tidal driven currents, water temperature, and bottom topography affect the mixing of silt laden fresh water with salt water at the location where a river flows into the sea. The less dense fresh water tends to float on the saltwater surface. During a storm with heavy rainfall, the large volume of freshwater outflow may form a shallow layer or lens that rapidly slides over the salt water and thereby carries the suspended sediment farther from the source than if the fresh water was mixing immediately with the seawater.

During calm weather, the muddy Manlag River formed an obvious plume extending into the bay. Wind was the primary factor controlling currents in Bacuit Bay. During windy periods, waves tended to break up the plume, mixing it with the surrounding water and shifting it laterally in the direction of the wind. As soon as it enters the bay, suspended sediment begins to sink at a rate primarily determined by particle size, shape and density, and water turbulence and density. The horizontal distance a given sediment particle travels before settling was largely dependent on wind velocity and direction and, to a lesser extent, tidal current velocity. The velocity of wind-generated currents ranged from 15 to 50 cm/s (Hodgson, in prep.).

Sediment deposition was measured throughout the bay using a sediment trap network described in Appendix B. To estimate sediment deposition, the bay was subdivided into zones associated with a given level of sediment deposition as measured by the sediment trap network. The sum of sediment deposition in the entire bay during the May to December 1986 rainy season was about 128,000 mt. An estimate of pristine sedimentation conditions can be made by multiplying the control station sedimentation rate (82.5 mt/km^2/mo) times the entire bay area (120 km^2). The result is 9900 mt/mo or about 79,000 mt for the 1986 rainy season. Subtracting this figure for "pristine" conditions from the measured total leaves 49,000 mt of sediment deposition that could be associated with the logging operations. This excess sediment deposition is clearly in line with the sediment discharge from the drainage basin attributable to logging, which was 41,000 mt. Additional inputs of sediment are undoubtedly occurring by way of small, ephemeral streams that drain from the logging concession directly into the bay and from rapid erosion of the earthen log pier. Sediment resuspension in the bay may also inflate the sediment deposition figure. These factors may account for the difference between the estimates for sediment deposition and Manlag River suspended sediment discharge due to logging.

The bay shoreline is protected from wave action generated in the South China Sea by its orientation, by islands blocking the bay entrance, and by fringing reefs. For these reasons, natural shoreline erosion is not expected to contribute significantly to the total Bacuit Bay sediment budget. This assumption was validated by weekly observations of most of the bay's coastline and by examination of aerial photographs taken in 1985 and 1986. These observations revealed that natural erosion events were rare and of small scale. Resuspension of shallow water sediment deposits by wave action, however, would be expected to contribute to some of the differences between estimated sediment input and sediment deposition. It is not possible to estimate the role of sediments deposited in shallow areas during active logging in 1985 and then resuspended/redeposited in 1986.

Effects of Sediment on Corals

During 1986, high rates of sediment deposition and a significant reduction in coral cover and diversity were measured on Bacuit Bay reefs (Figure 13). The control reef with a low (pristine) sedimentation rate showed no significant change in these ecological parameters. The greatest change occurred on the reef closest to the river mouth, which lost nearly 50 percent of its living coral cover. Most of this cover loss occurred following a high rainfall storm that resulted in high sediment discharge from the Manlag River for several days (Hodgson, in prep.). This devastating event highlights the importance of understanding the concept of biological stress thresholds. For example, although the increase in sediment deposition attributable to logging is only about 60 percent of the "pristine" rate, any increase in sediment deposition is additive and may stress a living organism, such as a coral, beyond its tolerance limits.

Since corals are sessile animals (attached to the bottom), they are unable to escape from temporarily high concentrations of suspended sediment, which may occur due to accelerated erosion of coastal land. Instead, they must rely on cleaning mechanisms such as polyp movement, ciliary action, and mucus production to remove the deposited sediment from their surfaces (Hubbard and Pocock 1972). This cleaning process requires energy, and each species has a limit to the rate, intensity, and duration of sediment deposition it can counteract (Hodgson, in prep.). If the sediment deposition rate exceeds the species-specific sediment cleaning limits (its biological threshold for this stress), the corals will die. Experiments have also demonstrated that corals held in aquaria and exposed to sediment deposition are more susceptible to lethal bacterial infections than corals held in control aquaria (Hodgson, in prep.); however, the

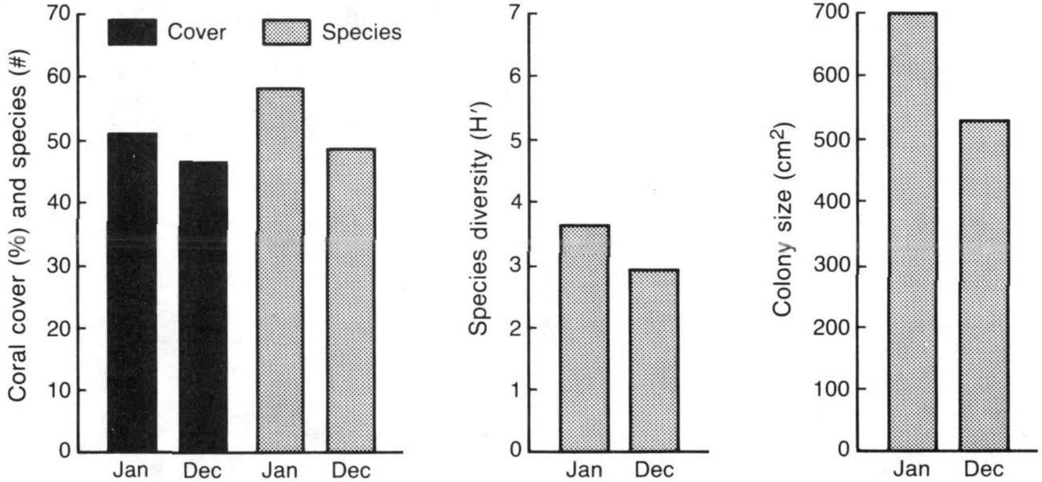

Figure 13. Percent live coral cover, number of coral species, species diversity (H'), and mean colony size per transect (8 stations) at the beginning (January) and end (December) 1986.

specific cause of death has not been established. Possibilities include oxygen or nutrient starvation, and poisoning by coral waste products or bacterial toxins.

Effects of Sediment on Fish

In contrast to corals, fish can escape from localized high turbidity areas by swimming both laterally and vertically. Some estuarine fish species may even prefer slightly turbid water over clear water during the early stages of their life cycle (Cyrus and Blaber 1987a, 1987b). Most likely, very high suspended sediment concentrations would be required to directly kill coral reef fish. Laboratory experiments have shown that the white perch (*Morone americana*), a North American estuarine species, is killed by exposure to a suspended sediment concentration of 19,000 mg/l. Mortality is due to gill clogging (O'Connor et al. 1976) and oxygen starvation. This extreme level of suspended sediment concentration is probably rarely found in nature. The highest turbidity recorded from the Manlag River was 3000 mg/l and from the Bacuit Bay, 1000 mg/l. Therefore changes in abundance and diversity of coral reef fish and pelagic fish dependent on the bay's food chain are not expected to be caused by fish mortality due to direct effects of sedimentation. One research topic that has received little attention so far is the effect of high turbidity on coral reef fish behavior. For example, intricate mating and territorial behavior patterns, which are reported to be highly dependent on visual cues (Thresher 1984), might be disrupted by turbid water conditions. This could result in a reduced reproductive rate that would eventually reduce biomass.

Numerous studies have documented direct and indirect dependence of coral reef fish on the coral reef community (Carpenter et al. 1982; and see Sano et al. 1987 for review). When the coral reef community is damaged, large decreases in fish diversity and abundance are measured. In one case, the complete destruction of a coral reef at Iriomote Island, Japan, resulted in the loss of 90 percent of fish abundance within 2 years (Sano et al. 1978). Hourigan et al. (in press) cite siltation due to dredging as the cause of local extinction of 12 species of butterflyfish at Johnston Atoll in the Central Pacific. In this case, local extinction was correlated with widespread coral mortality resulting in a severe food limitation for these species that feed directly on corals. In general, major shifts in fish diversity and abundance are expected to result from changes in coral reef community structure, which reef fish depend on for food, shelter, reproduction, and juvenile fish recruitment (Randall 1974).

Although some coral reef fish feed on coral directly (Reese 1981; Cox 1983; Tricas 1986), most depend for their food supply on prey organisms (e.g., crustaceans, other fish, or algae living in association with coral reefs). In addition reef fish use the reef structure for shelter. This dependency was examined by regression analysis of changes in coral parameters versus fish parameters on coral reef transects surveyed during 1986. This analysis depends on four linear relationships. The first and second are between sediment deposition at the different transect stations and coral diversity and living coral cover, respectively. That is, the different levels of sediment deposition measured during 1986 at the eight transect stations produced linearly proportionate reductions in coral cover and diversity. The third and fourth linear relationships are between coral cover and diversity, respectively, and fish biomass. These relationships, which reflect changes that occurred over a 1-year period, allow prediction of future changes in coral and fish ecological parameters due to specified increases in sediment deposition.

Analysis of changes measured in Bacuit Bay coral and fish populations during 1986 produced the following relationships:

<u>Correlation of sediment deposition with coral cover and diversity losses:</u>

- Annual decrease in coral cover of 1 percent for every additional 400 mt/km^2 of annual sediment deposition in Bacuit Bay

- Annual decrease of one coral species (extinction) per increase of 100 mt/km^2 annual sediment deposition in Bacuit Bay

<u>Correlation of coral cover and diversity losses with fish biomass reductions</u>:

- For each 1 percent annual decrease in coral cover, fish biomass is decreased by 2.4 percent.

- For each annual decrease of one coral species associated with coral cover loss, fish biomass is decreased by 0.8 percent.

In summary, sediment deposition is negatively correlated with coral cover and diversity, and a decrease in coral species diversity or living coral cover is correlated with a decrease in fish biomass. Using the preceding relationships, it is possible to estimate the long-term results of the loss of either coral cover or diversity on fish biomass and thus fish catch.

ASSUMPTIONS OF THE ECOLOGICAL IMPACT ANALYSIS

To simplify predictions of the physical and ecological impact of the alternative development options on Bacuit Bay drainage basin over the 10-year time horizon, several assumptions are made. The first assumption is that logging of the remaining 89 percent of the drainage basin will be finished within 5 years beginning in January 1986. For each of the 5 years, the resulting erosion will produce a sediment output calculated as follows:

Remaining primary forest = 37 km^2

To cut the remaining forest in 5 years:
$37\ km^2/5\ yr = 7.4\ km^2$ cut/yr

Dividing the required future annual logging area (7.4 km^2) by the area logged in 1986 (4.8 km^2) defines a factor that can be used to calculate the increase in sediment deposition due to the increased annual logging area:

$$7.4/4.8\ km^2 = 1.54$$

Assuming a direct relationship between area logged and sediment production, this will produce 1.54 x the 1986 sediment discharge (41,000 mt) = an additional 64,000 mt for each of the 5 years.

If a forest is logged and then left undisturbed, it has been generally accepted that surface erosion will eventually decrease with time as plant cover and soil stability increase (O'Loughlin 1985). The rate of decrease of total erosion following logging will depend on local conditions. For example, there could be a time lag of several years before total erosion begins to decline due to continuing gully formation and delayed mass erosion. Tree roots provide soil stability, especially on steep slopes. Following logging, the dead roots of cut trees decay and eventually lose their stabilizing capability, frequently leading to slope failures. Large-scale landslides could cause an increase in total soil erosion and sediment discharge several years after logging has stopped. Factors such as variation in annual rainfall will be important in determining the rate of total erosion following logging. In a California study, for example, Erman and Mahoney (1983) found that transportable stream sediment was still significantly higher in streams draining logged-over forest than in control streams 6 to 10 years after initial logging.

In tropical forests, ground cover may colonize and grow more quickly than in mid-latitude forests, thus protecting soil exposed by tree cutting, but the typically shallow layer of tropical forest topsoil may be washed away before recolonization by dipterocarpus tree species can begin. The soil surface of logging roads will generally consist of low nutrient level subsoil and often gravel. When this surface is highly compacted, it will provide a poor environment that only a few specialized plant species will be able to colonize (Hamzah 1978). In addition, gully erosion on steep road surfaces may become semipermanent features due to washouts during high intensity rainfall that eliminate plant colonization. This factor will tend to prevent a rapid decrease in the rate of erosion and sediment discharge from logged-over tropical forest. Observations of forest areas south of El Nido that had been logged several years before indicated that erosion, especially of the gully and rill type, was still severe on road surfaces.

In the present study, river sediment discharge was measured during the rainy season, beginning 5 months after the termination of logging. During the intervening dry season, some plant colonization and growth in low slope areas, combined with soil surface hardening, probably reduced subsequent erosion in those areas. According to farmers in El Nido, the 1986 rainfall was low to average; therefore, the 1986 sediment discharge estimate is considered a conservative estimate of sediment output during active logging operations.

In order to calculate the predicted sediment deposition for each succeeding year of the 10-year time horizon, the Manlag River sediment discharge in 1986 is increased in proportion to the yearly increase of newly logged area. The sediment deposition/logged area ratio is assumed to remain constant until 1 year after the forest within the drainage basin has been completely logged (1992). Sediment deposition is then reduced by 30 percent per year through the tenth year after logging began (Figure 14). Compared with rates of decrease reported in the literature (O'Loughlin 1985), and the slow recovery of nearby stands of previously logged forest cited earlier, a 30 percent per year reduction may be optimistic. In order to be conservative in predicting the effects of logging, the Manlag River sediment discharge figure rather than the higher 1986 estimate of sediment deposition is used in the calculations.

The second assumption is that sediment deposition and ecological effects (coral cover, species and fish biomass, catch decreases) will be averaged over the entire bay. Given a point source of sediment pollution in Bacuit Bay, gradients are expected in the suspended sediment distribution, sediment deposition, and in the deleterious effects of sediment on living marine organisms. For this analysis, the simplifying assumption of "average effects" was made to emphasize the significance of major trends rather than considering differential effects due to the complex biophysical gradients that vary temporally and spatially throughout the bay. A detailed biophysical analysis is beyond the scope of this paper and is reported elsewhere (Hodgson, in prep.).

The regression equation values for number of coral species and cover loss on sediment deposition are used to calculate predicted average changes in coral population parameters and fish biomass in response to increased sediment deposition (Hodgson, in prep.). Available evidence suggests that trophic (food web) structure of coral reef ecosystems may be tightly interlinked (Grigg et al. 1984); therefore, spatial averaging of the losses may be a realistic assumption in terms of the mean fish biomass production in Bacuit Bay. That is, a significant disturbance of the food resource base in one part of the bay will theoretically affect production in all parts of the bay trophic system.

The third assumption is that the entire bay and shelf fisheries catch will decline at a rate set by the regression

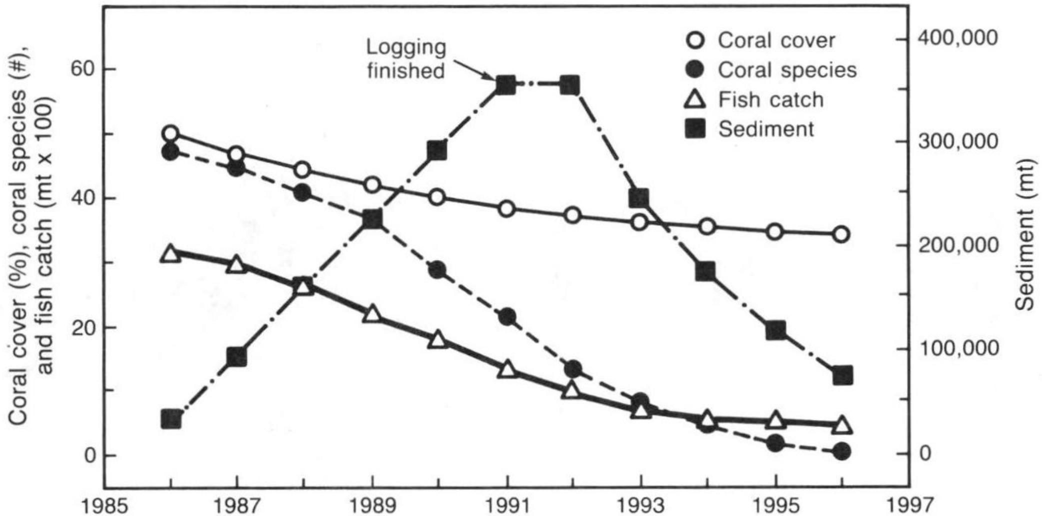

Figure 14. Predicted changes over 10 years in coral species number, percent live cover, fish catch (in hundreds of mt) due to increased sediment input and deposition in Bacuit Bay as a result of logging.

equations of coral ecological parameters on fish parameters. A precondition for the validity of this assumption is that fish catch is proportional to fish biomass, given a constant level of fishing effort. Reliable long-term data on fishing effort (or stock size) in and around Bacuit Bay are not available. It may be assumed, however, that fishing effort will increase as the population increases. In this case, fish catch would theoretically increase until some future time when overfishing would begin to reduce the catch. Even in cases where good data are available, predicting future catches of multispecies fisheries have proven difficult (see Pauly and Murphy 1982). Rather than attempting to guess the future of these complex relationships, a constant effort and catch is used to analyze Bacuit Bay fisheries.

ECONOMICS OF MANAGEMENT ALTERNATIVES

The Bacuit Bay ecosystem is an example of a complex natural system that provides a variety of resources. Multiple uses exist for the products of the system; some uses can coexist easily and others conflict. Tourism and fisheries, for example, both depend on the marine environment. The undisturbed bay ecosystem including algal, coral reef, plankton, and fish populations produces the products desired by the tourism industry (clear water, "good" diving) and the fishing sector (fish catch). The logging industry, on the other hand, is concerned only with timber extraction and has little or no economic interest in the marine environment. A reduction in marine resources will have no direct effect on timber production; logging activities, however, can have a major negative impact on the marine resource using sectors. In general, the commercial fisheries are directly dependent on the outer shelf of Bacuit Bay while the artisanal fishermen operate within the bay. There is presently good cooperation between the tourism and fisheries sectors in terms of law enforcement and the operation of marine preserves and fish-feeding stations for scuba divers. Assuming that this level of cooperation will continue, neither fisheries nor tourism should have a negative impact on each other in the future.

In the following section, the assumptions used as the starting point for an economic analysis of the Bacuit Bay case are discussed with respect to the two options presented earlier: Option 1, a ban on logging in the Bacuit Bay watershed, and Option 2, no change in the present plan to log the watershed within 5 years. The analysis will consider the value of products (fish and timber) and services (tourism) under the two alternative options.

Assumptions of the Economic Analysis

Ideally, it would be appropriate to make a complete social welfare, benefit-cost analysis that includes the differences between the three main resource users with respect to special tax incentives, low interest government loans, and foreign exchange components of each sector. In addition, it would be informative to examine the flow of capital and profits into and out of the Philippines and the distribution of incomes generated. Unfortunately, the three industries of interest are private and involve a dozen or more individual companies. Their financial records are not public; therefore, a full, appropriately shadow-priced, social welfare analysis is not possible.

An alternative is to make two simplifying assumptions: (1) that each industry is treated equally by the government and (2) that each spends an equal percentage of capital on imported goods and services. Potential problems with the first assumption due to government subsidy of the logging industry will be covered shortly. In the present case at least, the second assumption is reasonable. The logging industry in the Philippines is capital-intensive (Tadem et al. 1984). PTPI imported all of its heavy equipment, a helicopter, the sawmill and veneer processing plant machinery, and other items worth millions of dollars in total. Like the logging industry, most of the fishing industry's capital outlay is for imported goods such as fishing boats, electronic navigational gear, radios, generators, engines, and some fishing gear. The imported boat engines of the artisanal fishermen account for at least 50 percent of the cost of their boats. Only the paddle and sailboat fishermen avoid purchasing imported goods. In a similar fashion, the tourist industry imports generators, boats, outboard motors, compressors, and scuba equipment, and leases an imported airplane for transport of guests from Manila to and from the resort.

Although both the total amount and the percentage of capital outlay for imported goods and services may be higher for the logging industry than for the two other industries, these figures need to be adjusted by compensating for the percentage of use in the Bacuit Bay area. For example, 100 percent of goods imported by the tourist resort will be used in servicing their El Nido resort. In contrast, the Bacuit Bay drainage forest area makes up less than 4 percent of the entire PTPI concession. The entire inventory of logging equipment, veneer plant and sawmill machinery would be expected to be used for only a small percentage of their total useful life processing wood from Bacuit Bay drainage basin forest, and it is this percentage of the capital outlay for imported goods that should be compared to that of the other industries. A similar case exists for large commercial fishing operations that spend only a fraction of their total fishing time in the Bacuit Bay fishing grounds.

Assuming that the capital outlays for imported goods are comparable in each industry after adjusting for percentage use, it is possible to compare the gross revenues from each industry based on market prices of the commodities (fish and logs) and advertised rates for the tourist industry. (Although large discrepancies have been reported between the export volume of forest products from the Philippines and imports to its trading partners [Durst 1985; Durst et al. 1986], there is no evidence that market prices do not reflect actual cash transactions.) Note that this approach does not address the question of the profitability of each industry, it merely examines gross revenues. Although it would be desirable to do a complete benefit-cost analysis, sufficient data were not available to estimate profits. Rather, we will compare streams of gross benefits from the three main industries--logging, fisheries, and tourism. This approach is valid if, as assumed, the import component of each industry is roughly equivalent; therefore, the foreign exchange outflow share is not considered a crucial issue for assessing the economic value of each industry.

The foreign exchange earnings of each industry, however, may vary considerably. Tourism in El Nido is based almost entirely on foreign visitors; hence, foreign exchange makes up the bulk of total revenue. Timber products may be consumed domestically or exported. For the logging industry, the gross value of production allocated for domestic sales is estimated to be just over 10 percent of the gross value of total production. Fisheries show an opposite trend with more than 90 percent of gross value of total production derived from domestic sales (not including tuna exports from purse-seine operations, which would increase the export share from 10 percent to more than 40 percent of total gross value). There are several reasons for this difference. In the logging industry, poor quality goods are allocated for domestic sale, and there are domestic market limitations. In fisheries, there is high domestic demand and limitations in export marketing structures for the highly diverse range of fish products. The relative share of domestic consumption, exports, and replaced imports will determine the impact of each activity on foreign exchange earnings.

Although no information is available regarding the tax incentives for developing fisheries and tourism, a recent analysis of the logging industry in tropical nations concluded that inappropriate forest revenue systems "leave enormous economic rents to concessionaires," "provide concessionaires little reason to practice sustainable long-term forestry," and "encourage highly selective harvesting of tropical forests with undue wastage of remaining trees," leading to rapid depletion of forest resources (Repetto 1987). For example, total government revenues by export taxes and forest charges were less than 14 percent of the total $940 million generated by the logging industry in the Philippines between 1979 and 1982. The analysis concluded that government policies such as these "result in huge economic losses, wastage of resources, excessive costs, reductions in potential profits and net foreign exchange earnings, loss of badly needed government revenues, and unearned windfalls for a favored few businesses and individuals." Although government corruption (Durst et al. 1986) may increase the cost of logging and reduce "windfall profits," it will not increase tax revenue.

Calculation of Present Value of Gross Revenues, 1987 to 1996

In order to compare the benefits generated by each activity under the two development options, the present value of gross revenues over a 10-year period was calculated. A 10-year period was chosen to show the development of obvious trends in the system while limiting magnification of potential errors. Such errors could be caused by uncertainty in predicting the trajectories of parameters such as market prices and by the validity of simplifying assumptions. Constant 1986 prices and two discount rates, 10 and 15 percent, are used. These rates reflect the range of rates used when analyzing government and private projects. Despite wide fluctuations of many currencies against the dollar, the Philippine peso/dollar exchange rate has remained relatively stable from 1985 to the present.

Table 6. Mean capacity and daily occupancy of three categories of the El Nido tourism industry

Category	Mean capacity (persons/day)	Mean occupancy no. (%)	Daily rate ($)
Resort 1			
1987-91	60	39 (65)	100[a]
1992-96	200	130 (65)	100[a]
Resort 2			
1987-91	30	20 (67)	50
1992-96	100	65 (65)	50
Other			
1987-91	16	10 (63)	15
1992-96	40	26 (65)	15

[a]Plus one-time, lump-sum fee of $250 per person

The three use sectors are evaluated in turn. For each sector, the present values of gross revenues are calculated based on the assumptions cited. These discounted benefit figures are then compared for Option 1 (the proposed logging ban) and Option 2 (no change in present logging plans).

Tourism

Two tourist resorts are operating in El Nido, plus assorted small-scale lodging houses and tourism enterprises. The resorts are considered separately; estimates of gross revenue are based on information on mean length of stay, mean occupancy rate, and advertised daily rates. In addition, Resort 1 has a one-time, lump-sum fee of $250 per person. All other tourism revenue is lumped into the "Other" category.

The yearly gross revenue is calculated from the data shown in Table 6. An example of calculating gross revenue for Resort 1 is given at the beginning of Appendix C.

Table 7. Tourism gross revenue and present value of gross revenue using a 10% discount rate (x $1000)

Category	Gross revenue: Option 1[b]	Gross revenue: Option 2[c]	Present value 10%[a]: Option 1	Present value 10%[a]: Option 2
Resort 1				
1987-91	8,897	6,510	6,745	5,038
1992-96	29,656	0	13,961	0
Subtotal	38,553	6,510	20,706	5,038
Resort 2				
1987-91	1,834	1,306	1,388	1,010
1992-96	5,931	0	2,792	0
Subtotal	7,765	1,306	4,180	1,010
Other				
1987-91	276	202	208	157
1992-96	821	160	387	75
Subtotal	1,097	362	595	232
Total	47,415	8,178	25,481	6,280

[a]See text for present values using a 15% discount rate.

[b]Logging ban

[c]Continued logging

Gross revenue from each category of the tourism industry from 1987 to 1996, and present value of the gross revenue based on a 10 percent discount rate, are shown in Table 7. For Option 2, tourism revenue is reduced by 10 percent per year between 1988 and 1991 due to degradation of seawater quality and marine life on which the diving resorts depend. Beginning in 1992, yearly tourism revenue is reduced to the 1992 value of the "Other" category since the dive resorts are predicted to go out of business by this time. This latter prediction is considered realistic because the diving resorts in this remote location are marketing a single, costly product: pristine coral reefs and clear water for an international clientele. If the quality of this single product is dramatically lowered, tourist divers will choose alternative, well-known destinations. The lack of land-based facilities for nondivers precludes an expansion of the narrow target market without a complete reorganization and expensive construction program. The timing of the business failures will prevent the planned expansion in the tourism sector, thus drastically reducing gross revenue from 1992 to 1996.

From the tourism sector, the 1987-96 gross revenue from Option 1 ($47.4 million) is $39 million more than the gross revenue under Option 2. The present value at a 10 percent discount over the 10-year period from Option 1 ($25.5 million) is $19 million more than the present value under Option 2.

Marine Fisheries

In a similar manner, the fishing industry is analyzed based on the following assumptions. Under Option 1 (logging ban), the 10-year predicted fish catch and revenue is based on 1986 catch and gross revenue listed in Table 8. Local and commercial fishermen indicated that the 1986 fish catch was below normal and lower than the 1985 catch. Since the 1986 catch was considered subnormal, perhaps even reflecting initial effects of sedimentation during 1985, no further reduction in fish catch is made in the Option 1 analysis. Even without more logging, fish catch may possibly decline further due to continuing erosion and sedimentation before recovering to the prelogging, higher catch levels. In order to simplify the Option 1 analysis, the theoretical decline and recovery of fish catch are not included.

The larger commercial boats operate only a portion of their total fishing time in the Bacuit Bay area; therefore, the figures in Table 8 have been adjusted to include only fish catch from Bacuit Bay and the associated seaward shelf.

Table 8. Bacuit Bay fish catch by type and revenue in 1986

Type	Catch (mt)	Value ($1000)
Purse-seine	1,800	1,800
<u>Basnig</u>	2,460	615
Trawl[a] (bay shelf)	325	650
Outrigger		
Motor	132	66
Nonmotor	20	21
Shrimp	50	1,100
Anchovies	120	195
Lobster	8	113
Squid	22	27
Other (octopus, clams, etc.)	10	20
Total	3,147	2,807

<u>Note:</u> Totals do not include purse-seine catch or value.

[a]Trawling is prohibited inside the bay.

It may not be appropriate to include the value of the purse-seine revenue in the total. The primary catch of purse-seiners is tuna, which have generally been considered pelagic species. The extent to which tuna are biologically dependent upon coastal ecosystems such as Bacuit Bay has not been demonstrated. However, available evidence indicates a close association between tuna and inshore (reef and bay) food species at least during part of their life cycle. Brock (1985) examined the gut contents of 205 yellowfin tuna caught near FADs (fish aggregation devices) in Hawaii and found that 81 percent of their food was composed of coral reef, estuarine, and inshore species of fish and invertebrates. If this fishery is included, the 1986

Table 9. Fisheries gross revenue and present value of gross revenue using 10 and 15% discount rates, 1987-96 (x $1000)

	Gross revenue	Present value 10%	Present value 15%
Purse-seine included			
Option 1	46,070	28,308	23,122
Option 2	21,471	15,125	13,083
Purse-seine excluded			
Option 1	28,070	17,248	14,088
Option 2	12,844	9,108	7,895

Note: In calculations that combine revenue from all industries (e.g., Table 12), purse-seine (tuna) catch is excluded to maintain a conservative estimate of fish stocks affected by coral reef damage.

total catch is nearly 5000 mt with a gross revenue of about $4.6 million.

The 1987-96 predicted fisheries gross revenue and present value of the gross revenue (10 and 15 percent discount rates) under Option 1 (logging ban) and Option 2 (continued logging) are listed in Table 9. For Option 2, the reduction in fish catch is based on the linear equation obtained from multiple regression analysis of coral cover and species diversity on fish biomass. The results of these calculations are shown in Table B-2 (Appendix B). The assumptions pertinent to these calculations were covered in the previous section titled "Assumptions of the Ecological Impact Analysis."

The sizable reduction in fish catch predicted to result from continued logging under Option 2 is reflected in the gross revenue figures both with and without the tuna catch from the purse-seiners. More gross revenue is foregone when the tuna is included; but on a percentage basis, the loss is slightly greater when the tuna is excluded (56 percent) than when included (53 percent).

Table 10. Estimated annual production and gross value of logging products from the Bacuit Bay drainage basin, 1987-91

Product	Amount (m^3)	Value (x $1000)
Export logs	7,900	822
Export veneer	3,500	665
Export lumber	3,600	702
Domestic logs/lumber	7,900	332
Veneer log cores	900 (4,700 cores)	56
Total	23,800	2,577

Note: Primary forest will be completely logged by 1991.

Logging Industry

Annual production and gross revenue estimates for 1987-91 are listed in Table 10. These values were calculated using prices and estimated production data, including wastage estimates, listed in Table C-3 (Appendix C). Under Option 1, the logging ban would reduce gross revenue from logging the Bacuit Bay drainage basin to 0. Under Option 2, gross revenue is found by multiplying the sum of values listed in Table 10 by 5 years.

Gross revenue and present value of gross revenue using both 10 and 15 percent discount rates were calculated for the logging sector as well as for tourism and fisheries. The results of these calculations are shown in Table 11.

The PTPI logging concession is planned to operate on a sustainable yield basis, with a timber rotation of 85 years and a cutting cycle of 42 years. Assuming the threats to this operational plan are resolved and tree growth follows the expected pattern, no new production from the Bacuit Bay drainage basin would be expected until 42 years after logging was begun in 1985. Although the economic time horizon considered here is limited to 10 years, significant increases in the future value of wood products in real terms would have to occur over the 42-year

Table 11. Gross revenue and present value of gross revenue (x $1000) at 10 and 15% discount rates for logging industry production from Bacuit Bay drainage basin, 1987-96

	Gross revenue	Present value 10%	Present value 15%
Option 1	0	0	0
Option 2	12,885	9,769	8,639

Note: Production ends in 1991 as the area will be completely logged by then.

period to allow the expected revenue from the sale of these wood products to have an economically significant present value using a 10 percent discount rate.

SUMMARY OF ECONOMIC ANALYSIS

Through economic analysis, the gross revenue and the present value of the gross revenue have been estimated for each of the three sectors under Options 1 and 2 for the period 1987-96. A number of assumptions have been made and are explained in the text. The present values were calculated using both 10 and 15 percent discount rates. A summary of the results from all three sectors is presented in Table 12.

The results are striking. The gross revenue under Option 1 is more than double that under Option 2. Since Option 1 will prevent further logging in the Bacuit Bay drainage basin, the gross revenue from logging under Option 1 is 0. Fisheries and tourism, however, generate large and continuing benefits. Benefits from tourism are expected to grow over time as demand and market increase, while benefits from fisheries will remain constant. In contrast, Option 2, which allows continued logging, generates smaller and decreasing benefits. After 5 years, the

Table 12. Tourism, fisheries, and logging industries: Ten-year sum of gross revenue, present value of gross revenue (x $1000) using 10 and 15% discount rates

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	47,415	8,178	39,237
Fisheries	28,070	12,844	15,226
(with tuna)	(46,070)[a]	(21,471)	(24,599)
Logging	0	12,885	-12,885
Total	75,485	33,907	41,578
Present Value (10%)			
Tourism	25,481	6,280	19,201
Fisheries	17,248	9,108	8,140
(with tuna)	(28,308)[a]	(15,125)	(13,183)
Logging	0	9,769	-9,769
Total	42,729	25,157	17,572
Present Value (15%)			
Tourism	19,511	5,591	13,920
Fisheries	14,088	7,895	6,193
(with tuna)	(23,122)[a]	(13,083)	(10,039)
Logging	0	8,639	-8,639
Total	33,599	22,125	11,474

[a]Tuna revenues (in parentheses) are not used to calculate the totals.

logs will be depleted, as well as a significant part of the tourism and fishery sectors. The modest logging revenue generated under Option 2 is more than offset by the decreased income from tourism and fisheries.

The present value of gross revenue under Option 1, calculated using a 10 percent discount rate, is almost double that under Option 2. Since all logging production occurs during the first 5 years, the effect of the higher 15 percent discount rate on the gross revenue generated from this industry is relatively slight. In comparison, most of the tourism revenue is predicted to accrue during the post-5-year tourism expansion period; therefore, tourism revenue is reduced proportionately more than the logging revenue by the 15 percent discount rate. Even at the higher 15 percent discount rate, total present value of gross revenue under Option 1 is still 1.5 times larger than that under Option 2.

SENSITIVITY ANALYSIS

The preceding economic analysis is based on predictions of economic performance for each industry under Option 1 (a logging ban) and Option 2 (continued logging). In order to test the sensitivity of the results to variations in the value of key parameters, three alternative scenarios (A, B, and C) were created. Scenario A tests the sensitivity of the results to the predicted rates of revenue loss from tourism and fisheries due to increased sedimentation. Scenario B tests the sensitivity of the original results to the increase in tourism revenue due to the predicted expansion of the tourism industry during the last 5 years of the analysis period. Scenario C combines the effects of Scenarios A and B and therefore tests the sensitivity of the original results both to predicted levels of damage due to logging and to predicted tourism expansion. As in the previous analyses, results are presented for gross revenue, and present value of gross revenue for both 10 and 15 percent discount rates.

Scenario A

The effect of Scenario A is to reduce the predicted damage to tourism and fisheries attributed to logging in the original analysis. This results in increased gross revenues for these two industries under Option 2 (continued logging). In order to calculate the gross revenue stream for Scenario A, the yearly losses for tourism and fisheries were examined separately. In the original analysis under Option 2, the sediment input and resulting damage to the fishery industry are predicted to vary each year (Table B-2, Appendix B). Scenario A reduces the annual damage (revenue loss) to tourism and fisheries to half that used in the original analysis.

For example, in the original economic analysis of the tourism industry, a 10 percent yearly revenue reduction (1988-91), plus the loss after 1991, of all tourism revenue except the "Other" category was predicted under Option 2. For Scenario A (Option 2), 1986 tourism revenue is reduced by only 5 percent per year over the entire 10 years. Thus, annual tourism revenue declines at a slower rate in Scenario A (Option 2) than in the original analysis. In addition, revenue from all three tourism sources is included in Scenario A for the entire 10-year time horizon. A summary of the results of Scenario A is presented in Table 13.

Despite reducing the predicted rate of damage by half due to sedimentation (as reflected in increased Option 2 gross revenue for tourism and fisheries), the results are consistent with those of the original analysis. In each case, the Option 1 total is larger than the Option 2 total, indicating that a logging ban would produce greater gross revenue than would occur if logging is allowed to continue. Even given a 15 percent discount rate, the present value of gross revenue under Option 1 is nearly $8 million greater than under Option 2.

Scenario B

Scenario B's major impact is on testing the sensitivity of the original results to more modest tourism development. Scenario B uses the same predictions used in the original analysis, except that under Option 1 (logging ban), the projected tourism expansion is not included. Tourism revenue is held constant at the 1987 rate of about $2.2 million per year for the

Table 13. Sensitivity analysis under Scenario A, 1987-96, ten-year totals (x $1000)

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	47,415	**14,998**	**32,417**
Fisheries	28,070	**16,972**	**11,098**
Logging	0	12,885	-12,885
Total	75,485	**44,855**	**30,630**
Present Value (10%)			
Tourism	25,481	**9,587**	**15,894**
Fisheries	17,248	**11,541**	**5,707**
Logging	0	9,769	-9,769
Total	42,729	**30,897**	**11,832**
Present Value (15%)			
Tourism	19,511	**7,709**	**11,802**
Fisheries	14,088	**9,563**	**4,525**
Logging	0	8,639	-8,639
Total	33,599	**25,911**	**7,688**

Note: All values are in 1986 U.S. dollars. Bold figures reflect changes from the original analysis. All other figures are the same as in Table 12. Fisheries figures do not include purse-seine (tuna) catch.

entire 10-year period. As shown in Table 14, gross tourism revenue in Scenario B (Option 1) is less than half of the value shown for the original analysis (Table 12).

The results of the Scenario B sensitivity analysis show that regardless of the tourism expansion, the gross revenue under Option 1 (logging ban) is larger than under Option 2 (continued logging).

Scenario C

Scenario C combines the effects of Scenarios A and B. As in Scenario A, the first effect of the Scenario C sensitivity

Table 14. Sensitivity analysis under Scenario B, 1987-96, ten-year totals (x $1000)

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	**22,010**	8,178	**13,832**
Fisheries	28,070	12,844	15,226
(with tuna)	(46,070)	(21,471)	(24,599)
Logging	0	12,885	-12,885
Total	**50,080**	33,907	**16,173**
Present Value (10%)			
Tourism	**13,334**	6,280	**7,054**
Fisheries	17,248	9,108	8,140
(with tuna)	(28,308)	(15,125)	(13,183)
Logging	0	9,769	-9,769
Total	**30,582**	25,157	**5,425**
Present Value (15%)			
Tourism	**10,891**	5,591	**5,300**
Fisheries	14,088	7,895	6,193
(with tuna)	(23,122)	(13,083)	(10,039)
Logging	0	8,639	-8,639
Total	**24,979**	22,125	**2,854**

Note: All values are in 1986 U.S. dollars. Bold figures reflect changes from the original analysis. All other figures are the same as in Table 12. Fisheries figures do not include purse-seine (tuna) catch.

analysis is to reduce the predicted sedimentation damage due to logging by 50 percent, thus "allowing" larger revenues from tourism and fisheries under Option 2 (continued logging). The second effect of Scenario C is to exclude the tourism expansion planned for the final 5 years of the time horizon, exactly as in Scenario B. The cumulative effects of these changes are to decrease the gross revenue under Option 1 (logging ban) while increasing gross revenue under Option 2 (continued logging), relative to the results of the original analysis (Table 15).

Table 15. Sensitivity analysis under Scenario C, 1987-96, ten-year totals (x $1000)

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	**22,010**	**14,998**	**7,012**
Fisheries	28,070	**16,972**	**11,098**
Logging	0	12,885	-12,885
Total	**50,080**	**44,855**	**5,225**
Present Value (10%)			
Tourism	**13,334**	**9,587**	**3,747**
Fisheries	17,248	**11,541**	**5,707**
Logging	0	9,769	-9,769
Total	**30,582**	**30,897**	**-315**
Present Value (15%)			
Tourism	**10,891**	**7,709**	**3,182**
Fisheries	14,088	**9,563**	**4,525**
Logging	0	8,639	-8,639
Total	**24,979**	**25,911**	**-932**

Note: All values are in 1986 U.S. dollars. Bold figures reflect changes from the original analysis. All other figures are the same as in Table 12. Fisheries figures do not include purse-seine (tuna) catch.

The results of the Scenario C sensitivity analysis are based on the assumption of a 50 percent reduction in the predicted yearly rate of sedimentation damage to fisheries and tourism if logging is allowed to continue. In addition, no growth in the tourism industry is allowed, despite implementation of a logging ban. Even with these unlikely constraints, the gross revenue under Option 1 (logging ban) is still $5 million greater than under Option 2 (continued logging). At a 10 percent discount rate, the present values of the two options are roughly equal. At a 15 percent discount rate, Option 2 has a marginally larger present value (about $1 million, or 4 percent). For the sensitivity analysis, the fishery values do not include the tuna catch. However, even adding a small portion of the $18 million tuna catch to the gross revenue of fisheries would make the Option 1 present value larger than that under Option 2, even using the 15 percent discount rate.

Implications of the Sensitivity Analysis

Both the original economic analysis and the sensitivity analysis yield the same results. The Option 1 totals are larger than those of Option 2. Only under the unlikely and restrictive conditions imposed by Scenario C is the Option 2 present value marginally larger than that of Option 1 when using the 15 percent discount rate.

CONCLUSIONS FROM THE QUANTITATIVE ANALYSES

Based on the results of the ecological and economic analyses, the following can be concluded:

- Option 1, the ban on logging in the Bacuit Bay drainage basin allowing continued resort and fisheries development is preferred. It generates larger economic and environmental benefits.

- The tourism industry in El Nido appears to have a relatively low environmental impact and can continue to yield large and growing economic benefits to the economies of Palawan and the Philippines.

- The fisheries industry is important as a source of protein for the Philippines as well as a foreign exchange earner. Implementation of Option 1 will help to ensure the future availability of this resource.

- Given the large size of the logging concession, the local ban on logging in the Bacuit Bay drainage basin (Option 1) should not have a major financial impact on the concessionaire.

- The conclusions of the quantitative economic analyses are relatively robust. Significant departures from predicted revenues do not alter the conclusions.

So far, the analysis has been quantitative in nature and has focused on the ecology of Bacuit Bay and the coastal watershed and compared revenues generated by each economic sector under Options 1 and 2. The analysis has relied on numerous assumptions about the characteristics and behavior of both the ecological and economic systems. These have been clearly identified and their use justified. The conclusions based on the quantitative analysis are unambiguous; however, it may also be helpful to consider some qualitative dimensions of the two development options.

Additional socioeconomic dimensions include income distribution, job creation, intergenerational equity, and sustainable development. Qualitative environmental considerations include flood control and wildlife habitat destruction in relation to species preservation. These are considered in the last section.

QUALITATIVE SOCIAL, ECONOMIC, AND ECOLOGICAL CONSIDERATIONS

Intergenerational Equity

The goal of the economic analysis is to determine which of the two development options, 1 or 2, will maximize (1) combined gross revenues and (2) present values of the gross revenue stream of tourism, fisheries, and logging over the 10-year period of 1987-96.

The foregoing results show that implementation of a logging ban in the Bacuit Bay drainage basin (Option 1) would generate gross revenues of about $40 million larger than if logging continues (Option 2). Based on gross revenues alone, pursuing a ban on logging is clearly the most profitable option for the Philippine government.

Present value analysis is used to take into account the time factor in revenue production and the existence of private and social discount rates (Hufschmidt et al. 1983). For the El Nido case, present values are calculated by reducing the value of the yearly gross revenue stream by an appropriate discount rate (see Appendix C for details). For the Philippines, discount rates between 10 and 15 percent are commonly used in benefit-cost analyses of government development projects. A lower 10 percent discount rate gives greater weight to long-term benefits and costs and may be considered closer to a "social" as opposed to a "private" discount rate.

It has been argued that the use of near 0 discount rates may be appropriate when calculating present value of natural resources (Finney and Western 1986). This argument is based on consideration of economic time horizons that are long in relation to the human life span. By definition, renewable natural resources such as fish may be exploited indefinitely if they are not harvested or damaged at a rate higher than maximum sustainable yield. The conflict between purely economic priorities (e.g., maximizing present value) and socioecological priorities (sustaining resource yield) is illustrated by examining the present value of renewable resources to be harvested 30, 50, or 100 years in the future. The present value of such future harvests rapidly approaches 0, even when moderate discount rates are used.

Despite these problems, economists are hesitant to use very low discount rates because such low rates imply social indifference to present versus future benefits and costs. Such indifference contrasts with observed human behavior that generally places a higher value on present as compared to future costs or benefits. One way to clarify the limitations of present value analysis and approximately reflect longer run concerns would be to examine the distribution of benefits and costs among individuals and between generations of people in the Bacuit Bay region.

As presently carried out, the economic analysis does not account for the distributional aspect of resource exploitation with respect to time (i.e., profits taken today from resource exploitation may or may not be passed on to future generations). In the case of Bacuit Bay, for example, many individuals potentially benefiting from future fish catch or potentially hurt by lack of fish catch in the future may not be alive today to enjoy any possible benefits (e.g., jobs) from the logging operations that are predicted to eventually destroy Bascuit Bay fisheries. In this respect, the distribution of benefits (fish catch) between generations will not be equitable under Option 2. The analysis has been based on the theory of maximum social welfare and economic efficiency, which uses the traditional Pareto criterion whereby the preferred option is the one by which at least one more person benefits without making another person worse off. In the Philippines, the logging industry is considered relatively exploitative, leaving little sustained economic growth behind (Tadem et al. 1984). The benefits accrued from logging will be unlikely to create future income generation opportunities for the El Nido residents who are highly dependent on marine resources. Since these predictable inequities in intergenerational distribution of costs and benefits are important to El Nido residents, they should be considered in the socioeconomic evaluation of the alternative development options.

One possible alternative development strategy is to focus on preservation of future economic options rather than on the generation of present and future benefits and their distribution.

With this approach, the preferred development alternative is the one that maintains sustainable resource utilization in perpetuity. In the Bacuit Bay case, this approach would favor Option 1, the logging ban, with continued development of fisheries and tourism (see Warford 1986 and Barbier 1987 for discussions of sustainable economic development). It appears unlikely that sustainable use of forest resources is attainable due to lax enforcement of forestry regulations.

Income Distribution

Logging, a capital-intensive industry, appears to offer limited promise for equitable intergenerational income distribution. Many potential resource development opportunities will be damaged by continued logging. In addition, significant differences exist in present income distribution within each of the three industries. In 1980, for example, wood products made up more than 8 percent of the value of all Philippine exports; however, the lumber and wood processing industry employed less than 1 percent of the Philippine labor force. In contrast, the fish products made up less than 1 percent of the value of total Philippine exports, but fisheries workers accounted for about 5 percent of the work force (FAO 1986; Tadem et al. 1984). Although the value of annual production per employee is much higher in logging than in fisheries, the wages are similar in both industries, about $1 per day. Thus, the share of industry revenue received per employee appears much higher in fisheries than in the logging industry. Fox (1987) reports that municipal (artisanal) and many commercial fishermen generally receive from 60 to 100 percent of the profits (returns to labor) generated. Data are not available upon which to base firm conclusions. However, it appears that the short-term returns from logging are distributed less equitably than the longer term return from tourism and fisheries.

Employment and Job Training

A second factor to consider when comparing the development options is job training in the three industries. The logging industry hired about 100 El Nido residents as laborers in the logging camp. The employees are generally farmers who work for wages while leaving their fields fallow. After 5 years with the logging operation, these employees will have gained some specialized training for logging work but will lose their jobs when the company moves on to a new location. According to employees, company policy has been to hire new, unskilled laborers in each new logging camp rather than pay higher wages for skilled workers. In addition, some employees would be reluctant to move to a new logging camp far from their families and farms. Managerial, staff, and heavy equipment operation positions are filled primarily by nonlocal workers. In contrast, commercial fisheries and tourism provide training for lifetime employment. The tourism industry provides employment for about 100 males and females. The logging industry generally hires males only. Almost all male and many female residents of the Bacuit Bay coast are involved in artisanal fishing, either directly through active fishing or secondarily through fish preparation and processing (e.g., dried fish, fish paste and fish sauce preparation, or marketing the catch). Artisanal fishermen account for almost 10 percent of the total Bacuit Bay fisheries catch.

A number of significant, qualitative externalities should also be considered in evaluating the two alternative development options.

Infrastructure Improvement. Both logging and tourism development involve capital investments in infrastructure that may provide social benefits. The construction and maintenance of primary roads by the logging industry could save the government money if the roads are built in locations suitable for future provincial roads. Inspection of the roads built in El Nido indicates that they are poorly constructed with an estimated usable life span of only 1 or 2 years. Unfortunately, construction of logging roads provides swidden farmers access to new forestland. In contrast, the tourism industry has made a significant contribution to local infrastructure by investing in structural improvements to the government airplane landing strip and the hospital serving El Nido.

Flooding. Villagers living downstream from the logging concession reported that the incidence and height of river flooding increased dramatically in 1985 and 1986 compared to previous years. This resulted in lowland flooding and damage to existing structures. The villagers assumed that this was due to logging of upper hillslopes since the floodwaters were also abnormally muddy. Since the amount of rainfall during 1986 was not abnormally high, this could indicate increased runoff due to removal of trees, forest canopy, and soil exposure by road-building and perhaps an increase in the river stage height due to channel infilling. Further logging may exacerbate this problem.

Loss of Wildlife by Habitat Loss. Loss of wildlife species diversity due to habitat loss is a well-documented process (Suparto 1978). Forest cutting will undoubtedly increase the rate of wildlife loss in the concession area. Although little is known about Philippine endemic species, the monkeys, the Palawan bearcat, and the Philippine eagle will perhaps be the most seriously affected since they depend directly on the forest for habitat. The stocks of other rare species such as the native river otter would be deleteriously affected by habitat and trophic links to the forest ecosystem. Option 1, the logging ban, will help maintain the Bacuit Bay marine and terrestrial ecosystems for the future. The value of wildlife is likely to increase in the future as such resources become scarcer and demand for them grows. As such, the "opportunity cost" of preservation of unique or scarce habitats may be a small price to pay for potentially large future benefits. The basic natural history of the animals listed here should be studied so that potential damage to resources and habitat critical to their survival can be avoided.

The conclusions from both gross and present value analysis agree with results of a qualitative examination of inter-generational equity, present income distribution, employment, infrastructure improvement, and effects on wildlife. In order for the Philippine government to receive the maximum present value of the gross revenue stream and to maintain equitable socioeconomic growth and preservation of valuable wildlife resources, Option 1 (ban logging in the drainage basin) is the clear choice.

IMPLICATIONS FOR RESOURCE MANAGEMENT DECISIONS

The results of the ecological and economic analysis of the development alternatives for the Bacuit Bay area in the Philippines have implications for coastal development in many other countries. Specifically, the results indicate that sedimentation pollution can seriously degrade coastal marine fisheries in the tropics. Therefore, governments concerned with maintaining a sustainable marine fisheries catch might consider increasing the role of sedimentation pollution monitoring and control, both for rivers and the marine coastal zone. Many countries are now at risk from sedimentation pollution specifically due to logging that may already be creating significant resource use conflicts (Table 16).

In these countries, research efforts should be concentrated on specified areas with a known or suspected value to the fisheries trophic system. More basic research needs to be carried out to investigate the direct and indirect effects of coastal sedimentation pollution on commercially important

Table 16. Countries with tropical marine resources potentially at risk from sedimentation pollution due to logging

Africa	America	Asia	Oceania
Kenya	Bahamas	Burma	Australia
Madagascar	Belize	China	Fiji
Mozambique	Columbia	India	P.N. Guinea
Tanzania	Costa Rica	Indonesia	Samoa
	Dominican Rep.	Japan	Solomon Is.
	Fr. Guiana	Malaysia	Vanuatu
	Guatemala	Philippines	Fr. Polynesia
	Guyana	Sri Lanka	
	Haiti	Thailand	
	Honduras		
	Jamaica		
	Mexico		
	Nicaragua		
	Panama		

tropical marine fish species. High priority should be given to studying possible effects on valuable fish species such as tuna, which have traditionally been considered entirely pelagic (and therefore not affected by coastal pollution), but which may in fact be dependent on the nearshore marine environment for at least part of their life cycle.

From the perspective of coastal zone development planning, this work provides several valuable insights. First, this work shows that clear and useful answers may be obtained to development questions with modest commitments of time and money. The results of the study indicate that continued logging of the drainage basin will result in environmental damage and high economic costs compared to the effects of the alternative: prohibiting further logging in the specified area. Instituting a ban on future logging in the Bacuit Bay drainage basin is the preferred alternative.

Second, the results of the study suggest that valuable information and guidance can be obtained from combining integrated ecological research and economic evaluation. The primary feature of the integrated approach is consideration of the entire area of interest, in this case the coastal zone, to be composed of a series of linked ecosystems extending from mountain top to sea floor, and regards the dynamic links between these ecosystems to be equally as important as the processes occurring solely within each ecosystem. Natural systems are linked in this way in the real world; therefore, by conceptualizing the coastal zone or other biomes in this fashion, a more realistic scenario is created from which to build simplified predictive models. For this reason, the accuracy of predictions based on such models will be enhanced.

The third important message from this work is that the integrated ecological and economics approach is potentially applicable to similar situations in other regions. In light of Repetto's (1987) conclusion that many developing nation governments appear to be subsidizing their logging industries, the continuation of logging in other multiple resource conflict areas of the Philippines and in other tropical developing countries might benefit from a similar evaluation and analysis. The appropriate costs and benefits can then be identified and alternative development options explored.

The results of this study cannot be applied to similar resource conflicts without taking into account the peculiarities of each new situation. Obviously, not all areas will be equally endowed with natural resources with such a high intrinsic level of value for tourism, fisheries, or other competing industries. In addition, the ecological response of the biotic component (plants and animals) of different coastal ecosystems subjected to the same level of stress from sedimentation or other forms of pollution may differ due to differences in physical factors (e.g., annual rainfall, soil types, wave action, and local ocean currents). In order to be cost-effective, the level of detailed study required before development planning decisions are made should be based on the potential value of the threatened ecosystems. The higher the potential value of a given resource, the greater the research effort should be to describe the functioning of the ecosystems involved, their linkages, and potential threats to their existence. An initial reconnaissance study may be useful in determining the potential value of the resources involved.

Economic valuation techniques can be used to value a wide variety of resources that previously were not accounted for in a quantitative manner. Biologists, environmental managers, and planners should become familiar with these techniques and to apply them to the analytical process so that their voices will be heard and their recommendations will become more meaningful to decision-makers.

APPENDICES

PRECISION OF DATA AND CALCULATIONS

The quantitative results presented are based primarily on data obtained during 18 months of fieldwork by the first author. Some secondary data have also been used where indicated. Because of the level of uncertainty associated with many of the extrapolations, most numbers presented have been rounded off. The calculations and data lists that follow in Appendices A to C may contain more precise values that have not been rounded off. The values are presented in this format to be compatible with the calculations and do not represent an actual higher level of precision.

APPENDIX A

SUMMARY OF TERRESTRIAL METHODS

The terrestrial methods were designed to measure rainfall volume, surface erosion rate, river discharge, and suspended sediment load. (Complete details on site selection and data collection methodology may be found in Hodgson, in prep. Some of the problems associated with designing land management monitoring programs are discussed by Harper et al., 1987.) Surface erosion was measured using three adjacent 8 m^2 plots located on a primary forest stand, a cut forest stand, and on a tertiary road. Since all three plots were located on the same hillside, physical conditions such as soil characteristics and percent slope were similar. Runoff from each enclosed plot was collected in barrels and the volume measured. Subsampling was used to determine the sediment concentration. Plot parameters were: slope = 36%, length = 4.82 m. Total 1986 rainy season surface erosion rates were (dry weight) 13.5, 58.1, and 3210.8 g/m^2 for the primary forest, cut forest, and road plots, respectively.

The erosion plot results were used to estimate average surface erosion values for primary forest, cut forest, and logging road areas by adjusting them with the Universal Soil Loss Equation (USLE), length-slope (LS) nomogram (Wischmeier and Smith 1978). These results were further adjusted for tropical conditions and steep slopes following the work of Liang et al. (1987). Liang et al. found that the USLE grossly overestimates soil loss when extrapolating to steep slopes with tropical soils. In the present case, an LS factor of 4.4x was used to translate plot erosion to mean concession conditions (slope = 30%, average slope length = 30 m), thus reducing the USLE, LS nomogram estimate by a factor of 8. No attempt was made to use the complete USLE as an alternative estimate of erosion based on soil and other parameters, since problems have not yet been overcome with its use under tropical conditions (Bureau of Soils 1986).

Rainfall volume was measured at each erosion plot, at the river gage, and at the town of El Nido. River stage (height) was measured with a continuous recording analog gage from January to March and then daily with a nonrecording gage until the end of 1986. River flow rate was measured with a Price current meter. Suspended sediment load was measured daily with a US DH-59 depth integrating sampler and during rising floods with a serial bank of US U-59 single stage samplers (Guy and Norman 1970).

Land use was measured by analyzing stereo black-and-white and nonstereo color aerial photographs taken between April 1985 and January 1986, supplemented with ground truth surveys.

In order to estimate the total discharge from the Bacuit Bay drainage basin due to logging, the Manlag River sediment discharge figure is increased by 30 percent to account for the 30 percent of logged concession area that the Manlag River does not drain. The contribution of natural erosion is then subtracted from this value. Natural erosion from uncut forest accounted for 10 percent of total surface erosion (Table 5). If sediment discharge is assumed to be proportional to surface erosion from uncut forest, then the 30 percent increase discussed here can be reduced by subtracting the 10 percent of discharge attributable to erosion from uncut forest. The Manlag River discharge is thus increased by a factor of 20 percent in order to arrive at an estimate of discharge for the entire basin due to logging.

APPENDIX B

SUMMARY OF MARINE METHODS

Biological

Eight 50 m permanent transects were established on the reefs in Bacuit Bay. One of these, located on Dilumakad Island reef near the northern bay entrance, was designated as a control reef. The transects were surveyed in January and December 1986. The length of transect passing over all attached organisms was measured using a modification of the chord-intercept technique (Loya 1972). The length and width of coral colonies and size of any dead patches (partial mortality) were also recorded. All corals were identified to species level. Fish were counted visually, and a record was made of species composition, abundance, and estimated fork length in three replicate runs along a 3 m wide belt above each coral transect line. Fish biomass was calculated from estimated fork length using unpublished conversion coefficients developed by the Hawaii Cooperative Fisheries Unit, Honolulu, Hawaii.

In order to predict coral cover losses due to sediment damage over the 10-year time horizon, a baseline natural growth rate of 3.6 percent/yr was used based on data presented by Hughes and Jackson (1985). The natural increase of fish biomass due to growth and recruitment was assumed to equal fish catch and natural mortality.

Physical

Water temperature, salinity, turbidity, wave height, and wind speed were measured every two weeks at all transect stations. Sediment deposition was monitored using four replicate

Table B-1. Area of bay zones, corresponding sedimentation rates, and totals (minus calcium carbonate fraction) from May to December

Station	Area (km^2)	Rate (1000 mt/km^2)	Total (1000 mt)
1	0.40	2.5	1.0
2	2.60	5.8	1.5
3	0.93	2.2	2.1
4	0.58	2.8	1.6
5	0.28	71.4	20.0
6	0.40	10.5	4.2
7	5.15	4.1	21.0
8	109.66	0.7	76.8
Total	120.00		128.2

traps at each station. Traps were designed based on recommendations of Gardner (1980) concerning trap efficiency. Trapped sediment was collected monthly for 12 months, double-washed in fresh water, dried at 60°C in an oven, and weighed. Subsamples were analyzed for particle size and percent calcium carbonate. The calcium carbonate fraction was assumed to be of marine origin and was subtracted from the total weight of each sample. Total sediment deposition was calculated by first dividing the bay into zones of area corresponding to the respective sediment deposition measured at the transect located in each zone (Table B-1). The deposition rate in mt/km^2 was then multiplied by the area for each transect zone. To make a valid comparison between the rainy season (May to December), river sediment output, and sediment deposition in the bay, the January to April deposition was subtracted from the total bay sediment deposition (172,000 mt), leaving 128,000 mt.

Fish catch calculated by regression relationships from reductions in coral cover and diversity from 1986 to 1996 is shown in Table B-2.

Table B-2. Predicted sediment deposition due to logging (based on estimated river sediment discharge), living coral cover, number of coral species, and fish catch between 1986 and 1996

Year	Sediment deposition (1000 mt)	Coral cover (%)	Coral species (#)	Fish catch (1000 mt)
1986	41.4	46	50	3,147
1987	105.2	44	47	2,924
1988	169.0	41	45	2,591
1989	232.8	36	42	2,186
1990	296.6	30	40	1,749
1991	360.4	22	38	1,325
1992	360.4	15	37	1,003
1993	252.3	9	36	760
1994	176.6	6	35	669
1995	123.6	3	34	613
1996	86.5	1	33	581

APPENDIX C

SUMMARY OF ECONOMIC ANALYSIS METHODS

Tourism

Calculation of Gross Revenue for Resort 1

The following example demonstrates the calculation of gross revenues for Resort 1 from 1987 to 1991. (Data are from Table 6.) Yearly revenue for the 5-year period is found by multiplying the capacity (60 people) by the mean occupancy rate (65 percent), then by the daily rate ($100 per day), and finally by 365 days per year:

$$60 \times 0.65 \times 100 \times 365 = \$1,423,500$$

In addition, for Resort 1 only, there is a one-time $250 fee per person. To calculate the number of guests per year, divide 365 days per year by the mean length of stay (10 days), multiplied by the mean occupancy (39):

$$(365/10) \times 39 = 1424 \text{ guests/yr}$$

When multiplied by $250 per guest, the total is $355,875 per year in lump-sum fees. This figure, added to the daily rate total, amounts to $1,779,375 per year, and multiplied by 5 years totals $8,896,875 as shown rounded off to the nearest $1000 in Table 7.

The gross revenue and present value of gross revenue streams (10 and 15 percent discount rates) are shown in Table C-1.

Table C-1. Tourism gross revenue and present value of gross revenue per year using 10 and 15% discount rates (x $1,000)

	Gross revenue		Present value 10%		Present value 15%	
	Option		Option		Option	
Year	1	2	1	2	1	2
1987	2,201	1,970	2,001	1,792	1,913	1,713
1988	2,201	1,773	1,819	1,465	1,664	1,341
1989	2,201	1,577	1,653	1,186	1,447	1,037
1990	2,201	1,420	1,503	970	1,258	812
1991	2,201	1,278	1,366	795	1,094	635
1992	7,282	32	4,110	18	3,148	14
1993	7,282	32	3,737	15	2,737	12
1994	7,282	32	3,397	14	2,380	10
1995	7,282	32	3,088	13	2,070	9
1996	7,282	32	2,807	12	1,800	8
Total	47,415	8,178	25,481	6,280	19,511	5,591

Marine Fisheries

Table C-2. Fisheries gross revenue and present value of gross revenue per year using 10 and 15% discount rates (x $1000)

	Gross revenue		Present value 10%		Present value 15%	
	Option		Option		Option	
Year	1	2	1	2	1	2
1987	2,807	2,608	2,553	2,371	2,441	2,268
1988	2,807	2,311	2,320	1,910	2,122	1,747
1989	2,807	1,949	2,109	1,464	1,846	1,281
1990	2,807	1,560	1,918	1,065	1,605	892
1991	2,807	1,182	1,743	734	1,396	588
1992	2,807	894	1,584	505	1,213	386
1993	2,807	678	1,440	348	1,055	255
1994	2,807	597	1,309	279	918	195
1995	2,807	547	1,190	232	798	155
1996	2,807	519	1,082	200	694	128
Total	28,070	12,845	17,248	9,108	14,088	7,895

Logging Industry

Remaining primary forest is 37 km^2 with a mean harvestable timber volume of 4300 m^3/km^2. Predicted harvest time is 5 years. Yearly production for the 5 years is calculated below.

$$(37\ km^2 \times 4300\ m^3/km^2)/5\ yr = 31{,}820\ m^3/yr$$

Wood product revenues are based on the breakdown of total production shown in Table C-3.

Table C-3. Timber production, percent waste, and market prices (FOB) of PTPI logging concession wood products based on a harvest of approximately 32,000 m^3/yr from the Bacuit Bay drainage basin

Product	Total (%)	Waste (%)	Amount (m^3)	Price/m^3 ($)
Export logs	25[a]	0	7,900	104[b]
Export veneer	25	45[c]	3,500	190
Export lumber	25	55	3,600	195
Domestic logs/lumber	25	0	7,900	42
Veneer log cores	From veneer logs	0	900	62

[a]Maximum allowable by Philippine law

[b]Prices are U.S. dollars from Krutilla (in prep.) and IBRD/World Bank (1986), and wastage estimates are from Brion (1982).

[c]Veneer log core production is based on one 20 cm diameter core (pole) produced per veneer log.

The gross revenue and present value of gross revenue streams for the logging industry are shown in Table C-4.

Table C-4. Logging gross revenue and present value of gross revenue using 10 and 15% discount rates (x $1,000)

	Gross revenue		Present value 10%		Present value 15%	
	Option		Option		Option	
Year	1	2	1	2	1	2
1987	0	2,577	0	2,343	0	2,242
1988	0	2,577	0	2,130	0	1,949
1989	0	2,577	0	1,936	0	1,694
1990	0	2,577	0	1,760	0	1,473
1991	0	2,577	0	1,600	0	1,281
1992	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
Total	0	12,885	0	9,769	0	8,639

APPENDIX D

ABBREVIATIONS

All measurement abbreviations used are in metric units.

Measurement Units

cm	centimeter
g	gram
h	hour
km	kilometer
l	liter
m	meter
mg	milligram
mm	millimeter
mo	month
mt	metric ton
yr	year

Special Units

AAC	annual allowable cut (cubic meters of logs)
Dbh	diameter of tree at breast height
H'	Shannon-Weaver diversity index
LS	length and slope factors of USLE
USLE	Universal Soil Loss Equation

Organizations

BFD	Bureau of Forestry Development
FAO	Food and Agriculture Organization, United Nations
BIOTROP	SEAMEO Regional Center for Tropical Biology, Bogor, Indonesia
PIADP	Palawan Integrated Area Development Project
PTPI	Pagdanan Timber Products Incorporated

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