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TOWARD ENVIRONMENTALLY AND SOCIALLY SUSTAINABLE DEVELOPMENT

ECONOMIC ANALYSIS OF INDONESIAN CORAL REEFS

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Foreword

Coral reefs and their associated marine life are one of the greatest natural treasures of Indonesia. Furthermore, the richness and uniqueness of these ecosystems makes them a global asset. However, these reefs are increasingly being destroyed by a range of threats, including: poison fishing, blast fishing, sedimentation and pollution, overfishing and tourism development. This has prompted the Indonesian government to set up a program for Coral Reef Rehabilitation and Management (COREMAP). The World Bank is one of the key external institutions supporting this effort, together with the Global Environment Facility and other donors. Within this context, this study provides insights and analytical approaches which support the Government of Indonesia and the World Bank in their COREMAP undertakings.

This study analyses the often powerful economic forces created by short-term profits to individuals that lead to the observed destructive patterns of coral reef use. Measures for coral reef protection are often presumed to conflict with economic development, and are said to require a sacrifice of economic growth. However , this study shows that this perception stems mainly from a failure to recognize the magnitude of costs to the present and future economy resulting from reef degradation.

The study is particularly useful since it integrates a social-welfare based economic analysis and a stakeholder analysis with a discussion on options for rational coral reef management. It fits within the growing World Bank effort of promoting sustainable use of the environment and natural resources through integration of conservation and development. Also, it supports the International Coral Reef Initiative, launched in 1995 by a partnership of countries and international organizations including the World Bank. The study assists the Government of Indonesia in the implementation of its Biodiversity Action Plan which calls for conservation and sustainable utilization of biodiversity.

We are pleased that this report is being published in a format which facilitates wide dissemination as the issues it discusses are of broad interest. We hope that this study can help reverse the current trends and save coral reefs around the globe from severe degradation.

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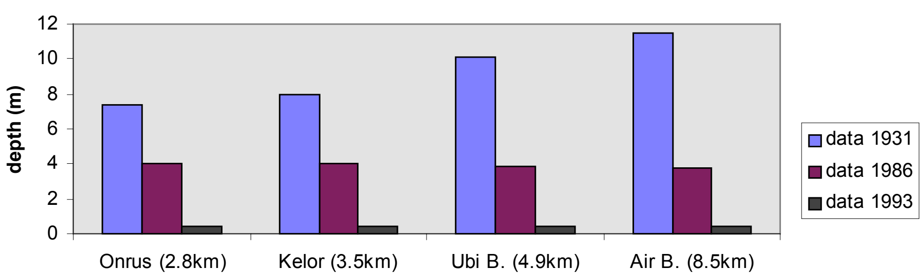
Executive Summary

Indonesian Coral Reefs - A Precious but Threatened Resource

Coral reefs and their associated marine life are one of the greatest natural treasures of Indonesia. Both their quality and their quantity are impressive: Indonesia is located at the center of the world's coral reef diversity and, with some 75,000 km^2 of coral,[i] it holds approximately one-eighth of the world's coral reefs. Coral reefs form the core of the livelihood for hundreds of thousands of Indonesian subsistence fishers, and a source of food security in times of agricultural hardship. They also provide a natural barrier against wave erosion, thereby protecting coastal dwellings, agricultural land and tourism beaches. They are a potential source of foreign exchange from divers and other marine tourists. In addition, because of their unique biodiversity, they are of great interest to scientists, students, pharmaceutical companies, and others. These and many other functions give coral reefs an important and growing value.

Despite this, the quality of coral reefs in Indonesia is declining rapidly. Even remote reefs in unpopulated areas are not free from man-induced deterioration. Anthropogenic (man-made) threats range from destructive fishery practices to pollution and from dredging to tourism-related damages. At the moment, only 29 percent of Indonesian reefs are in good condition (that is, with more than 50 percent of live coral cover). In Ambon Bay and near the Thousand Islands off the coast of Jakarta, once pristine reefs have been transformed into dead wastelands over the last twenty years. Figure E-1 shows this deterioration as measured by

Figure E-1: Temporal and Spatial Comparison of Maximum Depth of Living Coral Reef for 4 Islands in Jakarta Bay
(names and distance in km from coast are given for each island)



Source: Tomascik et al. (1993); reference to primary data sources are given there the maximum depth of live corals in four islands in Jakarta Bay.

The five main man-made threats leading to coral reef deterioration in Indonesia, are:

- poison fishing, where cyanide is squirted on coral heads to stun and capture live aquarium and food fish, but killing coral heads in the process;
- blast fishing, whereby small bombs are detonated in shallow reef areas, killing targeted schools of fish, but also killing larvae, juveniles and corals;
- coral mining, where corals are collected and smashed for house construction and lime-production;
- sedimentation and pollution, as a result of logging, erosion, untreated sewage and industrial discharges, which smother and kill the corals; and
- overfishing, which does not destroy corals but reduces abundance and diversity of fish and invertebrates.

Private Gains versus Social Costs

Powerful economic forces are driving the observed destructive patterns of coral reef use, often rendering short-term economic profits, sometimes very large, to selected individuals. Measures for coral reef protection are often presumed to conflict with economic development, and are said to require a sacrifice of economic growth. However, this study shows that this perception stems mainly from a failure to recognize the magnitude of costs to the present and future economy resulting from reef degradation. Table E-1 shows estimates of the benefits to individuals and losses to society from each square kilometer of coral reef destruction, providing an economic rationale for preventive or remedial efforts. For coastal protection and tourism losses, we have given both 'high' and a 'low' scenario estimates, depending on the types of coastal construction and tourism potential. "High" cost scenarios are indicative of sites with high tourism potential and coastal protection value. "Low" cost scenarios are indicative of sites with low tourism and coastal protection value.

Some of the most important values of coral reefs, such as those to future generations and intrinsic values, cannot be quantified. However, since the economic benefits from reef destruction are often used to justify continuation of these destructive practices, quantifying the costs associated with coral reef degradation is important to make a balanced assessment of the benefits and costs of various threats. The analysis is mainly based on observable data such as the value of the decline of fish catch or expenditures by hotels on groins to temporarily prevent beach erosion. Total costs should thus be interpreted as rough estimates of the lower range of true costs associated with reef destruction. The numbers in Table E-1 are generated on the basis of available data, using hypothetical examples of sites subject to one individual threat.

Table E-1 clearly points out the devastating economic consequences of a 'policy' of inaction. In fact, for none of the threats do the short term benefits even approach the long term costs (using a 10 percent discount rate[ii] and a 25 year time horizon). For example, coral mining is estimated to yield net benefits to individuals of US$ 121,000 per km^2 of reef (in net present value terms), while causing net losses to society of US$ 93,600 in fisheries value, US$ 12,000-260,000 in coastal protection

Table E-1: Total Net Benefits and Losses due to Threats of Coral Reefs *(present value; 10% discount rate; 25 y. time-span; in 1000 US$; per km2)*								
	Net Benefits to Individuals	**Net Losses to Society**						
Function / Threat	**Total Net Benefits**	**Fishery**	**Coastal Protection**	**Tourism**	**Food Security**	**Bio-diversity**	**Others**	**Total Net Losses (quanti-fyable)**
Poison Fishing	33.3	40.2	0.0	2.6 - 435.6	n.q.	n.q.	n.q.	42.8 - 475.6
Blast Fishing	14.6	86.3	8.9 - 193.0	2.9 - 481.9	n.q.	n.q.	n.q.	98.1 - 761.2
Coral Mining	121.0	93.6	12.0 - 260.0	2.9 - 481.9	n.q.	n.q.	> 67.0	175.5 - 902.5
Sediment. -logging	98.0	81.0	_	192.0	n.q.	n.q.	n.q.	273.0
Sediment. -urban	?	?	?	?	?	?	?	?
Overfishing	38.5	108.9	_	n.q.	n.q.	n.q.	n.q.	108.9

value, US$ 2,900-481,900 in tourism value, US$ 67,000 in forest damage, and unknown costs due to lost food security and biodiversity. Sometimes, the differences are even larger. For blast fishing in a 'high' value scenario, the costs are estimated to be more than 50 times higher than the benefits. Note that in the 'low' value sites, the largest cost to society is foregone fishery income, while in the 'high' value sites, coastal protection and tourism form the largest losses. Needless to say, costs and benefits are very site-specific and numbers will vary, depending on local circumstances.

Major Threats

Poison Fishing

With Hong Kong restaurant prices as high as US$ 60-180 per kilo for certain types of groupers and Napoleon wrasse, the wild-caught live-fish trade has a gold rush-like character. Though Indonesia has only recently become involved in cyanide fishing, it is now the single largest supplier of these fish for the Asian food market, holding more than 50 percent of the total share (Johannes and Riepen, 1995) and a total value estimated at some US$ 200 million per year. Both in the restaurant retail business and in the older aquarium fishery, cyanide is nearly exclusively used as the 'cost-effective' way of harvesting live fish. If current catch rates continue, the live-caught restaurant fish business will probably collapse economically in around four years (Johannes and Riepen, op. cit.), as rapidly decreasing stocks in Indonesia will make remoter Pacific Islands and Papua New Guinea fishing grounds more profitable.

Large scale poison fishing vessels operate in remote and unpopulated areas of Indonesia, leaving behind a mosaic of coral destruction. Table E-2 shows estimates of costs and benefits of these operations for the whole of Indonesia, under the assumption that this business will become economically non-viable in four years due to a decline in catch rates. Rough estimates of a sustainable alternative in the form of hook-and-line live-grouper fishery, as used in Australia and elsewhere, are also

Table E-2: Costs and Benefits of All Remaining Indonesian Large Scale Poison Fishing and their Sustainable Alternative over 25 years with 10% discount rate (in US$ 1,000,000)				
	with cyanide		sustainable (with hook & line)	
	costs	benefits	costs	benefits
direct costs/benefits				
sales of grouper		475.5		680.8
labour	108.1		154.7	
boat, fuel, etc.	79.2		204.2	
cyanide	6.3		0.0	
SCUBA/hookah	15.8		0.0	
side-payment (6.7% of sales)	31.7		0.0	
subtotal (direct)	241.2	475.5	359.0	680.8
indirect costs/benefits				
coastal protection	0.0		0.0	
forgone tourism	280.2		0.0	
hospital, mortality, etc.	n.q.		0.0	
biodiversity, etc.	n.q.		0.0	
quant. subtotal (indirect)	280.2	0.0	0.0	0.0
quant, total costs/benefits	521.4	475.5	359.0	680.8
net benefit to society	-46.0		321.8	

presented. Note that even in the absence of any alternative, the large scale poison fishery creates a net quantifiable loss to Indonesia of US$ 46 million over four years. On the other hand, a sustainable hook-and-line fisheries option could create foreign exchange for the country, jobs for an estimated 10,000 Indonesian fishers for many years to come and net benefits of some US$ 321.8 million (in present value terms).

Blast Fishing

Though forbidden in Indonesia and elsewhere, and despite the inherent dangers, home-made bombs are still a very popular fishing 'gear' used to catch schools of reef fish and small pelagics and thereby 'earning money the easy way'. In the past, the explosive charge came from World War II bombs, though fertilizers and illegally purchased dynamite, often from civil engineering projects, are currently used. The explosion shatters the stony corals and kills fish and invertebrates in a large surrounding area. Over time, blast fishing damages the whole reef and thereby destroys the resource base of many subsistence fishers. The analysis, shown in Table E-1, illustrates that the costs in terms of foregone sustainable fishery income alone are nearly six times as high as the short term gains from blast fishing (US$ 86,000 vs. US$15,000). The other losses to society, in terms of foregone coastal protection and tourism are even higher in areas with high tourist potential and/or considerable coastal construction. These losses are estimated at US$ 193,000 and US$ 482,000 respectively, as illustrated in Figure E-2.

Figure E-2: Net Present Value of Blast Fishing to Individuals and Associated Losses to Society per km2 of Reef
(Scenario: HIGH; in 1000 US$; over 25 years; 10% discount rate)

Coral Mining

Corals have long been used for building material and for the production of lime, as well as in the ornamental coral trade. The lime is often used as plaster or mixed with cement to reduce costs for private dwellings and local administrative offices. Coral mining not only destroys reef flats, and thereby its coastal protection function, but leads indirectly to logging of secondary forests, which is used for lime burning. The external economic costs of this logging is estimated at some US$ 67,000 per km^2 of coral flat mined, as much as the total rent that all the miners get for this area. Coral mining used to be very widespread in Bali, where some hotels are now paying high prices (over US$ 100,000 a year) to mitigate the resulting beach erosion. Hotel-chain managers have learnt from this, and state that the status of coral reefs is currently a decisive criterion in site-selection for new resorts. Mining activity is still practiced in other islands with large tourist potential, mainly Lombok, where <u>total net costs to society are estimated to be 7.5 times higher than the net benefits to individuals.</u>

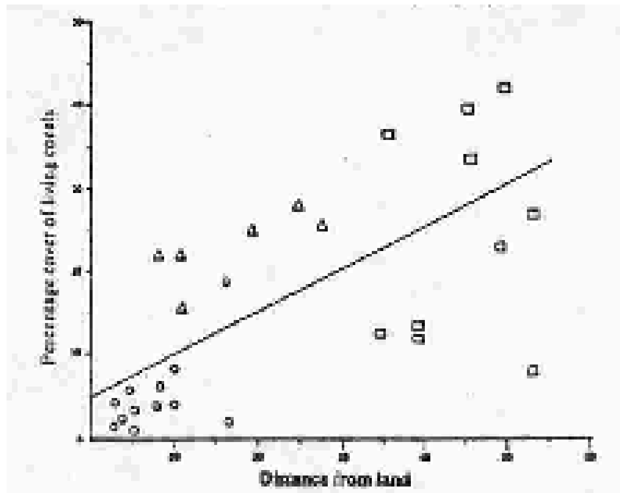
Sedimentation and Pollution

Sedimentation, both from urban areas and from logging activities, smothers corals as it prevents them from capturing sun light and plankton -- their primary sources of energy and nutrition. Pollution, both from agro-chemicals and industrial discharges, can also kill corals. These problems are particularly acute close to estuaries of rivers and urban centers. Figure E-3 shows the correlation between live coral cover and distance from land for islands near Jakarta. For urban-induced sedimentation, no economic costs have been calculated: typically they vary dramatically with the site, and reduction of discharges often has many other economic benefits (such as sanitary improvements and disease control), making the costs to corals probably minor. Estimates by Hodgson and Dixon (1988) for logging-induced sedimentation damage to a coral reef in Philippines showed costs 2.8 times higher than the associated benefits.

Overfishing

Though not necessarily as destructive as the other threats described above,

Figure E-3 ***The Relationship between Live Coral Cover and Distance from Land***
(28 observations from islands of the Pulau Seribu group off Jakarta; 1986 data; distance in km)



Source: Hutomo (1987); reference to primary data source is given there.

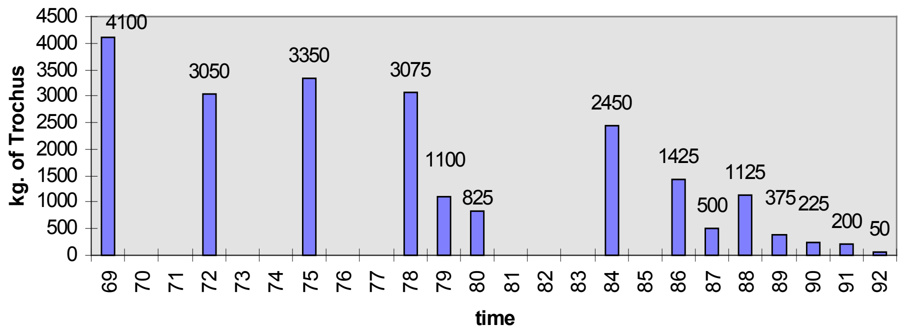
overfishing does damage coral reef, mainly through a reduction in fish diversity. It also decreases the value of corals to recreational divers, who are eager to see both large predators and abundance of small colorful fish. For the cost-benefit calculation of overfishing, we have abstracted from foregone tourist revenues and only estimated the loss in rent from the fishery at 'open access' vis-à-vis the 'maximum sustainable yield'. The present value of this loss per km^2 is US$ 70,000, as given in Table 1. This means that on average, coral reef fisheries could produce an additional US $70,000 in net present value per km^2 of reef if effective management was introduced.

In general, the necessary reduction in effort to avoid overfishing and achieve optimal sustainable yields is in the order of 60 percent (McManus et al, 1992). Alternative income generation, for instance in eco-tourism, could be one potential way of bringing about this reduction in effort. Besides lowering the total effort, fisheries management efforts should also focus on the creation of sanctuaries and establishment of closed seasons. Figure E-4 shows the dramatic difference in yield between a three-year harvesting cycle versus a one-year harvesting cycle for mother-of-pearl shells (trochus) in Maluku. Note that the three year closed seasons ending in 1978 gave an average yield of 3,400 kg, or more than 1,100 kg per year. In the annual collection pattern followed since 1987, the average yield per year is just over 400 kg. Transfer of fishing rights to local communities as well as reintroduction of traditional rights, such as the 'sasi' system in Maluku, are other effective ways of dealing with overfishing and destructive fishing practices.

Balancing Winners and Losers

Given the high societal costs created by these threats, the question arises why the threat exists in the first place. Two stakeholder issues seem to be of critical importance: (i) the size of the stakes per person; and (ii) the location of the individual causing the threat vis-à-vis the location of the threat itself. With respect to the first point, <u>the size of the stakes</u>

Figure E-4: Yield of Trochus (Mother-of-Pearl) in Noloth (Central Maluku) in 1969-1992 per kg



(Source: data gathered from village head in Noloth, Maluku)

per person, Table E-3 shows the private benefits that accrue to the various groups of stakeholders as well as to each of the persons/families/boats/companies involved. The total amount of benefit is equal to the value presented in Table E-1. The column 'Others' presents the payments to third persons, sometimes referred to as 'political rents'.

Note that the net benefits per square kilometer to individuals seem to be highest for coral mining. However, if we look at the private benefits per stakeholder (person/boat/company/etc.), poison fishing and logging-induced sedimentation have by far the highest private incentives, ranging from US$ 2 million per company in the case of logging to over US$ 0.4 million per boat in the case of poison fishing (in present value terms). Side-payments are also particularly high, very roughly estimated at some US$ 0.3-1.5 million for some receivers of large payments. On the other extreme, coral mining is a very marginal activity for the families involved, though the side-payments are not negligible.

Some major caveats apply with respect to Table E-3: the stakes per person are calculated on the basis of man-years. For

Table E-3: Net Benefits to Individuals: Amount per km^2 and per Stakeholder
(latter in parentheses; present value; 10% discount rate; 25 y. time-span; in 1000 US$; per km^2)

Individuals / *Threat*	Fishermen	Miners, Loggers	Others (payments)	Total per km2
Poison Fishing	29.3 *(468.6 per boat)* *(23.4 per diver)*	-	4.0 *(317-1585 per person)*	33.3
Blast Fishing	14-6 *(7.3 per fisherman)*	-	?	14.6
Mining	-	67 *(1.4 per mining family)*	54.0 *(18.0 - 54.0 per person)*	121.0
Sedimentation-logging	-	98.0 *(1990 per logging family)*		98.0
Sediment.-urban	?	?	?	?
Overfishing	38.5 *(0.2 per fisher)*	-		38.5

mining, where families are involved nearly full-time with this activity, this approach represents rather well the real stakes per person. But in the case of blast fishing, where many subsistence fishermen use bombs occasionally, the actual stakes involved per person are much lower than the net present value figure of US$ 7,300 given in Table E-3. For instance, if blast fishermen use bombs only once a month, rather than every day, the stakes in net present value are less than US$ 300 per person. A similar story holds for poison fishing, where divers are often recruited for short periods of time only, overestimating the real stakes per diver significantly. At the same time, the overall picture that incentives differ dramatically per threat remains valid and that types of management interventions differ accordingly. In the case of urban sedimentation, especially when some large industries are involved, the stakes are probably high, though we have not been able to estimate specific stakes per person for this situation.

For the second point, the location of the individuals causing the threat, it is crucially important to distinguish between stakeholders living in the area where the threat is posed (insiders) versus stakeholders coming from elsewhere (outsiders). For instance, in the case of large scale poison fishing operations, the captain and his crew are outsiders, as is also often the case with logging-induced sedimentation. Overfishing, on the other hand, can both come from local fishermen (insiders) as well as from outside fishermen. Population pressure and open-access problems respectively are often responsible for this situation. Mining and blast fishing are typically activities carried out by the local population, though large scale explosives fishery operations do exist (Erdmann, 1995).

The insider versus outsider issue and the size of the stakes per person are high-lighted in a two-by-two matrix presented in Table E-4. The boxes in the matrix refer to the specific threats, such as poison fishing in the box "big & outsider". Note that these are general tendencies, and there will inevitably be site-specific circumstances that form exceptions to this framework.

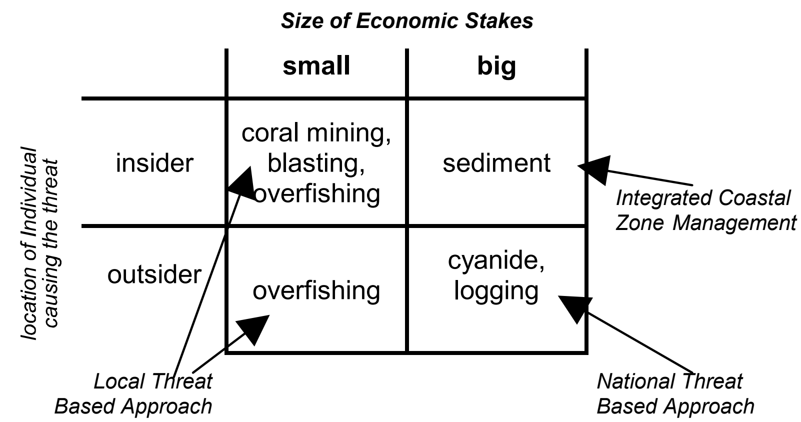
Designing Appropriate Policy Responses

In Jakarta, local stakeholder consultations are not very useful. If the stakes are small and there is one dominant threat, such as coral mining in some locations on West Lombok, integrated coastal zone management (ICZM) may not be necessary: a very direct approach, such as a small scale alternative income generation project, might be the easiest way to resolve the threat. If there are multiple threats, ICZM will be the preferred solution, although outsider threats have to be dealt with separately. Based on these features, the following three general types of management approaches are defined:

Local Threat Based Approach (LTBA)

If the dominant threat(s) in a specific site fall under the categories 'Small-Insider' and/or 'Small-Outsider', a local threat based approach is probably appropriate. This typically takes the form of community-based management. Examples are villages with a combination of overfishing and some blast fishing. Appropriate options include alternative income generation activities, enforcement of anti-explosives regulation and establishment of cooperatives or other

Table E-4 Size of Economic Stake and Location of Stakeholder



types of fishermen groups. Re-introduction of traditional common property resource management (e.g. 'Sasi'-system in Maluku) is another possibility. In some situations provincial regulations need to be adjusted to allow for common property resource management. In cases like coral mining, ad hoc solutions might be appropriate. An example is one village in Bali that stopped coral mining completely after a local hotel offered employment as gardeners to all the mining families.

National Threat Based Approach (NTBA)

In situations where the categorization 'Big-Outsider' applies for the main threat(s) in a specific location, action at the national level is required. The clearest example is large scale poison fishing operations, that often take place in remote and unpopulated areas. Strong initiatives at the highest national levels, involving the Navy and the Police are the only way to stop this threat, as local and provincial officials are powerless in the face of these operations. Likewise, sedimentation from large scale logging and mining operations can only be dealt with nationally, as it is at that level that the concessions are negotiated.

Integrated Coastal Zone Management (ICZM)

When sites cope primarily with 'Big-Insider' type situations, or if the site is confronted with an array of different threats that can not be dealt with separately, ICZM seems appropriate. This is for instance the case in Manado, with a large thriving diving tourism industry, that is more and more threatened by a variety of threats, from sewage to poison fishing. Other examples might include Jakarta Bay and Ambon Bay, also with a variety of threats, related to urbanization and population

Conclusions

Coral reefs are a precious resource, with a variety of functions, such as subsistence fishery, coastal protection, tourism and biodiversity. The Indonesian reefs are being rapidly destroyed by a number of different threats, especially poison fishing, blast fishing, coral mining, sedimentation/pollution and overfishing.

The private benefits to individuals involved in these destructive practices are often considerable. However, the costs to society are much larger, up to a factor of 50 higher in the case of blast fishing in tourist areas. The divergence between private benefits and social costs imply a highly inefficient outcome that calls for decisive government action to stop these threats.

The policy response differs with the type of threat. In cases where the immediate stakeholders are outsiders and the stakes are big, such as large-scale poison fishing and logging operations, a ‘national threat based approach’ is called for. With large stakeholders that are mostly insiders, ‘integrated coastal zone management’ will be optimal. When the stakes are small, a ‘local threat based approach’ would give the most immediate results, typically in the form of community-based management, assisted with appropriate property rights legislation and enforcement.

1. Introduction

With its more than 17,000 islands and some 50-100,000 km^2 of coral area[iii], Indonesia has one of the richest coral reef resources in the world. These form an important source of income to the local population (fishery, mariculture, etc.), often living at subsistence levels. Also, they are a potential tourist attraction, thereby contributing to local income generation and foreign exchange. Besides, they form a unique natural ecosystem, with important biodiversity value as well as scientific and educational value. Finally, coral reefs form a natural protection against wave erosion.

At the moment, however, coral reefs are being depleted rapidly in Indonesia and elsewhere due to destructive fishing practices (poison fishing, blast fishing, muro-ami, etc.), and due to coral mining, marine pollution and sedimentation. Inappropriate legislation, weak enforcement and strong incentives are responsible for this. For example, live-grouper poison fishery in Indonesia is now reported to be a US$ 200 million business per year. Buyers in export destinations give Indonesia another four years before this trade is no longer economical and will collapse, leaving behind a mosaic of coral destruction in an area of thousands of square kilometers of formerly pristine reefs. At the same time, explosive fishery destroy livelihoods of coastal communities, and coral mining is threatening some of the most important beaches in Indonesia.

In order to stop this coral reef deterioration, the Indonesian government has started a new national program: the Coral Reef Rehabilitation and Management Project (COREMAP)[iv]. The aim of the program is to maintain coral reef ecosystems and associated habitats (i.e. seagrass beds, beaches, sand dunes and mangroves) in their best condition, or at a level of best achievable ecosystem function, which means as near to the natural condition as possible. The World Bank is one of the key external players in this Indonesian program.

In order to understand the driving forces behind the current coral reef destruction, this paper provides an economic valuation and a stakeholder analysis of each major threat. To this aim, hypothetical examples for a representative ecosystem with only one specific threat in an area of one km^2 of reef are worked out. Costs and benefits are described for each of these hypothetical situations, by comparing the managed and the unmanaged policy alternative(s). The economic analysis includes a stakeholder analysis, showing who are gaining and who are losing from the persistence of each of these threats. This gives indications of the type of interventions that are needed to arrest the threats. Depending on whether the stakeholders are ‘insiders’ or ‘outsiders’ for a specific area, and depending on the size of the stakes, different types management will be called for.

The costs of a policy of inaction are the losses in the value of the functions of coral reefs such as sustainable fishery, food security, biodiversity, coastal protection, tourism, research. Only a few of these functions can be expressed in monetary terms, and some of the most important ones are not quantifiable. The benefits accruing to some specific stakeholders are much easier to monetise. In this paper, we have only attempted to quantify in money terms the functions of 'fishery', 'coastal protection' and 'tourism', giving together a lower boundary of the total costs involved. However, we feel that crude though this cost estimate might be, it is the best way to show policy-makers the enormous social costs involved in a continuation of the threat, compared to the often relatively small benefits from the destructive activities.

The paper will first discuss, in Chapter 2, the most important functions of coral reefs. It will also estimate the value of some of these functions. In Chapter 3, the five major threats (poison fishing, blast fishing, sedimentation/pollution, coral mining, and overfishing) will be analysed and an economic and stakeholder analysis will be presented for each of the threats. Finally, Chapter 4 discusses the management options for each of the threats. Appendix 1 also gives a short annotated bibliography of literature on man-made coral reef destruction.

2. Coral Reefs: Their Functions and Economic Value

2.1 Introduction

Coral reefs are the flowers of the sea, surrounded by fascinatingly-colored fish with remarkable diversity. Reefs are rather productive shallow water marine ecosystems that are based on rigid lime skeletons formed through successive growth, deposition and consolidation of the remains of reef-building corals and coralline algae. The basic units of reef growth are the coral polyps and the associated symbiotic algae that live in the coral tissues. This symbiotic relationship is the key factor explaining the rather strict environmental requirement of corals since the symbiotic algae require light for photosynthesis and can be easily destroyed by sedimentation (Tomascik, 1993).

Different structural types of coral reefs are distinguished: (i) fringing reefs; (ii) patch reefs; (iii) barrier reefs: and (iv) atolls. *Fringing reefs* are the most common type of coral reefs in Indonesia. They develop adjacent to the shore usually along rocky coasts of uplifted islands or along the shores of exposed limestone islands. *Patch reefs* are isolated and discontinuous patches of fringing reefs. *Barrier reefs* develop sometimes rather far away from coastlines in areas where coral growth has kept up with gradual drop of the sea-bed. Finally, *atolls* are circular reefs that arise from deep-sea platforms such as submerged volcanic seamounts (Tomascik; *op. cit;* Post, 1982).

The functions of coral reefs are numerous. They include (i) food and other resources (fish, mariculture, jewelry, aquarium items, etc.); (ii) construction material (sand, rocks); (iii) pharmaceuticals and other industrial chemicals; (iv) tourism and recreation (diving); (v) educational and scientific interest; (vi) biological support (e.g. breeding and feeding for offshore fish); (vii) coastal protection (to prevent sand erosion); (viii) fall-back life support system (during agricultural crises, etc.); (ix) genetic resources; (x) global heritage; etc. (Bakus, 1982; Tomascik, 1993; and others).

Each of these functions has an economic value. Spurgeon (1992) identifies different types of values for the various functions and divides these functions into these values. Following the environmental economics literature (Dixon & Sherman, 1990; Pearce & Turner, 1990), we distinguish (a) extractive direct use values; (b) non-extractive direct use values; (c) indirect use values; (d) non-use values. The mapping between the functions and the types of values is presented in Table 2.1.1. Note that the non-

Table 2.1.1: Types of Values Corresponding to Different Functions of Coral Reefs

types of values	***functions***
direct use value (extractive)	*- food/other resources (fishery, etc); - construction material - pharmaceuticals and other industrial chem.*
direct use value (non-extractive)	*- tourism and recreation; - educational, scientific interest*
indirect use values	*- biological support; - coastal protection*
non-use values	*- fall-back life support; - gen. resources; - global heritage; & known and unknown future uses of the functions above*

source: adapted from Spurgeon (1992)

use values also include known and unknown future values of direct and indirect uses, often referred to as quasi-option and bequest values.

These values together can be taken to calculate the Total Economic Value (TEV) for alternative uses (e.g. preservation area, tourism area, multiple use area, etc.). Note that the further down in Table 2.1.1, the less tangible and person-specific the benefits are. The aggregation of economic values needs to take the compatibility of the different functions for a specific use into account (Spurgeon, 1992; Barton, 1994). Following this method, the TEV for specific coral reefs can be calculated[v]. For West Lombok (NTT, Indonesia) this is calculated by Riopelle (1995), who estimated the total economic value[vi] of coral reefs as high as US$ 58.2 million for West Lombok, which corresponds to more than US$ 1 million per km^2 of reef.

In this study, no attempt is made to calculate the TEV. Instead, values are calculated for some specific functions, in order to calculate the economic loss due to destruction of these functions. The functions that will be analyzed in some detail are: (i) fisheries; (ii) coastal protection; and (iii) tourism. As stressed above, this does not imply that the other functions are less important, only that it is harder or even impossible to get reliable estimates for these other functions. For the three mentioned functions, values can be estimated relatively straightforwardly with techniques mainly based on market prices (Dixon & Sherman, 1990). Combined, these monetary values form a lower bound for the total cost of destruction of coral reefs. The sum of these quantifiable losses will, in Chapter 3, be compared with the benefits of reef damaging activities to evaluate the quantifiable net societal gains/losses due to these activities.

2.2 Fishery

Coastal communities throughout Indonesia rely heavily on reef fisheries. Especially for the poor, subsistence reef fishery is their main or only source of animal protein. Besides, collection of invertebrates, foodfish, shells, seaweed and corals on reef flats often by women gives badly needed additions to family income. Reef fishery constitutes some 10% of total fish production in the Philippines and some 5% to 10% for Indonesia. This number may, however, be much higher in actual fact as most subsistence fishery is often not included in fishery statistics. The percentages are much higher elsewhere in the Indo-Pacific region, up to 25% (Campos et al. 1994; Kelleher et al. 1995).

Types of Fishery

The fishery consists primarily of finfish, invertebrates (mollusks, crustaceans) and seaweed[vii]. The finfish catch is very diverse and includes both pescivores such as snappers (fam. *Lutjanidae*), groupers (fam. *Serranidae*), as well as herbivores, such as parrotfish (fam. *Scaridae*), surgeonfish (fam. *Acanthuridae*) and many others. Reef fishery also include significant proportions of small pelagics (*Scombridae, Clupeidae, Carangidae*), which move in and out of reef areas in search of food and protection. Invertebrate collection consists mainly of giant clams (*Tridacna spp*.) and other bivalves, seacucumber (fam. *Holothurioideae*), octopus (*Octopodidae spp*.), spiny lobster (*Palinurus spp.)* and mother-of-pearl shells (*Trochus spp*.). Seaweed (esp. *Eucheuma spp.)* is dried and sold as food additive (carrageenan).

Productivity

The primary productivity of reef ecosystems is very high (ca. 70 tons carbon/ha/yr.), but compensated by high respiration. Net productivity ranges around 300-1000 gram carbon/m^2/year, 20 times as high as the open sea. Some argue, though, that coral reefs only occur in waters of low nutrient content, and that they can therefore not generate large fishery. However, Munro & Williams (1984), argue that (i) coral reefs are often close to mangrove ecosystems with abundant nutrients; and (ii) many of the reef-dwelling fishes and invertebrates are planktivores, and reefs serve as a giant plankton net. This leads them to believe that reefs can indeed yield high fishery production.

Munro (1984) presents estimates of a sustainable harvest of edible finfish and invertebrates of 15 mt/km^2/yr. Yields for each of these vary significantly. Russ (1991) summarizes 11 studies on yields of small coral reefs in South East Asia, with estimates ranging from 0.42 to 36.9 metric tons per km^2 per year. According to Russ (1991), these differences may be due the following factors:

- the reefs differ in size: areas of large coralline shelf are less productive than small and actively growing coral reefs; this also explains why earlier studies focusing on large coral areas (Munro & Williams, 1985) have found yields with a lower range of 0.8 to 5 mt/km^2/year;
- the level of effort: this differs per site, but is generally considered to be high for the studies quoted; this means that the potential yield may be considerably larger than actual yields data where overfishing is not unusual;
- the definition of the total reef area: this depends on the assumption of the maximum depth reef fishing; Russ (1991) quotes an example of a yield estimate of 24.9 metric ton/km^2/year when the area estimate is based on a maximum depth of 60 meters; with a 20 meter maximum, the yield would have been 48.79 mt/km^2/year; a depth of 40 meter is often taken as a standard;
- the definition of reef fish: not all fish caught in reef areas are reef or reef related species; because pelagic 'off-reef' fish may dwell there occasionally as well; the quoted articles may have used different definitions of reef fish.

Alcala (1988) states additional factors influencing fish yields. He suggests among others that yields are positively correlated with the size of the adjacent shallows and with the degree of live coral coverage. Also, harvesting at different tropic levels influences fish yields where lower yields are expected when top carnivores are fished rather than herbivores and planktivores. The latter is shown in Alcala (1988) by comparing islands in the Philippines.

On the basis of the above considerations, Russ (1991) suggests that sustainable yields in the order of 10-20 metric ton/km^2/year are feasible for small areas of actively growing coral reef. This is in line with McAllister (1988) who assumes sustainable yields of 18 mt/km^2/year for reefs in excellent condition, 13 mt/km^2/year for reefs in good condition and 8 mt/km^2/year for reefs in fair condition. It also corresponds to a summary by Alcala (1988) on three Philippine islands with yields ranging from 10.94 to 24 mt/km^2/year.

With the above discussion in mind, we take as a working hypothesis a maximum sustainable yield of 15 mt/km^2/yr of reef fishery up to a depth of 30 meters for reefs in good to excellent condition (low level of hard coral mortality). Invertebrates are mainly collected at the reef flats while some of the more valuable finfish are harvested on the reef slope. Invertebrates are mainly collected on the reef flat, where they form around 50% of the total yield and finfish yield seems to be quite similar at different parts of the reef (McManus, personal communication). This means that in a reef with 50% reef flat and 50% reef slope, one-third of the total yield is invertebrates and two-third are finfish, though this depends on the type of reef and the length of the reef-flat. The assumptions are therefore:

- *The maximum sustainable yield of finfish and invertebrates in reefs in excellent or good condition up to a depth of 30 meters is 10-20 mt/km^2/yr with a mid-point of 15 mt/km^2/yr.*[viii]

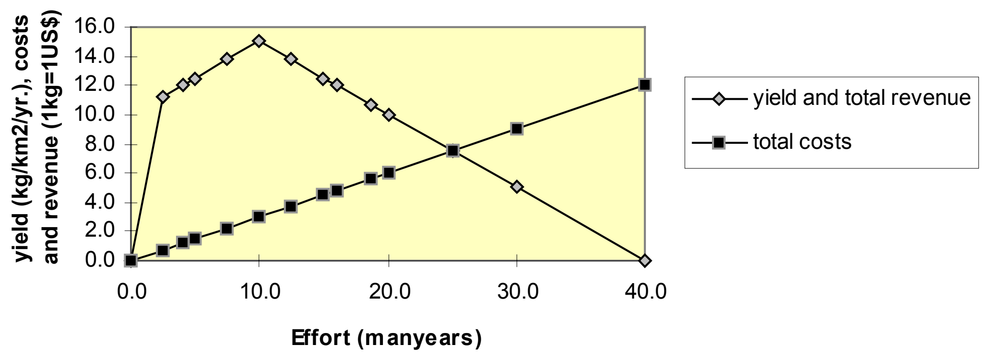
- *Of this total, finfish form two-third of the yield or 10 mt/km^2/yr and invertebrates form one-third or 5 mt/km^2/yr, if we use the mid-point estimate of total reef yield and a 50% reef flat, 50% reef slope assumption.*

Fishing Effort

Fishing methods include hook and line, portable fish traps and gill nets, as well as spear-fishing and destructive techniques (blast fishing, poison fishing, muro-ami). Invertebrates such as lobsters and sea-cucumber are often collected using free-diving. Others are often gathered by hand on the shallow reef flat (reef gleaning). Fishing effort varies greatly per technique. Campos et al. (1994) gives catch per unit effort for different type of gear on reefs, showing that species composition and the total catch per unit effort vary considerably with different techniques.

The optimal level of effort for a productive reef is difficult to calculate. This is partly because of the subsistence nature of much of the reef fishery: many people use the reef for a couple of hours a day, part of the year. Here, we assume as a very rough working hypothesis, on the basis of the available data and on the basis of our own observations in Biak (Irian Jaya, Indonesia), that the catch at the optimal effort level is five kg/day/person. With a yield of 15 mt/km^2/yr, this implies an optimal effort of 10 full-time menyears for a square kilometer of reef (with 300 fishing days per year). Note that in reality, several members of many subsistence fishermen families are involved on a part-time basis in the harvesting of the fishery. So, in actual fact, fifty or more subsistence fishery families may well live from the

Figure 2.2.1: Yield-Effort Curve in Non-Destroyed Reef and Costs of Effort per km2 of Reef per year (in 1000 US$)



reef-related yields for part of the year, as our own investigations of a representative COREMAP-site show. However, for the economic analysis, we will work with full-time men-years. Figure 2.2.1 gives the yield-effort curve in this situation, on the basis of discussions in Munro & Williams (1985)[ix], McManus et al. (1993) and others.

The yield-effort curve in Figure 2.2.1 is a piece-wise linearisation of the standard dome-shaped curve in fishery economics. The curve is constructed so that the optimal sustainable yield is twice as high as the open access yield, with a 60% lower effort (McManus et al, 1992)[x]. This implies a yield per full-time fisher of 1 kg per day. Note that, especially in tropical fishery, one should ideally look at more complex multi-species models. However, we lump here all reef fishery together for simplicity, following Munro & Williams (1985), and many others.

The shape of the yield curve implies that the optimal sustainable yield (OSY) and the maximum sustainable yield (MSY) coincide. This point is the highest point of the dome-shaped yield-effort curve. Though the OSY and MSY are different in reality, the assumption that they coincide is probably not a serious drawback: given the virtual absence of capital costs and the very low opportunity costs of labor, the points will be close together in reality. The point in Figure 2.2.1, where the yield-effort curve and the cost curve intersect, is the open access yield (OAY). In this situation, the level of effort is such that that fishermen are, at least in theory, indifferent between fishing and alternative employment. The cost curve will be discussed below. Needless to say, concepts such as MSY and OAY are not as clear-cut in case of subsistence fishery, with a lot of part-time work and very few alternative income possibilities, as they are in the case of large-scale fisheries.

Fish Prices

McManus et al. (1992) gives an extensive list of prices of many fish and invertebrate species at a local market in the Philippines. Most species are in the range of *P*15-40 per kg (US$ 0.6-1.6). In Biak (Irian Jaya, Indonesia), our own survey results show that the local cooperative gives a price of Rp. 1800 (US$ 0.82) per kg, irrespective of the type of fish. Some local fishermen said

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that they would typically bring most of the catch to the cooperative with the exception of a few valuable species. Given that the species composition is rather variable, it is very difficult to make any generalizations. Besides, the prices vary considerably with availability of markets, consumers, etc. Here, on the basis of the prices quoted above, we make the bold working assumption that the economic value of an average catch is US$ 1 per kg. This means that the yield-effort curve can both be interpreted in volume terms (kg) and in value terms (US$).

- *The economic value of the catch of reef fishery is US$ 1 per kilogram.*

Costs

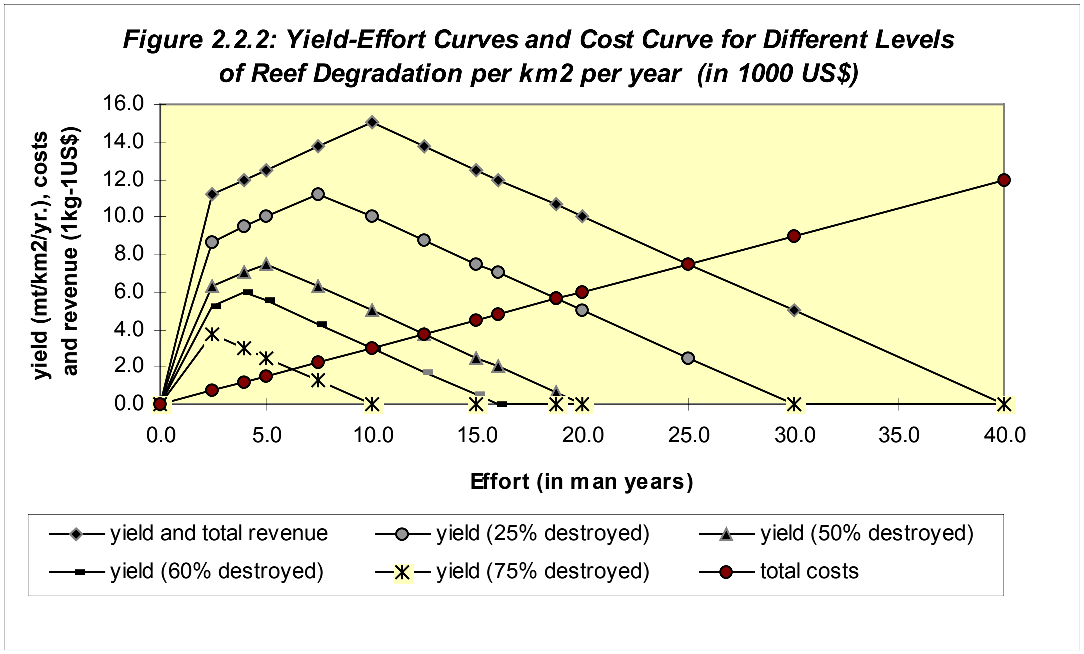
Subsistence fisheries involve typically minor capital costs. This might consist of costs for a little out-rigger boat without motor and some home made gear. Sometimes they use ice to keep the fish fresh. On the basis of our own survey in Biak and other available data[xi], we assume that total costs are Rp. 60,000 (US$ 27.3) per year per person. Fishermen often have very few possibilities for alternative income generation. Here we take as opportunity cost of labor the wage of a rural worker of Rp. 2000 (US$ 0.9) per day[xii]. Combining yields, prices and costs, we get Table 2.2.1, which forms the basis of Figure 2.2.1.

Reef Destruction

In many instances, the yields in the literature are much lower than the ones presented here. This could be the result of anthropogenic destruction of the reef (blast fishing, poison fishing, etc.). Therefore, we have created graphs and tables similar to the ones above for different degrees of reef destruction. The numbers for 25%, 50%, 60% and 75% destruction are given in Appendix 1. These are summarized in Figure 2.2.2. The exact numbers are unknown, but the present estimates seem to be reasonable: a reef area that is 50% destroyed is assumed to have a maximum sustainable yield that is 50% lower than that of an intact reef, etc.

Condition of the Reef

Reefs can vary enormously in their coral cover, even in pristine state. In early works, coral cover was often used as an indicator of the condition of the reef (>75% coral cover: excellent condition; 50-75%; good condition; 25-50%: fair condition; < 25% bad condition; see McAllister, 1988). However, reefs can be in pristine state and have a high fish abundance with a coral cover under 50%, and likewise, reefs with nearly 100% coral cover can have low fish abundance. Therefore, Gomez et al. (1994) use a mortality-index as a proxy for the condition of the reef. This mortality index is defined as the ratio of dead coral cover



to the sum of total dead and hard coral cover. Following this approach, the mortality index is used as a proxy for reef degradation in Figure 2.2.2.

Recovery

Besides the maximum sustainable yield and the open-access equilibrium, it is crucial to have insight in the recovery time of intensely fished reefs once appropriate management is installed. McAllister (1988) states that the effects of overfishing, once corrected, are restored in less than ten years in most tropical fisheries. However, if the reef habitat is partly destroyed due to blasting, cyanide, etc. recovery may take much longer (see below). Data on Sumilon and Apo, two islands with medium to good coral cover show that fish recovery takes place in 6 to 8 years, but that a collapse of management leads to the same pre-management level in as little as 4 years, even in the absence of destructive fishery practices (White, 1989). On the basis of the presented evidence, we assume here a recovery time of 7 years.

Summary of Fishery Assumptions:

- *The hard coral mortality-index is used as proxy for the condition of the reef;*
- *The maximum sustainable yield of fishery in reefs in excellent or good condition up to a depth of 30 m. is 10-20 mt/km^2/yr with a mid-point of 15 mt/km^2/yr; Reefs that are 50% destroyed (mortality-index 50%) have a 50% lower maximum sustainable yield;*
- *Of this total finfish form two-third of the yield and invertebrates form one-third;*
- *Recovery of the fishery stock of healthy reefs is assumed to take place in 7 years;*
- *The average economic value of 1 kg of fish or invertebrate is US$ 1;*

2.3 Tourism

The tourism/recreation function of coral reefs depends crucially on the area. Accessibility is one of the most important determinants of tourism potential of an area. Here, three areas will be distinguished: (i) remote and sparsely populated areas (no current tourism nor future potential); (ii) less remote areas (some present tourism and/or future tourism potential); (iii) areas with major tourism activities/potential. The distinction is rather arbitrary. For instance, tourism in Lombok was virtually non-existent in the 1960s, whereas currently it amounts to 16% of total GNP of the island (Riopelle, 1995). Therefore, areas currently not viewed as having tourism potential due to reasons such as inaccessibility might open up in the future. Note, however, that tourism can also be a significant threat, due to solid and human wastes, boat anchoring, coral breaking (inexperienced divers), etc. For a recent study on tourism carrying capacity, see Dixon *et al*. (1995). For an overview of the literature on tourism-related damage, see Appendix I.

The valuation of the three types of areas will be used to construct two scenarios: LOW and HIGH. The LOW scenario is a situation in between 'no' and 'some' tourism activities and/or potential. The HIGH scenario is a situation in between 'some' and 'major' tourism activities and/or potential. These two scenarios will allow us to give, in Chapter 3, a range of the costs involved in damage to the tourism function of coral reef. Expenditures on tourism are often assumed to have a high multiplier effect for the local economy. Lindberg & Enriquez (1993) and others give a multiplier for coastal tourism of 2-3. Here, we assume conservatively, that coastal tourism has a multiplier of 2.

Though not all tourism depends on coral reefs, much coastal tourism depends to an extent on the quality of the reefs. In a nation-wide review of marine tourism potential, the status of coral reefs came up as one of the decisive factors in site selection (Dutton, 1993). This was confirmed by a manager of one of the largest Indonesian tourist resort groups, who states that healthy reefs were a *sine qua non* for new sites. This policy was introduced after major investments had to be made in two other sites where coral destruction had taken place. This conveys the importance of healthy reefs for any type of possible future coastal tourism developments.

Major Tourism Potential

In important tourist areas, the net benefits from tourism are probably larger than the value of any other function. Riopelle (1982) studied reef-related tourism on West Lombok (coastline of around 40-50 km), and found a total net present value of benefit from divers and snorkelers of US$ 23.5 million at a 10% discount rate[xiii]. This would mean a present value of direct total net benefit of around US$ 500,000 per km of coastline. With the tourism-multiplier of 2, this gives a net present value of US$ 1 million per km of coastline. This number is even much higher in Bali and in Manado, which currently derives tens of millions per year from marine tourism, much of it from visitors to the Bunaken Marine Park.

Some Tourism Potential

In areas with some tourism potential, it is very hard to assess the net benefits from tourism. In South-West Ambon (Maluku,

Summary of Tourism Assumptions (with a 10% discount rate and a 25 year period)**:**
- *The value of the tourism function is zero in areas with no tourism potential;*
- *Its net present value is US$ 6,000 per km of coastline in areas with some tourism;*
- *Its net present value is US$ 1 million per km of coastline in areas with major tourism;*

For our two scenarios per square kilometer of coral reef, this corresponds to:
- *The LOW scenario has a net present value of US$ 3,000/km² of coral reef;*
- *The HIGH scenario has a net present value of US$ 503,000/km² of coral reef.*

Indonesia), some data were gathered on losmen (homestays; bed & breakfast). The village had three losmen in an area of around one km of coastline. The price was 20,000 Rp. per room per day with an occupancy of around 25% (two rooms per losmen). Of the tourists, some 30% was linked to coral reef tourism (of a small nearby Dive Center). Taking this example, the gross revenue of small scale tourism per km of coastline would be US$ 550 per year. Taking a 60% profit margin, that seems in the appropriate range for losmen, we get a net direct revenue of US$ 330 per year or a net present value (25 years; 10%) per km of coastline of US$ 3,000. With a multiplier of 2, this implies a total net present value of US$ 6,000 per km of coast.

No Tourism Potential

In remote and sparsely populated areas, we assume that there is no tourism potential. At the same time, even in the remote areas there might be occasional presence of some live-aboard diving operations, and some eco-tourism potential. However, we take here as working assumptions that the value of the tourism function is zero in remote areas.

HIGH and LOW Scenario per km² of Reef

The values presented above are in the units 'per km of coastline'. Fishery and other data are in the units 'per km²'. In order to match these two numbers, we assume here as a working hypothesis that one km² of coral reef corresponds to one km of coastline. Needless to say, this is a very rough assumption: there are coral reefs with no coast (atolls), and there are areas with only a few meters of reef. But for some of the areas for which the data have been gathered, this seems a reasonable average. As discussed above, the HIGH scenario represents a situation in between 'some' and 'major' tourism activities and/or potential. Its value is taken to be the mid-point of the valuation of the two situations or US$ 503,000 per km² of reef[xiv], again taking a 10% discount rate and a 25 year time horizon. The LOW scenario corresponds to the situation in between 'no' and 'some' tourism potential and/or activities. The net present value, again the mid-point, is US$ 3,000 per km² of reef.

2.4 Coastal Protection

Coral reefs act as wave breakers and thereby fulfill an essential function of coastal protection. The valuation of the impact of decreased protection due to coral mining or other forms of destruction is dependent on current and/or potential future economic activities of the area. Three situations will be distinguished: (i) areas that are remote and are sparsely populated; (ii) areas that are less remote and moderately populated with some stone construction; (iii) areas with major infrastructure (e.g. tourism facilities). These are mapped, as before, into a HIGH LOW scenario. Also, as before, we assume that one km of coastline corresponds to one km² of reef. Moreover, we assume for simplicity that destruction of one km^2 of reef leads to beach erosion of one km of coastline.

Coastal Protection in Remote and Sparsely Populated Areas[xv]

In areas without major tourism potential and without other construction of economic significance, the value of land lost could be used as a proxy for the cost of coastal erosion. The value of land can be estimated as the present value of typical agricultural production, such as coconut plantations. These have an average yield of around 1 million Rp. per year, so that the value of this land is the present value[xvi] of its yield: around US$ 4,500/ha. Taking a loss of 0.2 m/yr (Cambers 1992; data for Caribbean), this implies that per km of coastline some US$ 90 worth of land is lost. This corresponds to a total value of US$ 820 of land lost over 25 years per km of coastline. Note that the estimate of 0.2 m/yr of coast erosion is very conservative: some areas have an erosion of several meters per year on average. Other costs might be related to some destruction of bamboo houses and dirt roads. However, given the slow pace of land-loss and given the quick deprecia-tion of these constructions, they will not be considered as additional cost items.

Coastal Protection in Areas with Some Coastal Construction[xvii]

Other areas might be less remote and might have quite some population in the coastal stretch of land. There may be houses of stone (or at least with stone foundations) and there may be gravel roads, or even partly asphalted roads. Where some construction is built in the immediate vicinity of the beach, the cost of these constructions may be a proxy for the value of decreased coastal protection. The cost per km of a roads in rural Indonesia ranges from US$ 5,000 to US$ 150,000 depending on quality, material and terrain. The roads built close to the shore are probably on the lower end of this cost range. Therefore, we take here as a rough estimate of the costs: US$ 25,000/km. The costs of a stone house with concrete foundation might be in the order of US$ 1,500-2,500. Assuming 100 houses along 1 km of coast, this means a total replacement cost of US$ 150,000-250,000 for the houses.

The damage due to sand erosion might take place within a few years, or after decades, depending on how close to the shore the houses and roads are. The depreciation of these constructions, however, is much lower than what was assumed for bamboo houses and dirt roads above. Given the replacement costs of roads and houses, we assume a conservative estimate of a net present value of combined damage to gravel roads

and houses in the order of some US$ 50,000 over 25 years with a 10% discount rate. This would be the case if around 2.5% of property is destroyed every year.

Coastal Protection in Areas with Major Infrastructure

The destruction of corals has also led to sand erosion, beach damage, land loss, etc. in tourist areas. In both Bali and Lombok, this has forced hotels to make major investments in groined and other constructions to reclaim beaches. These investments give often only temporary

Summary of Coastal Protection Assumptions (with a 10% discount rate and a 25 year period):

- *The valuation of the impact of decreased protection due to coral destruction on current and/or potential future economic activities. The total costs over 25 years are:*
- *US$ 820 per km of coastline in remote and sparsely populated areas;*
- *US$ 50,000 per km of coastline in areas with stone construction near the shore;*
- *US$ 1,000,000 per km of coastline in areas with major infrastructure (tourism);*

For our two scenarios per square kilometer of coral reef, this corresponds to:
- *The LOW scenario has a net present value of US$ 25,410/km^2 of coral reef;*

The HIGH scenario has a net present value of US$ 550,000/km^2 of coral reef.

relief and continuous efforts are necessary to prevent the erosion from re-appearing. One hotel in West Lombok has spent over the last 7 years a total of US$ 880,000 (that is $125,000 per year) for restoring their beach stretch of around 250 meter, allegedly damaged as a result of past coral mining (Riopelle, 1992). Other hotels on Lombok have also made investments, though at a much lower scale. In Bali, one account gave a rough estimate of total expenditures over several years of US$ 1 million for 500 m. of coastline protection[xviii].

These examples imply that total costs of beach protection per km are US$ 5.0million and US$ 2.0 million respectively[xix]. On the basis of these examples, a net present value of US$ 1 million per km over 25 years (10% discount rate) for defensive expenditures is taken as a conservative proxy for the cost of decreased beach protection due to coral mining and other destructive activities for areas with major tourism activities. These estimates are in line with accounts from the Caribbean where major investments have been necessary to prevent beach loss. Cambers (1992) describes two coasts in Barbados that have been eroding over the last thirty years at an average rate of 0.2 m/year as the result of coral destruction. It was estimated that beach restoration measures would cost approximately US$ 30 million (in 1984 dollars). Failure to do so would result in the potential loss of between 6% and 18% of tourism contribution to GDP in ten years time. Also, the Government of Indonesia is currently planning massive additional investments (US$ 67.5 million) in Bali to prevent beach erosion and rehabilitate damaged beaches[xx], though the total area of the proposed project is not yet known.

2.5 Summary

In this chapter, the functions of coral reefs have been discussed, and economic values for three of its functions have been calculated: fishery, tourism and coastal protection. These values correspond to the economic costs of the loss of these functions due to coral reef destruction. Table 2.5.1 presents these data for the HIGH and LOW scenario[xxi]. As explained before, for some of the most valuable reef functions, it is impossible to put monetary values to their losses. However, if the total net losses of the quantifiable functions alone are higher than the net gains to individuals from reef damage, then that is sufficient reason to arrest the reef threat.

Table 2.5.1: Net Present Loss to Society due to Destruction of 1 km^2 of Coral Reef over 25 years (in US$ 1000; 10% discount rate)

<table>
<tr><th></th><th>Fishery</th><th>Coastal Protection</th><th>Tourism</th><th>Others</th><th>Total Net Losses (quantifiable)</th></tr>
<tr><td>HIGH Scenario</td><td rowspan="2">108.9</td><td>550.0</td><td>503.0</td><td>n.a.</td><td>1161.9</td></tr>
<tr><td>LOW Scenario</td><td>25.4</td><td>3.0</td><td>n.a.</td><td>137.3</td></tr>
</table>

Note that in the LOW scenario - the situation with little tourism potential and minor coastal construction - the main quantifiable costs of coral destruction are losses in sustainable fishery. In the HIGH scenario - with some or major tourism potential and also with substantial coastal infrastructure - the coastal protection and tourism functions form the main quantifiable losses. These estimates will be used extensively in the next chapter, where the benefits and costs of several threats will be discussed in detail.

3. Threats to Coral Reefs

3.1 Introduction

Coral reefs and their associated environments are sensitive to any changes in conditions, be it of natural or of man-made (anthropogenic) origin. The last three decades have witnessed an unprecedented escalation in human-induced stresses. These relate to fishery, industry, urbanization, agriculture, and tourism. Some 29% of Indonesian reefs are currently in good to excellent condition (LIPI-P3O, 1996) and the deterioration is continuing rapidly. Both natural and anthropogenic threats have been extensively studied in the literature. Appendix 1 gives an overview of studies on many of these threats.

Destructive fishery

Several forms of unsustainable fishery practices lead to reef destruction. Poison fishing stuns targeted species that can then be scooped easily and sold live. This process can kill parts of coral heads as well as other associated small organisms. Blast or explosive fishing uses small home-made bombs, thrown into the water at a selected location close to a reef. The explosion stuns and kills schools of fish, but also shatters the corals and destroys the habitat where the fish live, feed and breed. Muro-ami fishing consists of setting a deep net near or around the reefs, with the aid of swimmers, sometimes as many as 300 young boys. Scare-line with plastic strips and a stone weight are jiggled, whereby the stone bounces off the coral, driving the fish out of the coral towards the net (Rubec, 1988)[xxii].

Net fishing and bamboo trap fishing are other techniques that often cause much damage, even though these could be rather harmless, when carried out more carefully. Gathering of invertebrates and live corals on reef flats also destroys the corals, as collectors typically trample on the reefs thereby breaking the coral. In addition to these destructive fishing practices, most reef fisheries close to population centers are exploited far beyond their maximum sustainable yield, leading to loss of biodiversity.

Industrialization, urbanization and agriculture

Rapid economic development in Indonesia is causing a different set of threats to reefs. Sedimentation from the discharge of industrial effluents and domestic waste is the prime threat. The turbidity kills the corals by blocking sun-light, essential for photosynthesis of the symbiotic algae associated with reef building coral polyps. Also, pollution of chemicals and heavy metals destroys the reef ecosystem. Dredging of sand and stone for the construction industry, and coral mining for lime production or rock extraction has also a heavy toll on reefs. Runoff from agricultural sources and logging practices can do great harm to reefs, either through sedimentation or through increases in pesticides and nutrients.

The latter leads to algae blooms that kill coral. At a global level, industrialization also leads to global warming, opening the potential for sea-level rise. This might also affect coral reefs, though the degree is highly uncertain.

Tourism

Coastal construction of beach resorts, solid and human waste from tourist resorts, boat anchoring and coral breaking by inexperienced divers are some of the adverse effects of tourism development. For a recent study on tourism carrying capacity, see Dixon *et al*. (1995). For an overview of the literature on tourism-related damage, see Appendix I.

Economic Analysis

This chapter will focus on the economics and incentives behind five of the most important threats to coral reefs in Eastern Indonesia: poison fishing, explosive fishing, coral mining, sedimenta-tion/pollution, and overfishing. To this end, the costs and benefits are described for hypothetical sites of one square kilometer where only one single threat is taking place. This means, for example in a representative coral mining site, that we assume that no other threats are taking place. Hence the loss of the fishery function in such a site equals the value of the maximum sustainable yield in that area (minus remaining fishery during and after mining). Therefore, we assume away the possibility that the area did not yield much fish before the miners even started, due to, for example, poison fishing. The economic analysis on a one-threat, one-square-kilometer basis is supplemented with an investigation of the stakeholders that reap the benefits of the coral destruction.

3.2 Poison Fishery

Introduction

Fish poison has been produced and used for centuries all over the world (Eldredge, 1988). The use of poison in Indonesian waters was first mentioned by Rumphius in his biological studies in the Moluccas in the 17th century. In his description, roots and stems containing rotenone from the tropical derris plant were used to narcotize fish in order to facilitate their catch (Eldredge, *op. cit*.). This practice is still going on in some parts of Indonesia, where natural poisons are mixed with pulverized fish and this bait is handcast over reef flats. The stunned or killed fish are collected by free-diving (Erdmann, 1995).

Since the 1960s, however, this small scale use of natural poison has been supplemented with the application of commercial poisons, especially cyanide[xxiii] (Galvez et al, 1989). The main users are the aquarium fish trade and, more recently, the wild-caught trade in live food-fish. Currently, Indonesia is the single largest supplier of wild-caught live-fish to the Asian food market, with more than 50% of the total share in Hong Kong and Singapore (Johannes & Riepen, 1995) and a total value estimated at US$ 200 million[xxiv]. Prices of live-fish are exorbitant in Asian restaurants where some premium species are sold for more than US$100 per kg. This section will describe the economics and the management options of both the wild-caught food-fish trade and, briefly, also the aquarium trade.

The use of cyanide, both for aquarium fish and for food-fish, is highly destructive, as many larvae, fingerlings and other organisms are killed in the process. Also, according to Rubec (1988), aquarium fish collectors only select an average of ten percent of total stunned fish, taking only the colorful species of interest to aquarists. Cyanide exposure has been shown to cause internal damage to the fishes' liver, intestines and reproductive organs (Rubec, *op. cit*.). Therefore, most of the other fish that are not captured, die within months. In fact, this is also the reason that the Philippine aquarium fish trade has obtained such a poor reputation worldwide: most of the ornamental fish captured with cyanide will die soon in the aquaria (Hinggo & Rivera, 1991).There are no indications, however, that cyanide use for live food fish catch is harmful for human consumers: the poison is partly excreted and partly converted by the liver into a non-toxic substance: thiocyanate. The remaining quantities of cyanide in tissue are below WHO-standards[xxv]. On the other hand, commercial poison fishery is a risky business for the divers, especially if compressed air (hookah, SCUBA) is used. In one Filipino village of 200 divers, 30 cases of serious bends were reported and 10 divers died in 1993 (Johannes & Riepen, 1993).

Apart from this, cyanide can also kill parts of coral heads, especially when applied repeatedly (Rubec, 1988). There is some proof that even a one-time squirt of cyanide on a coral head is enough to kill coral colonies and cause bleaching (Johannes & Riepen, 1995), though this is denied by others. The coral structures stay intact, but might gradually erode under physical and biological processes. Recolonization could take place in the long run, though is it claimed that effects of cyanide could last up to 30-35 years (Galvez, et al., 1989). Besides, dead corals yield much fewer fish than live corals.

Cyanide and its Effects

Techniques

In poison fishing, cyanide is typically dissolved in plastic bottles filled with water, and squirted into holes of coral heads. This seems the most common and effective technique, though other methods are used as well (See : Johannes & Riepen). There are various accounts on how much cyanide is used in the aquarium and live food-fish trade. From the available data, it seems that cyanide is only a minor cost component in the food-fish trade (see below), whereas, in the aquarium fish trade, cyanide is apparently a major cost component (McAllister, 1988).

Quantities used

When 1-6 tablets of cyanide are dissolved in a plastic bottle (50-70 tablets per kg)[xxvi], one filling generally suffices for the capture of three commercial-size fish[xxvii].

Summary of Cyanide Use Assumptions:

- *The price of cyanide is US$ 6 per kg;*
- *16 grams of cyanide at a price of 0.1 US$ are used per live fish (restaurant trade);*
- *An estimated 320-640,000 kg/yr of cyanide is sprayed on Indonesian reefs for live fish collection.*

Taking as an average three tablets of cyanide per bottle, and 60 tablets per kg, this would mean 16 gram per food-fish. This is in line with accounts that a fisherman needs about 1 kg of cyanide per week and catches around 9-10 groupers a day in the remoter areas[xxviii]. Given a total annual live-fish export for Indonesia of 10,000-20,000 mt (see below), the total amount of cyanide squirted on the reefs for food-fish is estimated at some 160-320,000 kg[xxix].

Per diver, the aquarium fishery uses apparently much more cyanide. Rubec (1988) reports that large ships for aquarium fish collection use up to 1250 kg of cyanide for a single 10-20 day trips. This would amount to 1.25-2.5 kg per fisherman per day[xxx], compared to 1 kg per week for restaurant food fishermen. At the same time, it seems that currently, there are many more full-time food-fish divers than aquarium collectors currently operating in Indonesia. Therefore, we assume here very roughly that the total aquarium trade uses the same amount as the food-fish business. This gives a total cyanide use in Indonesia in the order of 320-640,000 kg/year.

Price of cyanide

Generally, cyanide is relatively cheap and easy to obtain. Fishermen in Ujung Pandang, for example, purchase it from local silver and electroplating industries or purchase it on credit from local owners of fish cages[xxxi]. Retail prices are around Rp.11,000-15,000 per kg (US$ 5-6.8)[xxxii]. This is in line with accounts from the Philippines, where prices range in the order of US$ 6 per kilogram[xxxiii], though prices might differ quite a bit depending on availability[xxxiv].

Destruction of coral reefs and of its functions

Cyanide tends to kill coral colonies. Johannes & Riepen (1995) quote research of Dr. Richmond (University of Guam), suggesting that coral show typical stress responses within 30 seconds of exposure to cyanide. Often they die subsequently, sometimes after appearing healthy for several weeks. Soon the bleached corals are overgrown by filamentous algae (turf). Coral bleaching in laboratories is reported at cyanide concentrations two hundred thousand times less the concentration used by poison fishermen (Johannes & Riepen, 1995). Divers of a tourist live-aboard operation in Eastern Indonesia reported that areas that were still untouched one year before had turned into fishless and partially destroyed terrain after poison fishing had taken place. It is estimated for the Philippines that as much as 33 million coral heads are squirted with cyanide each year (Rubec, 1988).

The impacts on the fishery and tourist functions cannot be underestimated. Dead corals are much less productive in fishery terms than live corals, though dead corals can still provide shelter and a surface for algal growth. Tourism will obviously cease in poisoned areas: live-aboard operations in Eastern Indonesia have more and more trouble finding good diving spots. The coastal protection function will probably not be directly affected, as the coral structures stay intact. However, there are accounts that these structures might gradually erode under physical and biological processes. Besides, the corals will not adapt any more to any changes (e.g. sea level rise). We take here the simplifying assumption that coastal protection will not be affected at all by poison fishing. On the basis of these accounts, we <u>assume</u> (see Box).

Summary Assumptions on Effects of Poison Fishing:

- *Poison fishing partly destroys the squirted coral heads;*
- *The fish productivity of cyanided reefs is dramatically reduced (for assumptions of the precise losses, see the subsequent sections);*
- *The tourism function will cease to exist;*
- *Biodiversity of both corals and related fish and invertebrates suffers severe damage;*
- *The coastal protection function will not be affected by the cyanide.*

Recovery of coral reefs and its functions

Evidence of recovery of corals after cyanide poisoning is anecdotal, especially because cyanide has only been used extensively over the last two decades. One account states that recolonization could take place in the long run, though it is claimed that effects of cyanide could last up to 30-35 years (Galvez, et al., 1989).

Others claim that this period is much shorter, as the substratum is not affected by the cyanide use, though recovery could take a very long time in the presence of other stresses (Dr. J. Post, personal communication).

We assume:

- *full recovery of the coral reef takes 30 years, starting a year after destruction ends;*
- *recovery of the fishery goes hand in hand with recovery of the corals;*
- *tourism will only restart after full recovery (30 years).*

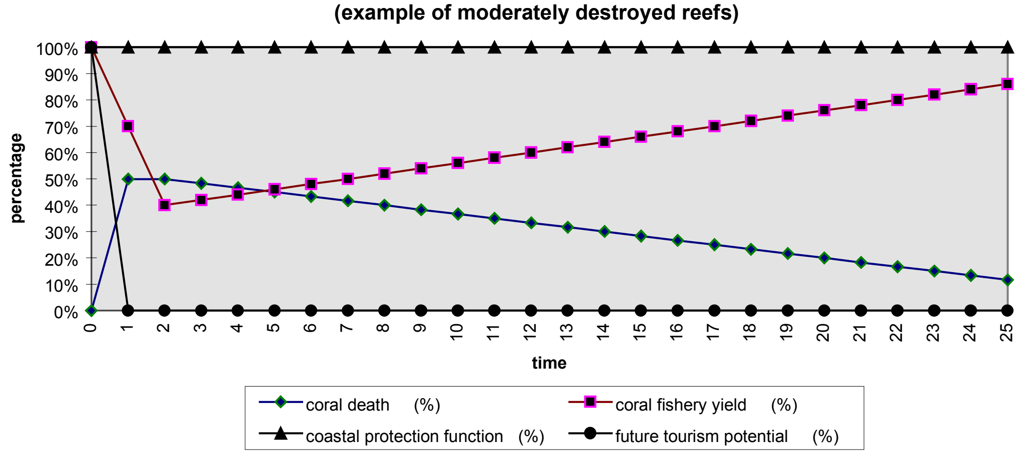
As an example, the destruction and recovery of moderately destroyed reefs in small scale operations is depicted in Figure 3.2.1.

Poison Food Fish

Extent of the food-fish trade

The cyanide food fish business in Indonesia has been rapidly expanding over the last couple of years. Johannes & Riepen (1995) estimate conservatively that the total wild-caught live fish trade in South-East Asia amounts to 20-25,000 metric ton per year (nearly all with poison). These figures are based on

Figure 3.2.1: Destruction of Coral Reefs and of its Functions due to Poison Fishing (example of moderately destroyed reefs)



official import statistics from Hong-Kong and other countries (Taiwan, Singapore, etc.).

Indonesia's share in this business is well over fifty percent of the total (hence, over 10.000

mt/yr.). Another account[xxxv] puts the number for Indonesia alone as high as 20,000 mt. Yet another account[xxxvi] stated that the live-fish trade was a US$ 200 million business for Indonesia, which also indicates a total export of 10-20,000 mt per year, given current export prices.

The official fishery statistics[xxxvii] for Indonesia gives an export volume of 1,522 mt (in 1993) with a value of US$ 4.7 million. If the figures given above are correct, this would mean that around 90% of wild-caught live-fish exports are not officially reported at the customs and that the total value is more than 40 times higher than reported in the fishery statistics. However, it may also be true that exports have increased dramatically since 1993, so that the official statistics might underestimate the exports assumed here. For the further analysis, we assume:

- *the total export-volume of wild-caught live fish from Indonesia is 10-20,000 mt/year;*
- *the corresponding total export-value is currently around US$ 200 million per year;*
- *if our data are correct, only 10% of the wild-caught live fish trade is reported to the Indonesian customs officially, and the total value is underestimated by a factor 40.*

Price of Live-Fish

The wild-caught live food-fish trade concentrates on the catch of groupers and coral trout (fam. *Serranidae*, especially species *Epinephelus spp*., *Plectropomus spp*. and *Cromileptes altivelis*) and of Napoleon wrasse (*Cheilinus undulatus*)[xxxviii]. Prices for live fish in restaurants in Hong Kong are very high: Napoleon wrasse sell for as much as US$ 180 per kg, and the lips of Napoleon wrasse, seen as a delicacy, are sold for up to US$ 1,000 per plate (Johannes & Riepen, 1995). Ever since Indonesia has restricted the export of Napoleon wrasse, the prices have increased (Johannes & Riepen, 1995, *op cit*.).Highfin groupers (*Cromileptes altivelis*) sell in restaurants for up to US$ 180 per kg, while other groupers go for US$ 25-50. For the purpose of this report, the term 'groupers' is used to designate all target restaurant food fish species, including wrasse.

Johannes & Riepen (*op cit*.) give a detailed account of wholesale prices in various

Table 3.2.1: Wholesale prices in Hong Kong (US$) in 1994

Species (common name)	scientific name	wild-caught	aqua-culture	chilled/dead
Napoleon Wrasse (or: Humphead Wr.)	Cheilinus undulatus	75	n.a.	30
Highfin Grouper (or: Panther Grouper) (or: Barramundi cod)	Cromileptus altivelis	88	n.a.	n.a.
Red Grouper (or: Greasy Grouper)	Epinephelus akaara	51	34	8
Malabar Grouper (or: Estuary cod)	Epinephelus malabaricus	25	20	8
Leopard Grouper (or: coral Trout)	Plectropomus leopardus	34	22.5	8

Source: Johannes & Riepen (1995). Prices for chilled fish are for Taiwan (Hong Kong prices are lower).

Summary of Assumptions on Biomass and Yield of Groupers:
- *The catchable biomass of groupers is 3 mt/km^2 in moderately fished reefs and 10 mt/km^2 in pristine reefs;*
- *Large-scale poison fishery will harvest the whole catchable biomass of groupers;*

- *Napoleon wrasse populations are close to depletion and grouper stocks in Indonesia will be considerably depleted in some four years if current fishing efforts continue;*
- *Some 3,000 km^2 of pristine reefs are considerably destroyed (a mosaic of destruction) each year by cyanide fishing by poison food fishery;*
- *In moderately fished reefs, the MSY of groupers is 1 mt/km^2, whereas in pristine reef, the yield of groupers is estimated here to be 1.5 mt/km^2.*

Asian markets for wild-caught live fish, aquaculture live fish and their freshly chilled equivalents. The difference in wild caught fish and aquaculture fish is due to the fact that the former taste allegedly better. The Hong Kong restaurant prices are around twice as high as the wholesale prices. Besides groupers and Napoleon wrasse, spiny lobsters (*Panilurus spp*.) are also caught by free divers and hookah divers using cyanide in moderately fished reefs. The market is primarily export to Japan. The prices are not known exactly, but seem to be similarly priced (Erdmann, 1995).

Biomass and sustainable catch of live fish per km^2

In heavily exploited reefs, there are typically very few to no market-sized groupers. However, in reefs without overfishing, the sustainable catch of groupers is reportedly between 7-16% of total finfish catch[xxxix], though percentages outside this range are not uncommon either. Here, we take as a rough working hypothesis a grouper fraction of 10% of total finfish catch for lightly and moderately fished reefs. Taking, as in Chapter 2, a maximum sustainable yield (MSY) for finfish of 10 mt/km^2/yr, this would mean that the MSY[xl] of groupers is implicitly assumed to be 1.0 mt/km^2. For pristine reefs we take as a working hypothesis a grouper fraction of 15%, hence, an average sustainable yield of 1.5 mt/km^2.

On the basis of published growth rates[xli], the catchable biomass is assumed to be three times the sustainable yield (3 mt/km^2) in moderately fished reefs. For pristine reefs, this number may be much higher as the average size is typically large in unfished reefs, though only anecdotal information is available. We assume as a first guess a biomass-yield ratio of 6.67, so that the catchable biomass is 10 mt/km^2. Note that grouper-yields are very site specific, and very little information is available in general about all of the numbers.

Actual yield of live-fish per km^2

The sustainable yield of groupers and Napoleon wrasse is unknown, though it is clear that current catches in Indonesia are unsustainable. In fact, Johannes & Riepen (1995) report that Napoleon wrasse exports have declined due to depletion and large specimens have become especially hard to get. According to fish buyers in Hong Kong and Singapore, large-scale grouper fishery in Indonesia will become commercially inviable in three to four years. We will therefore assume that the poison grouper fishery basically catches the entire adult grouper population in the fishing area. The rapid depletion is not surprising given the reported current export levels of 10-20,000 mt/km/yr. In fact, if these export figures are correct, the biomass assumptions above are of the right order of magnitude: assuming, as argued above, that an untouched reef has a biomass of some 10 mt/km^2 of groupers and that there are some 20,000 km^2 of untouched reefs[xlii] (in good to excellent condition), <u>grouper stocks will indeed be considerably depleted in four years time</u>[xliii].

Poison food-fishing operations

There are several types of poison fishing operations going on in Indonesia. The two most characteristic and probably the most common ones will be analyzed below.

They are: (i) the large-scale operations in remote areas and (ii) the small scale ones in traditional reef fishery areas. Data are mainly from Johannes & Riepen (1995), as well as from a number of well informed anonymous sources.

The first type, the large scale operation, takes place in the remote areas of the country, like most parts of Maluku, Irian Jaya, as well as atolls in Central Indonesia, such as Take Bone Rate. These operations use 'live-hold catcher boats' that are generally Hong Kong owned. They bring their cyanide from Hong Kong and use a local Indonesian crew of some 20 persons. Some of these boats are based in Ujung Pandang and leave for pristine islands and atolls in Eastern Indonesia where no or very little fishing effort is taking place. They stay for as much as a month at a time. Once back in Ujung Pandang, the food-fish are put into live cages off the coast until they are transported to mainly Hong Kong by a large Live Fish Transport Vessel (LFTV). Recently, air transport is being used more and more instead of LFTV because of lower fish mortality rates. In Bali alone, there are now ten air-freight companies for live food-fish (Johannes & Riepen, *op. cit.*).

The second type, the small scale operation, on the other side of the spectrum takes place in less remote areas and is not capital intensive. One or two fishermen go out on the reef close to their villages in relatively heavily fished areas. They use out-rigger boatlets and goggles. They free-dive mainly for coral trout (*Plectropomus spp*.), but also other groupers, Napoleon wrasse and spiny lobster (*Palinurus spp.*). They bring the fish to live cages where they are again pickedThe ecology and economics of both types are quite distinct. Besides these operations, intermediate types of operations exist where the fishermen middleman, who sells it to live-cage owner. Also, small operation with a few divers using ferry-rigged hookahs takes place in some areas. We will focus here, however, on the two polar cases described above. In order to study these markets and the benefits of various stakeholders, the sales prices from fisherman to restaurant are analyzed (Table 3.2.2). These data are explained in the text below. Using these data as well as figures on operational costs and capital costs, the net benefit to the individuals and the social costs to society are calculated.

Large scale operations

In large scale operations, the main stakeholders are the fishermen, the operators of the live hold 'catcher' boats, the exporters (LFTV or air-freight), the Hong Kong wholesalers and the restaurant owners. If it is true, as reported, that the total live food-fish trade is some 15,000 mt/yr and that the live-hold 'catcher' boats hold about 3 mt of groupers which they catch during one trip of up to a month with a crew of 20, it is likely that around

Table 3.2.2: Sales prices of wild-caught live-fish from fisherman to restaurant in US$/kg for large and small scale operations

	small scale operation		large scale operation	
\types of fish sales price\	coral trout and other groupers	Nap.wrasse/ Highfin grouper	coral trout and other groupers	Nap.wrasse/ Highfin grouper
restaurant owner	60--90	180	60--90	180
wholesaler	25--50	70--90	25--50	70--90
exporter	n.a.	n.a.	n.a.	n.a.
export agent/live cage	15--20	40--50		
boat owner/middleman			15--20	40--50
local fishermen	7	9--11	2	2

Sources: collected from Erdmann (1995), Johannes & Riepen (1995), Alvarez (1995) and various anonymus pers. comm. and own observations (see text above for assumptions)

500 'catcher' boats or other similar operations are currently active, and that as much as 10,000 people might be employed in the business.

As elaborated above, the total annual export of wild-caught live food-fish is 10-20,000 mt/yr, with a point estimate of 15,000 mt/yr. We assume here tentatively that two-third of this trade (10,000 mt/yr.) is carried out through the large scale operations, although this is not based on precise information. At the current rate, Indonesia's wild-caught grouper export will become commercially inviable within three to four years (see above). Hence, we assume conservatively that the operations have 4 more years to go, and that there are in total 12,000 km^2 of pristine reefs left (see above), of which 8,000 km^2 will be explored by the large operations. It is assumed that the fishermen will earn the amount equal to the opportunity costs of labor in rural areas (Rp. 2000; US$ 0.91) per day after the cyanide fishing operation has ceased to exist.

Though there is a diversity of semi-large and large scale operations going on, we assume for the sake of simplicity that all operations are exactly the same. The assumptions are listed here and the costs and benefits per trip are given in Table 3.2.3.

Sustainable alternative

Harvest of wild-caught groupers without cyanide is growing rapidly in Australia and in some places in the Philippines. It has also started in Indonesia over the last year or two, especially in areas close to the live-pans. However, this sustainable practice is less efficient. According to some fishermen involved, it takes twice as much time to catch groupers this way than with using cyanide in pristine reefs. In order to compare this sustainable harvest with large scale poison fishery, we make the heroic assumption that the same 500 operations are able and willing to switch to this alternative.

This sustainable live-fish operations would be able to sustain grouper exports over time, though at a lower rate. With 50% of the productivity of poison fishery, the 500 large scale operations will harvest 7,500 mt per year. Note that, in fact, the current level of export can be maintained sustainably by having twice as many people involved, assuming as above that the sustainable catch of groupers is 2 mt/km^2/yr. With an area of 8000 km^2, this means 16,000 mt per year of sustainable

Table 3.2.3: Cost and Benefits per Trip with 'Catcher' Boat
(in 1000 US$: one trip takes around one month)

Items	with cyanide		without cyanide	
	costs	benefits	costs	benefits
sales of grouper		30.0		15.0
labor	6.8		3.4	
boat, fuel, etc	5.0		4.5	
cyanide	0.4		0.0	
SCUBA/hookah	1.0		0.0	
side-payment	2.0		0.0	
Total	15.2	30.0	7.9	15.0
Profit	14.8		7.1	
Profit margin	49%		47%	
Profit per fish	$7.4		$7.1	

catch. However, here we will assume that only the current fleet of 500 boats will be used.

For the rest, the costs are the same as above, though there are obviously no costs for SCUBA/hookah-equipment and cyanide. The hook-and-line gear is virtually costless. Also, since this trade is not illegal, no side-payments have to be made. The payments made to the divers/fishermen are again Rp. 5000 per live-fish caught. Given the lower productivity, this is a 50% drop in income. However, the risk of decompression illness, etc. is eliminated and income could be insured over time.

Other costs

Poison fishery involves other costs also, especially to biodiversity and tourism. Biodiversity is particularly important here as most areas are remote and have high diversity both in coral and in reef-related fish and other biota. Also, some of the large scale operations take place in marine protected areas (Take Bone Rate, Bunaken, etc.).It is ironic that the large scale operations actually go to these marine parks, because they assume that there will be major quantities of groupers. Enforcement is extremely difficult in these, often remote, areas, and seems hardly of concern to live-fish catchers[xliv].

The Assumptions for Large-Scale Poison Grouper Operations are:

- *The live hold 'catcher' boat (referred to as boat) has a crew of 20 people;*
- *Each trip lasts for a month and has a catch of 3 mt and there are 10 trips per year;*
- *Total mortality rate of groupers is 50%: the fishermen collect 4 mt per trip of which 3 mt is safely stored in the ship, of which 2 mt are delivered alive in the harbor;*
- *The fishermen get Rp. 5000 (US$ 2.27) per fish caught alive and the boat gets US$ 15 upon delivery to the LFTV or airport;*
- *The operational costs (including depreciation, fuel, etc.) are US$ 5,000 per trip;*
- *The total costs of SCUBA/hookah-equipment, compressor, etc. is US$ 1,000 per trip;*
- *The costs of cyanide are US$ 400 per trip (US$ 0.1 per grouper caught);*
- *Costs of side-payments (cyanide fishing is illegal) are US$ 2,000 per trip[xlv];*

Tourism potential is limited in most of the areas due to inaccessibility. As a working hypothesis, we assume that 5% of the total of 8,000 km^2 has high tourism potential (such as Bunaken), 15% has moderate possibilities for (diving) tourism (e.g. Biak) and 80% has no tourism potential. With opportunity costs of foregone tourism, as presented in Chapter 2, we get a present value of US$ 369 million for the whole area. These costs will accumulate over the four years that remain for cyanide fishing, if operations continue at the current speed.

Danger to fishermen

The hookah and SCUBA diving that is essential to large-scale poison fishery operations is extremely dangerous for the fishermen. As mentioned before, Johannes & Riepen (1995) report of a case in the Philippines where in one year, out of the 200 divers in the village Marinduque, 30 divers got serious cases of decompression sickness ('the bends') and 10 of them died. Paralysis from the waist down is common in serious bends cases: this can be temporal or can last till death. Other records are less dramatic but also severe (e.g. McManus et al, 1992). On the basis of available data, a mortality rate of 1% per year seems a very conservative first proxy. The typical problem is that divers are too often, too long, and too deep under water. One anonymous account mentioned cases where people had made up to five consecutive 20-30 minute dives to 40-60 meters each day and other cases where people made ten 20-40 minute dives to 20-30 meters[xlvi]. We have not attempted to quantify the morbidity, invalidity and mortality, but the implied social costs are substantial.

Table 3.2.4: Costs and Benefits of All Remaining Indonesian Large Scale Poison Fishing and their Sustainable Alternative over 25 years with 10% discount rate (in US$ 1,000,000)

	with cyanide		with hook and line	
	costs	benefits	costs	benefits
direct costs/benefits				
sales of grouper		475.5		680.8
labour	108.1		154.7	
boat, fuel, etc.	79.2		204.2	
cyanide	6.3		0.0	
SCUBA/hookah	15.8		0.0	
side-payment (6.7% of sales)	31.7		0.0	
subtotal (direct)	241.2	475.5	359.0	680.8
indirect costs/benefits				
coastal protection	0.0		0.0	
forgone tourism	280.2		0.0	
hospital, mortality, etc.	n.q.		0.0	
biodiversity, etc.	n.q.		0.0	
quant. subtotal (indirect)	280.2	0.0	0.0	0.0
quant. total costs/ben.	521.4	475.5	359.0	680.8
net benefit to society	-46.0		321.8	

- *Mortality rates of divers/fishermen are conservatively estimated at 1% per year*

Economic Analysis for Indonesia

In order to get a flavor of the order of magnitude of total costs and benefits involved in the combined large-scale poison-grouper operations, the costs and benefits for the 'catcher' boats per trip (Table 3.2.3) will be multiplied by the total number of trips. We assume tentatively that 10 such one-month trips take place per year and that 500 such large scale operations are going on[xlvii]. These data can be combined with the external costs to give the net benefit of poison and sustainable fishing. The present values are summarized in Table 3.2.4. Precise calculations are presented in Appendix 3. Needless to say, these are very rough first guesses on the basis of the scarce information available.

Note that even in the absence of alternative grouper fishery, large scale poison fishery does not make economic sense: the net loss to society is US$ 46 million, excluding costs to biodiversity loss and human suffering as a result of decompression sickness. On the other hand, sustainable hook-and-line live grouper harvesting could be very profitable: using the existing fleet for this purpose gives a net benefit to society of US$ 321.8 million. The costs and benefits are presented visually in Figure 3.2.2.

Fishermen/divers

For the divers, cyanide fishing is extremely hazardous, but very well paid. However, the income can not be sustained over time. We assume that the same divers will be employed for the four remaining years of cyanide fishing, after which they will earn an income equal to the opportunity costs in rural Indonesia (Rp. 2000; US$ 0.9 per day). In the sustainable alternative, the fishermen will continue for 25 years. The income streams are presented in Figure 3.2.3.

From Figure 3.2.3 it is clear that divers with a reasonably long time horizon (e.g. 10%) would have a clear incentive to opt for sustainable fishery if they had the choice. However, as can be calculated, a risk-neutral diver would become indifferent between both fishing techniques at a discount rate of 16%. In real life, the trade-offs for fishermen might

Figure 3.2.2: Annual Net Revenue and Value of Poison Fishing Compared to Net Revenue of Sustainable Live-Fishing (in mil. US$)

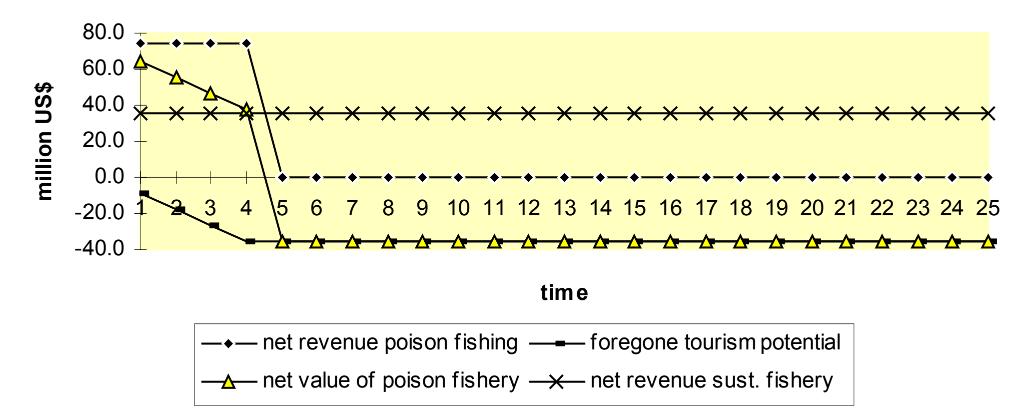
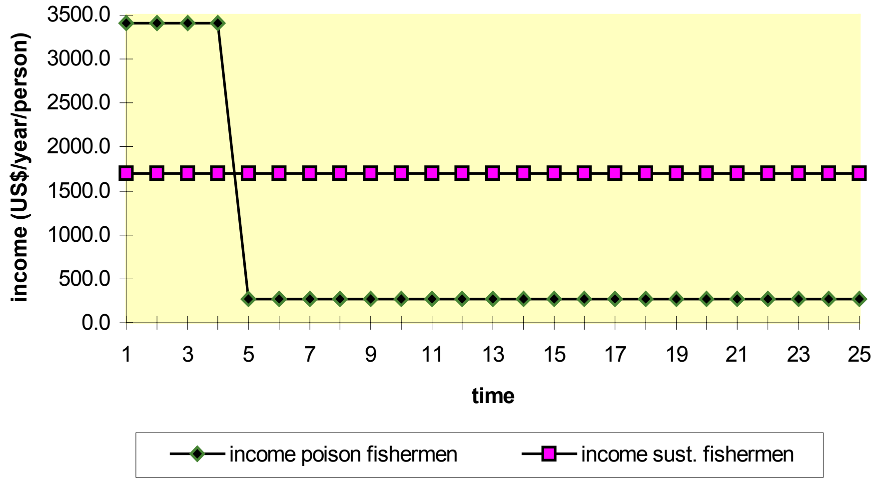


Figure 3.2.3: Annual Net Income of Poison Fishermen and Sustainable Live-Grouper Fishermen (in US$/manyear)



be much different, as divers are often replaced, or fishermen from local areas are chartered for short periods of time. In this situation, given the poverty that most coastal fishermen are trapped in, it is very hard to have an incentive mechanism in place that could reverse the divers' choice for 'big q uick money' by joining poison fishing operations.

'Catcher' boat owners

For the owners of the (semi) large scale boats, sustainable hook-and-line grouper fishery could be an economic alternative as well. The current practice is illegal and there is a constant, be it small, chance of willingness to switch depends crucially on their outside options: if they have the possibility to move to other countries (e.g. Papua, New Guinea) afterwards, there seems to be very little that can prevent them from continuing to destroy the reefs apart from strong enforcement measures. If, on the other hand, they are firmly located in Indonesia and have little alternative income generation for the boat, the sustainable live-grouper operations may be an economically viable option.

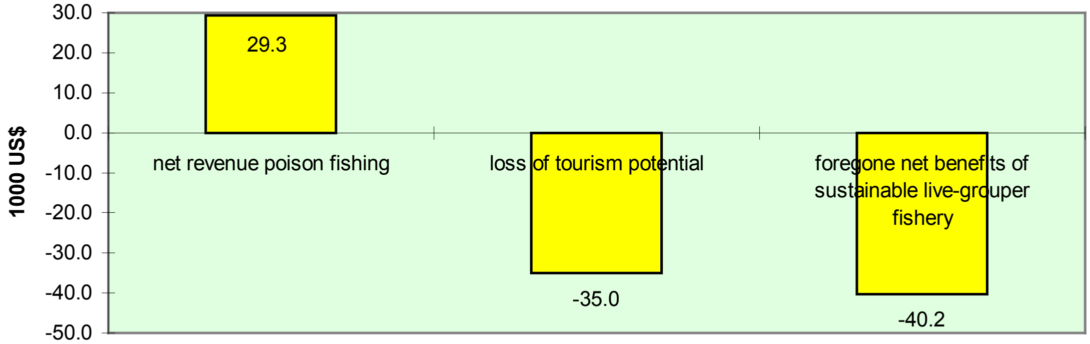
Costs and Benefits per km^2

The analysis above can easily be translated on a per km^2 basis, by dividing all the numbers by the area (8,000 km^2). The results are summarized in Table 3.2.4.

Sensitivity Analysis

As stressed several times, there is large variation and uncertainty about the grouper fishery. Besides, because the poison grouper trade is illegal, the facts about the catches, prices and profits are not known with precision either. A sensitivity analysis could check how robust the results are for variations in the assumptions. However, given the margins that exist between the benefits to individuals on the one hand and the costs to society on the other hand, even considerably higher benefits would not alter the broad picture. Besides, where working hypotheses were formulated above, we have tried to be as conservative as possible with respect to the social costs and to the income generated by sustainable alternatives. For instance, we assumed that poison-free groupers do not

Figure 3.2.4: Net Present Value of Poison Fishing to Individuals and Associated Losses to Society per km2 of reef in Large Scale Operations (in 1000 US$; over 25 years; with 10% discount rate)



yield higher prices, nor that their survival rates are greater. Both these conservative assumptions probably deflated the true benefits of sustainable grouper catch.

Small scale operations

Contrary to the large scale operations, the small scale poison grouper business takes place in or close to fishermen's traditional fishing grounds near their villages. We will present here a cost-benefit analysis for one km^2 of coral reef, based on a hypothetical example of ten menyear of traditional sustainable fisheries (see analogous example in Chapter 2). At some stage, poison fishery is introduced by fishermen from a neighboring village. Once all groupers are harvested, these fishermen move on to other reefs further away from the village.

Yields

As described above, we assume tentatively as a working hypothesis that in moderately fished reefs with 50% reef flat and 50% reef slope, the maximum sustainable fisheries yield is 15 mt/km2/yr of which 5 mt/km2/yr are invertebrates, 1 mt/km^2/yr are groupers (and Napoleon wrasse) and 9 mt/km^2/yr are other finfish. Poison fishery is assumed to harvest the total catchable grouper biomass of 3 mt/km^2, though in reality free-diving probably does not allow the fishermen to catch some of the deeper dwelling groupers. It is not clear what the level of destruction of the coral reefs is once they are impaired by poison fishery: the only examples in the literature discuss situations with various threats at the same time. Due to lack of concrete data, we take the hypothetical situation that poison-damaged reefs have a maximum sustainable fishery yield of 7.5 mt/km^2/year, which goes gradually back to 15 mt/km^2/year with the recovery of the coral colonies[xlviii].

- *A moderately fished reef gives a sustainable finfish yield of 10 mt/km^2/year of which 10% are groupers, as well as a sustainable harvest of 5 mt/km^2/year of invertebrates;*
- *Live food fishery with cyanide yields 3 mt/km^2 of groupers, and destroys coral heads so that the maximum sustainable catch of other fish drops to 7.5 mt/km^2/year with gradual recovery over 30 years.*

Prices

When fishermen sell directly to the live-cage owners (*i.e.* the export agents), prices they can fetch are rather high, though these depend on their bargaining position. One account for Ujung Pandang gives Rp. 15,000 (US$ 7) for red groupers, Rp. 20,000 (US$ 9) for highfin grouper and Rp. 25,000 (over US$ 11) for Napoleon wrasse[xlix]. If reefs are further away from the live cages, a middleman might be present who buys the fish from the fishermen and sells it to the export agent. In this case, the fishermen get a price close to that of the hookah divers of the live-hold 'catcher' boats[l]. This is in line with accounts that fishermen were offered prices of Rp. 4,000-8,000 (i.e. US$ 1.8-3.6) per piece of 0.5-1 kg depending on the species of grouper (i.e. on average around US$ 3.5/kg). In other countries, these prices might be quite different[li]. However, we will stick to the case without middleman, and we will assume that the average price of all groupers and Napoleon wrasse is US$ 7.

- *In Indonesia, fishermen in small operations get on average US$ 7/kg for groupers.*

Hypothetical example

Assume the situation of a reef where no overfishing takes place. The reef is being sustainably fished at the optimal level of effort by 10 menyears. This level of effort might come from more than a hundred subsistence fishermen each catching part-time for some months per year, or from 10 full-time fishing families. We assume that at a certain moment, fishermen from a nearby village fully exploit the grouper stock using cyanide. Before the cyanide destruction, sustainably fishery yield was 15 mt/km^2/yr at an average price of all produce of US$ 1/kg, as explained in Chapter 2. Therefore, gross income is US$ 1500 per year per fisherman (US$ 5 per day). The costs are assumed to be Rp. 60,000 (US$ 27) per family per year (US$ 0.09 per day), so that net income per family is US$ 4.91 per day. The opportunity cost of labor is Rp. 2,000 per day (US$ 0.91), so that net benefits are 80% of gross income.

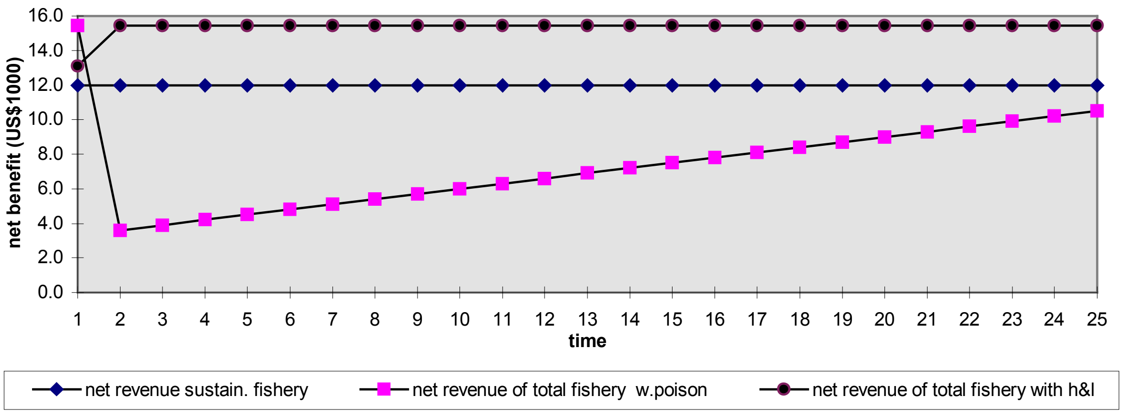
Once the corals have been impaired by cyanide, the effort level of the sustainable yield at 10 menyear drops to 6 mt/km^2/yr (2.55 kg/family/day). The costs stay the same, so that net income isUS$2.47 per day. This means that net benefit is now a smaller fraction of its gross value than before, as more effort is needed for the same catch (the rent drops). Total net benefits become US$ 3,600 for the 10 menyears (60%). Summarizing these assumptions, we get:

- *The net benefit of sustainable fishery is US$ 12,000 per km^2;*
- *The net benefit drops to US$ 3,600 per km^2 after poison fishery has taken place;*
- *Net income drops from US$ 4.91 per day to US$ 2.47 after poison fishery.*

Poison fishermen

Fishermen from the nearby village in our hypothetical example will harvest the catchable biomass of 3 mt/km^2 of groupers within a few months with free diving (very strenuous). We assume conservatively a grouper mortality rate of some 33% during collection. The dead groupers are sold for the normal price of US$ 1/kg (assuming they have no equipment to preserve the fish freshly chilled). Taking a price per live grouper of US$ 7, we therefore get a gross income per year of US$ 15,000. Though it does not take the cyanide fishermen the whole year to collect this catch, we assume that they are not involved in other fishing activities for the rest of their time, therefore, their opportunity costs of labor for the divers is US$ 1200, the net benefit

Figure 3.2.5: Annual Net Benefits of Fisheries With and Without Poison and Hook-and-Line Alternative **(1000US$; per km2)**



they would have had with sustainable fishing.

Other costs for cyanide fishermen are the cyanide and capital and operational costs. Cyanide costs US$ 0.1 per grouper (see above). If the average body weight of groupers is 1 kg, this would imply a total cost of US$ 200. The other costs are mainly a boat with out-board motor (goggles, some life-nets, etc. are often hand made) The total annual costs (capital, depreciation , etc.) are US$ 300 per boat per year. We assume that for the activity of the outside fishermen, two boats will be used)[lii]. Hence:

- *Gross revenue of poison fishing is US$ 15,000 per km^2;*
- *Cyanide costs are estimated at US$ 200 to collect the entire grouper stock per km^2;*
- *Other capital and operational costs total US$ 600 per km^2 for this operation;*
- *Opportunity costs of total labor effort for small-scale poison fishing per km^2 is US$ 2400 (this effort will harvest the entire grouper stock).*

These fishery benefits and costs are depicted in Figure 3.2.5, where sustainable hook-and-line grouper fishery is also considered (to be discussed next):

Sustainable hook-and-line grouper fishery

There are several sustainable alternatives for the poison live-grouper catch. One is grouper aquaculture, which is a difficult and capital intensive business (see for an analysis, Johannes & Riepen, 1995). The other one is hook-and-line grouper fishery, though other non-destructive techniques also exist. This is carried out currently in some places in the Philippines, Indonesia as well as in Australia (where poison fishery bans are well-enforced). For examples of sustainable fishing techniques for live-grouper fishery, as well as prices and exports in Central Sulawesi, see Subroto & Subani (1994).

Here, we will concentrate on the hook-and-line technique, where a bait (typically groundscad) is attached to a hook and a small stone and lowered at some 20-30 meter. The baited groupers are brought to the surface, where their swim bladder is decompressed with the use of a hypodermic needle and kept alive in cages or pens (Marinelife, 1995). A closed season or a refuge can help promote the sustainability of the catch (see above).

This technique is used more and more in Australia for their rapidly growing sustainable live-grouper trade. An experiment in the Philippines was carried out where local cyanide fishermen were trained to use hook-and-line grouper fishery. A philanthropist helped them financially in the first two months to build large live cages and to learn the hook-and-line technique. Since then, the villagers, who used to move with their family from one place to another, have stuck to the new sustainable technique in the same location (Dr. V. Pratt, personal communication). For 10 people, this would imply opportunity costs of labor of two months (no fishery yield in this period). The capital costs for wood and small mesh netting are in the order of US$ 1000, which corresponds to annual costs (interest, depreciation) of US$ 200.

This hook-and-line technique is more labor intensive (it takes 2-3 times as much labor time)[liii] but it can be carried out in a sustainable way with either a closed season or an area closed for hook-and-line grouper fishery. For our hypothetical example, we assume very conservatively that 2 groupers can be caught per person per day, so that a total of around 500 fisherman-days are needed for the sustainable catch of 1 mt of groupers (see above; 1 grouper = 1 kg). With our assumption of 10 menyear per km^2, the remaining effort can be used for other types of fishing in the same area to catch the remaining 14 $mt/km^2/yr$[liv]. If we take the same price per grouper (US$ 7) and the same mortality rate (33%), gross revenue of hook-and-line fishery will be US$ 5,000.

Apart from the two initial months of learning and constructing the cages, the costs are minimal. We assume here that for the sustainable operation, the fishermen need, besides their own out-rigger boats, one out-board motor boat (to bring fish to the LFTV, etc.): costs as above US$ 300 per year. The other direct costs are assumed to be three times as high as before: Rp. 180,000 per person per year (US$ 81.8), due to extra material, such as needles, and the annual costs of the construction and maintenance of live-cages. Opportunity costs are as above. The remaining fishery yields are US$ 14,000/km (with US$ 1/kg)^2. The two months of learning mean that the fishery yield in the first year is only 83% of US$ 14,000 (10/12th). Thus:

- *A sustainable catch of 1 mt/km^2/yr of groupers can be achieved with 500 days of hook-and-line fishery; gross revenue will be around US$ 5,000 plus two initial months of learning and cage construction;*
- *The remaining fishery yields US$ 10,800 in the first year and US$ 14,000 thereafter;*
- *The direct costs of total fishery (including sustainable live-fishery) are US$ 818 and the opportunity costs are US$ 2727;*
- *A closed season or a sanctuary can help promote that grouper fishery is sustainable.*

Costs and benefits of small scale poison fishing

On the basis of the data presented, net benefits are calculated of three fishery options: (A) '<u>fishery with poison for live-fish</u>', (B) '<u>sustainable fishery (no live-fish)</u>', and (C) '<u>fishery with hook&line for live fish</u>'. Appendix 4 gives all the cost items[lv]. The loss of other functions, such as biodiversity and coastal protection is assumed to be the same as for large scale poison operations. For tourism, we make the same assumptions as above[lvi]. Note that recovery of fishery, coastal protection and tourism was presented above in Figure

Table 3.2.5: Present Value of Costs and Benefits of Small Scale Operations of Poison Fishery and Sustainable Alternatives (in 1000 US$; per km2; 10% discount rate)

	fishery with poison for live-fish (A)		*sustainable fishery (no live-fish) (B)*		*sustainable fishery with live-fish (C)*	
	cost	**benefit**	**cost**	**benefit**	**cost**	**benefit**
I groupers						
yield		13.6		9.1		45.4
cyanide	0.2					
other costs	0.5		0.2		5.2	
opportunity labour	2.2		1.7		1.7	
subtotal groupers	2.9	13.6	1.8	9.1	6.8	45.4
net benefits groupers	10.7		7.3		38.6	
II other fishery						
yield		72.3		127.1		125.0
other costs	1.9		2.3		2.3	
opportunity labour	19.8		23.1		23.1	
subtotal other fishery	21.7	72.3	25.4	127.1	25.4	125.0
net benefits others	50.6		101.7		99.6	
III other c&b society						
tourism	40.8		—		—	
coastal protection	0.0		—		—	
biodiversity, etc.	n.a.		—		—	
total	65.5	86.0	27.2	136.2	32.2	170.3
net benefits to soc.	**20.5**		**108.9**		**138.1**	

Source: hypothetical example on the basis of data referred to in the text (Erdmann (1995), Johannes & Riepen (1995), and various pers. comm.

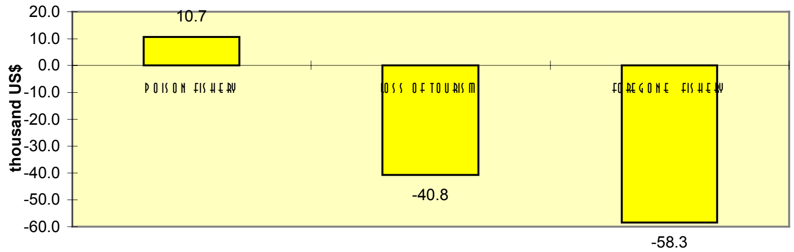
3.2.5. The data are summarized in Table 3.2.5.

Note that benefits are highest in case (C) 'fishery with hook & line for live fish': US$ 138,100. The net loss to society of poison fishery versus sustainable fishery is US$ 88,400 (US$ 108,900 - 20,500) per km^2. It is interesting to see that most of this net loss is due to the loss in the 'other fishery' that suffers from coral destruction. Note also that the net benefits of grouper catch is 3.6 times higher in the hook & line case (C) than in the cyanide case (A). Note that this is much higher than in the large scale operations, because there the 8000 km^2 was sustainably harvested. Instead we assumed that grouper catch was confined to 500 operations. Again, unsustainable practice has lower net benefits, even in the absence of sustainable live-grouper catch, as shown in Figure 3.2.6. The stakeholder analysis will show why the non-sustain-able and destructive practice might still occur in practice.

Cyanide fishermen

The fishermen from the nearby village scoop the catchable biomass of 3 mt/km^2 of groupers out of the area, earning in total a gross income of US$ 15,000 within a year. If two fisherboats (direct costs of around US$ 800 per boat) with two or three men on board are involved in this business, they each earn at least twice as much with considerably less effort that their income of US$ 1,200 in the sustainable situation. When they move on to different reefs in the area every year, they continue to have (C) over and above sustainable fishery (B) is US$ 29,800. Therefore, it is impossible to make the cyanide fishermen better-off with sustainable practices, as long as they are allowed to move around and enforcement is lax.

Figure 3.2.6: Present Value of Net Revenue of Poison Fishery and Associated Losses to Society of reef in Small Scale Operations
(per km2; in 1000 US$; discount rate 10%)



Other fishermen

The other fishermen are big losers in the case of poison fishery. Total net income from one km ^{2} of reef in present value terms is a mere US$ 70,400 in the case that their reef is affected by poison (case *A*). In the case of sustainable fishery, the total net income in present value terms is US$ 133,700 (case *B*: sum of *I* and *II*). Hence, per full-time fishermen, income drops (in present value terms) with more than 36% from net benefits of US$ 13,700 to US$ 8,800. On the other hand, the investment to learn hook & line live-fishery and to construct the live cages during two months is well worth the costs: the additional net benefits are US$ 2,900 per full-time fishermen in net present value terms. This corresponds to a increase in net present income of some 22%.

Rest of Society

The rest of society will clearly win from a shift away from poison fishery. In the first place, tourism potential will go up, the benefits of which are estimated at some US$ 40,800 per km^2 in case of a weighted average of tourism potential[lvii]. As in the case of coral mining, societal loss due to cyanide is much more in famous tourist areas. Besides tourism, other costs of cyanide are biodiversity loss, etc. The rest of society will also clearly gain from a sustainable hook & line live-fish industry that gives value-added to coastal communities.

Aquarium fishery

In the Philippines, it is estimated that there are some 4000 aquarium fish gatherers[lviii]. For Indonesia, no such data are available, though the numbers are probably even higher. Riopelle (1995) states that in North West Lombok alone, over 250 people were involved in the aquarium fish collection. Though ornamental fish can be caught with small nets, cyanide seems the most cost-effective way of collecting them (Riopelle, 1995). This is a rather damaging development for the whole industry, but in particular for the Philippines, once a leader in the global aquarium trade business. This country started to get a bad reputation in the eighties, because of the use of cyanide (Hinggo & Rivera, 1991), though still an estimated 80-90% of collectors in the Philippines use cyanide.

Aquarium fish exports from Indonesia using cyanide seems to be expanding (Erdmann, 1995). Therefore it seems a matter of time, before the Indonesian aquarium fish gets a similar reputation as the that in the Philippines. Aquarists are rightly concerned about the effects of poison: the ornamental fish die typically within months of purchase, because of internal damage due to the cyanide (see above). Besides, more than 80% of the aquarium fishes die throughout the chain from collector to the marine hobbyist (Rubec, 1988).

Riopelle (1995) states that most aquarium fish collectors use compressors or SCUBA equipment. This is also indicated by Galvez et al. (1989). Hinggo & Rivera (1991) indicate that there are two operations: (i) individual shallow water operations with free diving, and

(ii) deeper water operations with compressors and hookah-diving and with 8-12 divers. This is analogous to the live grouper-catch described above, except that the aquarium fish operations stay closer home and probably return daily to the harbor. Riopelle (1995) reports only the larger type of operation (with 5 SCUBA-divers on board). The boats go out apparently to collect aquarium fish one week per month for 10 months of the year.

A short economic analysis of the ornamental fish collection on West-Lombok is given by Riopelle (1985). He reports that fishermen receive on average Rp. 5,000 (US$ 2.25) per fish, but for some Trigger fish, they can receive up to Rp. 40,000 (US$ 18.20). Riopelle shows that the net present value from aquarium fish collection is as high as that of all other coral reef fisheries together. He shows that the net present benefit (at 10%) of aquarium fishery in West Lombok is some US$ 5.5 million, with annual export of US$ 0.8 million. If we assume roughly that 2000 aquarium divers are active in Indonesia, half the number of the Philippines, this could amount to a business in Indonesia with an annual exports[lix] of around US$ 32 million and a net present benefit value of some US$ 42 million.

Christie et al. (1994) report that traditional fishermen in one location in the Philippines earn around US$ 44-66 per month compared to US$ 100 for aquarium fishermen. However, a recent study by Syukur et al. (1994), discussing the aquarium fish market in Southeast Maluku and Sorong (Irian Jaya)[lx], gives a less rosy picture: lack of knowledge of handling, marketing and transportation to international airports local fishermen would not earn more than a mere Rp. 20,000 (US$ 9) per month with aquarium. However, this situation is very site-specific, and probably mainly dependent on transportation possibilities. In Biak (Irian Jaya), aquarium fishery declined dramatically after international Garuda flights discontinued their fuel stop-over there. This also shows that getting environmentally-friendly high-value fishery from the ground is difficult and requires patience and knowledge of local circumstances and market-opportunities.

The aquarium trade will not be discussed further for two reasons: (i) from the above description is appears that the poison aquarium fish trade is in many ways rather similar to the live food-fish trade, especially the smaller and medium size operations; therefore, the aquarium fish trade gives, in its impacts, in its incentives and in its sustainable alternatives, a picture rather similar to that of the analysis for groupers above; and (ii) it seems that the live grouper trade is at the moment much more important in economic terms: taking the above figures, the live-grouper trade appears to be at least three times as big as the aquarium fish trade, and probably even much more.

3.3 Blast Fishing

Introduction

Blast fishing (or explosives fishing) is one of the most destructive anthropogenic threats to reefs. A hand-made bomb is dropped into coral areas, killing or stunning entire schools of reef-fish and small pelagics. These fish can then be scooped up or gathered by free-diving. Introduced in many areas in the Philippines and Indonesia by the Japanese troops in WW-II using hand grenades, it became a popular fishing technique of local fishermen as a way to earn money the easy way[lxi]. Nowadays, it is sometimes the only way for fishermen to earn enough money to feed their families. The gunpowder used to come from old WW-II ammunition shells, dug up by the fishermen. Presently, bombs are often made with chemical fertilizers, such as ammonium/potassium nitrate (NH_4NO_3; KNO_3). Sometimes, dynamite obtained from police and military personnel or from mining companies and civil engineering projects is used[lxii].

Explosives fishermen hunt specifically for schooling reef fish and pelagics. However, the blast also kills many other species, especially with air bladders, as well as many larvae, juveniles and inedible species. The explosion often shatters the stony corals to pieces, especially when the explosion occurs close to the reef bottom. A beer bottle-sized bomb typically destroys an area with a diameter of 2-3 meter (McManus et al. 1992). In this way, the live coral cover has been reduced with 60% due to blast and cyanide fishing in the Philippines (McManus et al.; 1992). Fishermen themselves can also get hurt. In coastal localities, the presence of men with only one arm is apparently a reliable indicator of dynamite fishing (Alcala & Gomez, 1987).

Though forbidden in Indonesia and elsewhere, and despite the dangers, home-made bombs are still a very popular fishing ‘gear’. Close to the town of Biak (Irian Jaya, Indonesia), bombs are timed to coincide with the noise of arriving airplanes, so as to avoid detection (Muller, 1995). In other coastal areas, there is little chance of being caught and several explosions can be heard per hour[lxiii]. It is not clear how many fishermen use explosives. Rubec (1988) states that in the Philippines, 50% of fishermen use bombs at least part of the year, though Pauly et al. (1989) state that in Lingayen Gulf, this number is only 3-4%. Besides the small scale blast fishery, there is a considerable large scale explosion fishing fleet, mainly operating from Ujung Pandang with fishing grounds often in Eastern Indonesia.

Galvez et al. (1989) describe socio-cultural aspects of blast fishery in the LingayenGulf area (Philippines). They point specifically to the local acceptance of this fishing technique, because almost all members of the community benefit from it: poor families often get a handful or more of the harvest of blast fishermen. With peak catches, a fiesta is celebrated by the whole community, attended also by members of the town police, the constabulary and the coast guard. Also, other fishermen who do not use explosives are allowed to accompany the blast fishers, sometimes in exchange for part of the catch that the non-blast fishermen trawl in the dynamited area.

Explosives and their effects

Damage to Corals, Fish and Fishermen

A beer bottle bomb appears to shatter to pieces stony corals in an area of some 5 m^2 (diameter 2.5 m) and a one gallon sized bomb destroys corals in an area of around 20 m^2 (diameter 10 m)[lxiv]. The area in which most fish with air bladders are killed by an explosion is many times greater than this (McManus et al. 1992). Alcala & Gomez (1987) quote findings that four of the five genera tested of Pacific Ocean fish with air bladders were killed ca. 16 meters away from a bomb with some 4 kg of explosive charge and that five genera of fish without air bladders all survived at this distance. Translating this, it suggests that a bomb destroying corals in an area of a diameter of β meter would kill most fish with air bladders in an area of at least 2β meter and probably much more[lxv]. Human hazard: one in every 5-6 dynamiters in three Philippine localities has either lost one or two arms or died instantly.(Alcala & Gomez, 1987).

Fishery

Blasted areas have lower fish biomass and fewer fish species, partly because larger reef fish can not find shelter any more in the destroyed reefs, making them an easy prey for pelagics. Also, less demersal plankton is generated by coral rubble as compared to that found among healthy corals (Alcala & Gomez, 1987). McAllister (1988) suggests that reef productivity declines from 13-18 mt/km^2/yr for reefs in good to excellent condition to 3 mt/km^2/yr for reefs in poor condition, often as a result of blasting. Rubec (1988) suggests a difference of a factor five or so between yields of non-destroyed and heavily blasted reefs[lxvi].

On the basis of these records, we will assume here very roughly as a first conservative guess a factor four difference in maximum sustainable yield between heavily blasted reefs (75% destroyed or more) and intact reefs. Hence,

- *Reefs destroyed by explosives are assumed to be four times less productive in terms of max. sustainable yield than intact reefs.*

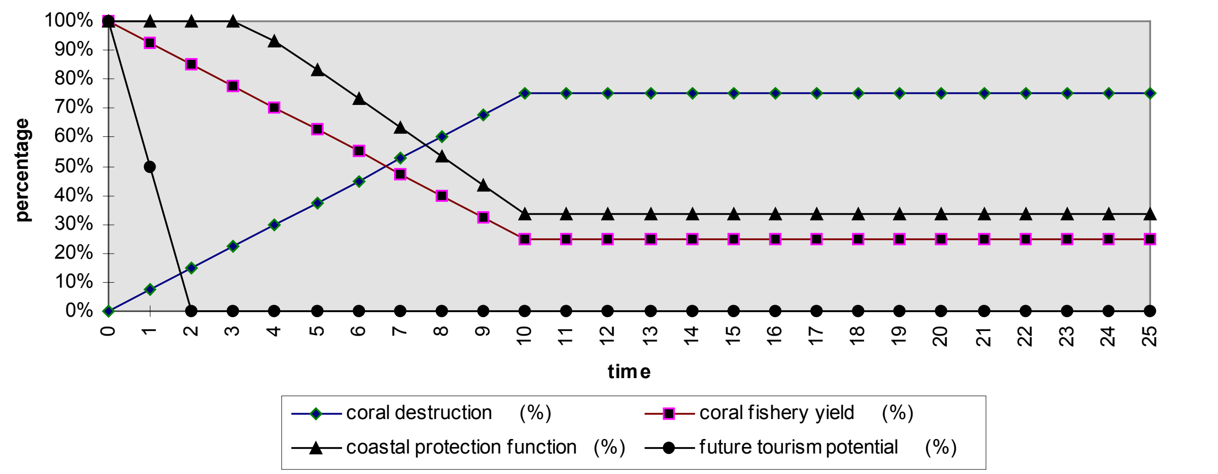
Tourism, Coastal Protection and Other Functions

The tourism industry holds a great promise for alternative income generation in reefs that are not too remote. However, even sporadic blast fishing can kill the reputation of a SCUBA-area for divers. Divers who happen to be in the vicinity of blast fishermen can feel a thud on their body and can even die. The coastal protection function will suffer over time with the destruction of the stony corals, after a period of time when enough coral are left to prevent sand erosion. Our working hypothesis is that that the coastal protection function starts to be affected once 25% of the corals are destroyed and that function will decline linearly, reaching zero when all corals are destroyed[lxvii]. The dynamics of this process will obviously vary greatly with the local circumstances, and are very difficult to generalize. Other functions, such as biodiversity and research, will also be severely impaired by bombing: fish abundance and density are dramatically lower in blasted areas[lxviii].

- *In areas with blasting, there is assumed to be no coastal tourism;*

- *The coastal protection function will start to be affected once 25% of stony corals have been destroyed and decrease linearly, reaching zero when no corals are left*

Figure 3.3.1: Destruction of Coral Reefs and of its Functions due to Blast Fishing



Recovery

Coral recovery after blasting can be extremely slow. Alcala & Gomez (1979) mention that 38 years are thought to be required for a reef to recover to 50% hard coral cover. This may even be an underestimate of the time required: certain reefs in the Philippines have not recovered significantly in 9-10 years following the blasting[lxix]. This may be due to the fact that the rubble can move back and forth with the current, making recolonization difficult. Also, recovery of fishery is also slow.

Christie et al. (1994) present a comparison of recovery after overfishing between two Philippine islands, where sanctuaries were established. The relatively intact reef, in Apo island, with a total live coral cover of 64% and a mortality index of some 25%, had an increase in fish abundance of 173% in one year[lxx]. The other island, San Salvador, with a total coral cover of 32% and a mortality index of 51%, witnessed an increase of only 43% in two years. Besides, fish abundance was already more than three times higher in Apo to begin with.

Economic Analysis of Explosives Fishing

On the basis of factual information as well as our own tentative assumptions, a hypothetical example for one km^2 of reef will be constructed in order to gain a rough first insight into the economics and stakeholder analysis of small scale blast fishing. As before, we consider only one threat at the same time, so we assume that no poison fishing, no overfishing and so forth are taking place at the same time in the one km^2 area. The economic analysis will be carried out over a 25 year time horizon.

Types of Operations

There are several types of blast fishing operations. Erdmann (1995) describes vessels of around 10-15 meter with a crew of some 10-14, embarking on week-long trips to patch reefs or fringing reefs of uninhabited islands around the Spermonde archipelago (South Sulawesi, Indonesia). Their weekly profit is reportedly some US$ 2,800-4,650 per week.

Given the relatively low price of the fish, this implies a catch per week in the order of 5,000-10,000 kg[lxxi]. Galvez et al. (1989) describe small scale operations with one 'diver' who tries to detect schools of fish and one 'thrower', going out for a couple of hours per day. Both scoop and free-dive for the fish after the explosion, possibly helped by some others. It is these small scale operations that we will investigate further in the remainder of this section, as the large scale operations are probably rather similar to those of poison fishing. Our choice does not imply that large scale operations are less of a problem: in fact, recent information suggests that the large scale operations might be much more problematic in Indonesia, contrary to the Philippines where the small scale operations are much more widespread.

Frequency

The blasting frequency can be extremely high, as mentioned above. McManus et al. 1992) report the occurrence of 10 explosions per hour in an area of 2-3 km in Bolinao (Philippines), which corresponds to some 2-5 blasts per km^2 per day (taking 6 hour fishing days[lxxii]). After rumors of tightened enforcement spread, this number dropped with 90%. Christie et al. (1994) report 3.2 bombs per day on the west coast of San Salvador Island (Philippines), an area with some 3-4 km^2 of coral reef. After the introduction of community-based management, only a single blast has occurred. Note that in the small scale operations, often only one bomb is used per day[lxxiii]. Taking these numbers as a yard-stick, we assume conservatively in our <u>hypothetical</u> example that one bomb is used per day per km^2, and we assume no bombing in case of appropriate enforcement.

- *In our hypothetical example, we concentrate on small scale operations (two fishermen); such operations make one-day trips, using one bomb per day;*
- *We assume that on average one bomb is used per day per km^2; this can either be done by one full-time operation or many part-time operations;*

Price of Fish

Explosives fishermen catch especially schooling reef fish, such as fusiliers (*Caesio spp.*), surgeon fish (*Acathurus spp.* and *Naso spp.*) and rabbitfish (*Siganus spp.*), as well as pelagics, especially mullets (*Mugilidae*), jacks (*Carangidae*) and sardines (*Clupeidae*). The price of fish caught with bombs is considerably lower than when other techniques are used, because they get stale more quickly and typically have broken bones. Information sources in Biak (Indonesia) mentioned a price of Rp.1000/kg of such fish, 45% less than the regular price there (around Rp.1800/kg). Other accounts have also indicated a lower price, but with a less dramatic difference[lxxiv]. On the basis of combined information, we assume roughly that blasted fish cost one-third less than other fish. So:

- *Blasted fish have a price 33.3% lower than the 'normal' price.*

Costs of Explosives Fishing

Bombs are often hand-made by filling a beer-bottle with explosives charge and sand and using a wick and a blasting cap. On the basis of different sources of information[lxxv], we tentatively estimate the price of a beer bottle bomb to be US$ 1. Other costs are typically the same as in small scale fisheries without explosives. As in the previous sections, opportunity costs are taken to be Rp. 2000 per person per day. The other daily costs are capital and recurrent expenditures for an out-board motor boat, for petrol, nets and ice. In this hypothetical example, these are roughly taken to be Rp. 4800 per day. This gives:

- *A beer bottle sized bomb costs US$ 1.*
- *The opportunity costs of labor is in total Rp.4000 (US$ 1,82) for two fishermen;*

- *The other costs (boat, petrol, ice, nets, etc.) are taken to be Rp.4,800 (US$ 2.18).*

Yield

Non-blast fishermen quote that the reason for explosive fishing is to "earn money the easy way" (Galvez et al., 1989). Andersson (1995) reports that in Mafia island (Tanzania), dynamite fishermen catch in 2 days as much as other fishermen catch in around 20 days. McManus et al. (1992; p. 12) reports that blast fishers have "returns of ten times or more on the investment in the blasting device, and substantially better catches per hour than with traditional gear". Own observations have indicated that in Biak (Indonesia), where reefs are in moderate condition[lxxvi] one bomb allows the catch of some 10-20 kg of fish (US$ 5.5-11), whereas traditional grill nets would allow these values of sales only in "very good days". McManus (personal communication) stated that in heavily overfished reef areas of the Philippines, blast fishermen catch 10 kg in two hours, whereas traditional fishermen catch only 1 kg in six hours, though sold at a higher price.

Note that the above accounts are all for partly or heavily damaged reefs. We assumed that intact reefs have a yield four times higher than that of a largely destroyed reef. On the basis of this combined information, we take that the yield per small scale blast fishing operation is 30 kg of reef fish and small pelagics for intact reefs and 7.5 kg for largely destroyed reefs.

The 7.5 kg is the yield at which fishermen are indifferent between using explosive fishing and alternative income generation, given the opportunity costs of labor of Rp. 2,000 per day[lxxvii].

- *The yield per bomb is 30 kg for intact reefs and 7.5 kg for heavily bombed areas.*

Other fishery

The remaining fishery will undoubtedly suffer from the blasts: non-targeted fish are wiped out, juveniles and larvae are killed and, probably most importantly, the resource base itself is destroyed. In order to keep the analysis as simple as possible, we assume here that blast fishing does not lead to overfishing and that the remaining catch is at its maximum sustainable level (MSY) every year. The 'other' fishery yield will therefore be the MSY, given the level of destruction, minus what the blast fishermen have caught. The MSY's for the different levels of reef destruction have been discussed in Chapter 2. The total 'other' costs and the total opportunity costs of labor will change over time due to the fact that the total level of optimal effort declines over time with the destruction of the resource base.

- *The blast fishery yield and the remaining fishery catch together will equal the maximum sustainable yield for the prevailing level of coral destruction:*

Table 3.3.1: Present Value of Costs and Benefits of Blast Fishing and the Sustainable Alternative per km2

(in 1000 US$; 10% discount rate; 25 years)

	fishery in presence of blast fishing		sustainable fishery (no blast fising)	
	cost	benefit	cost	benefit
I blast fishermen				
yield		28.2		
explosives	2.7			
other costs	5.9			
opportunity labour	5.0			
subtotal blast fishing	13.6	28.2		
net benefits blasting	14.6		0.0	
II other fishery				
yield		28.2		136.2
other costs	0.5		2.5	
opportunity labour	5.1		24.8	
subtotal other fishery	5.6	28.2	27.2	136.2
net benefits others	22.6		108.9	
III other c&b society				
tourism	481.9		—	
coastal protection	193.0		—	
biodiversity, etc.	n.a.		—	
total	694.1	56.4	27.2	136.2
net benefits	**-637.7**		**108.9**	

Source: hypothetical example on the basis of data referred to in the text (esp. Galvez et al, 1989; McManus et al, 1992; Alcala & Gomez, 1987; Pauly et al, 1989; Rubec, 1988, and various pers. comm.

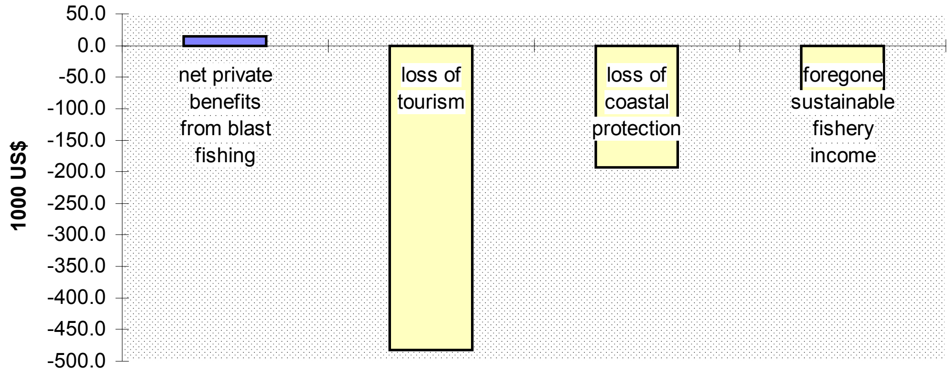
Costs and Benefits to Society

Blast fishing destroys the very habitat that the fish are directly or indirectly dependent upon. Therefore, it is no surprise that explosives fishery generates a net loss to society, compared to non-destructive fishing. This is shown in Table 3.3.1, where the present value of costs and benefits of blast fishing and the sustainable alternative are given per km^2 in the case of low tourism potential.

The net loss to society due to blast fishing is US$ 92,200 per km^2 of reef (US$ 108,900 - US$ 16,700). Both the sustainable fishery and the remaining fishery take place at the level of maximum sustainable yield for remaining fishery, this implies a very low level of effort: only one man-year after year 10. In reality, we will probably find overfishing occurring once the resource base has been partly destroyed, slightly changing the results. Here, we have deliberately chosen for 'optimal rent' fishing of the remaining fishery. This means that it is assumed, for simplicity, that the redundant fishermen will find alternative sources of income. Note that all data are in man-year. Given the subsistence characteristics of much of the artisanal fishery, this might actually imply that quite a large number of fishermen are involved who spend only part of the time and part of the year in fishery.

The main cost of blast fishing in the case of low tourism potential are the net forgone benefits of sustainable fishery (see Figure 3.3.2). In the case of high tourism potential, the coastal protection and tourism value

Figure 3.3.2: Net Present Value of Blast Fishing to Individuals and Associated Losses to Society per km2 of Reef
(Scenario: HIGH; in 1000 US$; over 25 years; 10% discount rate)

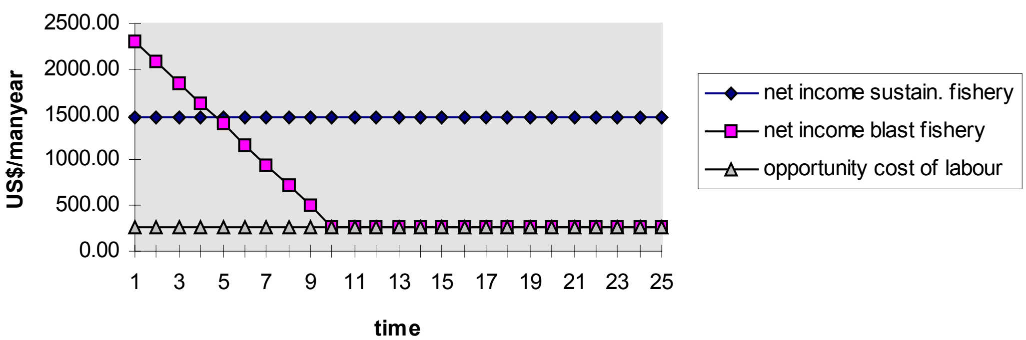


become the main cost of blast fishing. Given the large net loss to society from blast fishing, one might wonder why this activity continues to exist. In order to answer this, a very brief stakeholder analysis will be carried out.

Blast Fishermen

The small-scale blast fishermen are, in the beginning, often attracted by the ease with which they can earn money (Galvez et al., 1989). Later on, it becomes much more difficult to have the same success, but by that time, the resource-base has been destroyed, and traditional fishery, especially with overfishing, would only give them income close to the opportunity costs of labor. Figure 3.3.3 illustrates this trap. Note that if one fisherman decides not to use bombs but his neighbors do, this fisherman is even worse off: he does not reap the benefits, but does incur the costs. This prisoner dilemma situation probably increases the incidence of blast fishing considerably. At a low discount rate, such as the 10% we use throughout, a traditional fisherman would have little incentive to change. However, at a higher rate of some 23%, it starts becoming attractive for a fisherman to shift to blast fishing.

Figure 3.3.3: Annual Net Income of Poison Fishermen, of Other Fishermen (in Absence of Blasting) and Opportunity Cost of Labour
(per manyear; in US$)



3.4 Coral Mining

Hard corals have long been used for building material and for the production of lime, as well as in the ornamental coral trade. For the Philippines, Rubec (1988) gives an estimate of 48,000 mt/yr of stony corals gathered, of which a considerable portion is exported as ornamental coral, by far the largest exporter (92%) of live coral to the United States, itself the world's largest importer. Exports totaled more than 420,000 pieces in 1993. Dead coral exports from Indonesia to the USA amounted to an annual average of some 642,000 pieces over the last five years. The total value of this trade in, unfortunately, not known[lxxviii]. Nor is it certain whether these figures reflect the corals collected in Indonesian waters or whether a portion originates from the Philippines which has banned exports, in order to avoid customs' problems in the USA.

In the Maldives, coral rock is now the main construction material, with mining taking place at a rate of 20,000 m^3 per year (Brown & Dunne, 1988). In Indonesia, mining of coral rock for construction is taking place in Kalimantan and to some degree in Java, Sulawesi and Maluku[lxxix], though the extent is unknown. Coral mining is relatively less important in Eastern Indonesia where fewer houses are built of stone. Coral mining for lime production for the construction of houses is widespread in Lombok, where some 500-1000 families used to be involved in the business, but recently that number has come down. In South Sulawesi, coral rocks are used to line shrimp ponds, and coral lime is used as a pH-regulator.

Collection, mining and dredging of corals impact heavily on the reef ecosystem. For instance, sites where coral rock mining took place ten or more years ago, show very slow recovery of the mined areas (less than 10 cm). Also, current live coral cover is still very low ($< 1\%$)[lxxx]. Mining also decimates the reef fishery in these areas and might even lead to an irreversible collapse of the reef ecosystem. Beside these direct effects, unintended off-site impacts of mining, such as sand-erosion, loss of land, sedimentation, etc. are often severe[lxxxi]. Some hotel owners in Bali and Lombok invest over US$100,000 annually to protect beaches prone to mining-induced beach erosion. Collection of ornamental coral rocks (live rock) could, in principle, be done in a sustainable way without much damage, though there are reports on impacts of such activities as well (Wells & Alcala, 1987).

Few data exist on both the extent of coral collection and mining as well as on damage due to these activities in Indonesia. Here, data will be presented on lime production only. Coral mining estimates for other purposes (e.g. coral rock for construction) will not be presented due to lack of available data[lxxxii]. The estimates for lime manufacturing are partly based on data gathered from a village in West Lombok, as well as on other accounts in the literature. In the economic analysis, the costs and benefits will be calculated for one km^2 of reef, in the absence of any other threats. Note that in the village used in the example, this was probably not exactly the case. Here - and throughout the paper - we assume however a hypothetical example of sites subject to an individual threat.

Lime Production[lxxxiii]

In West Lombok, 60 families have mined over the last 10 years a stretch of 2 km along the shore. The reef flat is 0.5 km wide. The coral is collected, burnt and sold as lime. The lime is of poor quality and sells for one third of the price of cement: lime is Rp.80-120/kg and cement is around Rp.250-400kg. It is sold to the private sector and to the local government, mainly for house construction and plaster for schools and other government buildings. The lime is of poor quality, however, and is mixed with cement and sand before use for construction. For plaster, it can be used on its own. Each year, a family produces and sells around 600 bags of lime (25 kg) for Rp.3,000 per bag[lxxxiv]. This gives the following estimates for further analysis[lxxxv]:

- *Each family mines on average about 1660 m^2 per year, or one ha. every six years. This corresponds to 3.3 meters of coastline per family per year.*
- *A family produces 15 mt of lime per year sold at a total price of Rp.1.8 mil.(US$ 818).*

Fuel Wood[lxxxvi]

A crucial input for the mining process, besides coral, is locally harvested wood. Each group of 3 families uses one truck load (5 m^3; 100,000 Rp.) per month. Not much is known about this fuel wood, but, given the price, it is assumed that it is secondary forest exploited in a non-sustainable manner. Secondary forest would give 100m^3 of fuel wood per ha. This means that one ha. of this forest is destroyed every 5 years for lime production of one family. If the fuel wood came from sustainable logging in plantation forests, the price in Indonesia would be twice as high (1 m^3 is around Rp.40,000), but no forest would be irreversibly destroyed. Hence:

- *Each family uses 20 m^3 of fuel wood per year, harvested from 0.2 ha;*
- *The financial costs of the fuel wood per family per year is Rp.400,000 (US$ 182), whereas the economic costs are assumed to be double that amount (Rp.800,000)*[lxxxvii].

Side-payments

The other main cost is a payment for protection -mining is illegal- of around 240,000 Rp. per year per family. However, this is only a transfer of resources, and this political rent-seeking is assumed not to have efficiency implications. Therefore, this cost will not be included in the economic analysis, though it is part of the financial analysis. In other areas, instead of protection-payments, there may be similar transfers for renting the land. Thus, we assume here as a first approximation that:

- *The annual cost of side-payments per family is Rp.240,000 or US$ 109. This is a financial but not an economic cost.*

Labor[lxxxviii]

The lime production process is a family business where the father and some of the sons are involved in mining, and the whole family - particularly women - is involved in the breaking of coral, burning and sieving process. In the financial analysis, cost of labor input to the family is therefore zero. In the economic analysis, however, opportunity costs of rural labor will be taken into account. For Lombok, these costs are taken to be Rp.2,000 per person per day[lxxxix]. However, the labor opportunities are severely constrained. Otherwise, they would, according to themselves, not have started with the coral mining in the first place. We therefore assume conservatively that only one person in the family could otherwise have been employed productively elsewhere in the local rural economy for Rp.2,000 per day. Assuming a six day work week and 50 weeks per year, we get:

- *The labor costs in financial terms are zero;*
- *The opportunity cost of labor is taken to be Rp.600,000 (US$ 273) per person per year; in the absence of mining, only one person per family is assumed to find work.*

Alternatives For Lime[xc]

There are several alternatives for lime. First, lime can be produced differently, using hard coral rock found inland. However, this is not economical, as one needs 5 to 10 times as much wood for burning inland limestone , making the price of this similar to that of normal cement[xci], unless other types of energy are used[xcii]. Secondly, lime can be substituted for an alternative product, such as pure cement. This is not produced in Lombok and is imported from elsewhere in Indonesia. The price difference is around a factor of 3 (see above), but cement is of much higher quality (see above). Typically, hotels and other big constructions use cement, whereas, lime is used for housing for the relatively poor on the island. Note however, that pure lime is too weak for construction, but can be mixed with cement (J. de Schutter, personal communication).

A third alternative is to build without using lime or cement, e.g. by using wood only. However, houses of stone are often a status symbol. Besides, wood also has its problems (non-sustainable logging). Basically, the only reason why lime is so cheap is that the corals are unpriced and the wood is underpriced. Therefore, we will assume for the remainder of the analysis that there are no economic costs involved in substitution to cement and other alternatives in case of an effective enforcement of the ban on coral mining. Thus:

> *Substitution to alternatives in case of effective enforcement of the ban on coral mining is assumed to have no economic cost to society.*

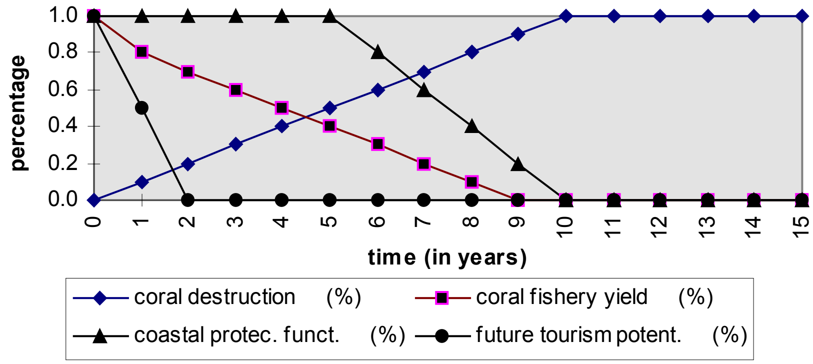
Costs to Society

- Extraction of corals for lime production affects the reef functions of fisheries, coastal protection, tourism, biodiversity, etc. The costs of some of these have been discussed in Chapter 2. Coastal protection and tourism have different values depending on the location of the threat (the LOW and

Summary of Assumptions of Lime Production:
(See also calculations in Appendix)

- Each family sells 600 bags (15 ton) of lime per year at Rp.3,000, earning gross annual income of Rp.1.8 million (US$ 818). Each family spends 400,000 Rp. (US$ 182) on fuel wood and Rp.320,000 (US$ 145) on side-payments as well as Rp.80,000 (US$ 36) on other cost items. So net annual family income is 1 million Rp (US$ 455).
- In the absence of mining, families would earn a net income of Rp.600,000 (US$ 273).
- Every six years, a family harvests the corals of one ha. of reef and the fuel wood of 1.2 ha of secondary forest, thereby producing 90 tons of lime; one ha. of reef gives a total gross revenue of Rp.10.8 million (US$ 4,909).

Figure 3.4.1: Destruction of Coral Reefs and of its Functions due to Coral Mining



the HIGH value scenario). Annual fisheries income is assumed to be US$ 15,000 and net revenue is US$ 12,000. As stated before, the other functions will not be valued, however important they are. Instead, the sum of quantifiable damage will be used as a proxy for the lower-boundary of total costs of reef destruction.

Destruction and Recovery of Coral Reefs

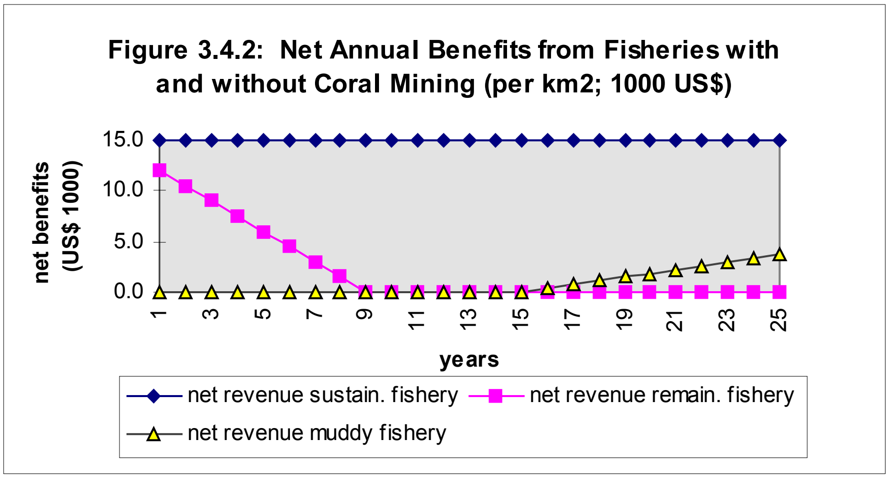
As discussed in Chapter 2 above, much controversy exists over the recovery of corals and of reef products after destruction. In several areas, mining and the subsequent loss of coastal protection give rise to a soft-bottom eco-system, with no corals and muddy water. It is unclear how quickly the new eco-system will have taken over. From field observations in Labuhan Haji (Eastern Lombok), it seems that five years after mining has stopped, the water has become turbid and no new coral growth was visible[xciii]. We assume here that gradual destruction (over 10 yr.) of the corals takes place. This leads to a linear decrease in the yield of reef fish and other reef-related organisms.

The coastal protection function is not directly affected, as long as there are enough corals left to break the waves. Therefore it is assumed that the protection function starts breaking down gradually after five years of mining. Tourism, on the other hand, is assumed to be directly affected. Since diving tourists are very sensitive to coral destruction, they will switch quickly to other diving destinations. Therefore, it is assumed that after two years, tourism has gone to zero. After the area has been fully mined, the new soft-bottom eco-system will slowly take over. It is assumed that no recovery of the corals, the coral reef organisms nor of the coastal protection function and tourism. Therefore:

- *Mining of 1 km^2 over ten years leads to irreversible destruction of the reef ecosystem;*
- *The coastal protection function decreases gradually once 50% of the reef is affected;*
- *Reef fishery will decline gradually with the mining;*
- *Tourism will collapse immediately (no tourism left after two years of mining).*

Pelagic Fishery after mining

It is assumed that the maximum sustainable yield (pelagics) of the new soft bottom ecosystem is 50% of that of the old system and that this starts to take over 5



years after the threat has disappeared and takes 10 years till it reaches its potential. The price of soft bottom is assumed to be Rp.1,000 per kg, whereas, average price of reef-related organisms is Rp.2,000 per kg. As above, we assume a 20% gap between gross and net revenues. This gives the following (see also Appendix 7):

- *Mining implies succession of a coral ecosystem to a muddy water ecosystem;*
- *The present value (25 yr.) of net benefits from the sustainable yield of the reef is US$ 108,900, whereas the corresponding value of the reef yield, gradually destroyed by mining is US$32,300;*
- *The present value of the muddy ecosystem is US$2,100; Therefore, the incremental foregone cost of fishery is the difference of the three: US$74,900.*

Overview of Costs and Benefits

The production figures for lime, together with the fishery data, forestry data, opportunity cost of labor and the estimates for sand erosion and tourism allow us to calculate the net present value of mining, both in economic and in financial terms The estimates are given on a per km^2 basis. Given that coral mining is by definition not sustainable, the only alternative to mining is 'no mining'. This does not imply, however, that 'no mining' is per definition the preferred option: it will depend on the costs and benefits of both options. The option 'no mining' has zero costs and benefits: the only benefits and costs are the foregone gains and damages of mining, which are already included in the costs of mining.

The direct costs and benefits are calculated over a 10 year period, the time it takes for the village to mine a km^2 of reef. The estimates follow straight from discounting the data discussed above over a 10 year time period. The indirect cost and the opportunity cost of sustainable fishery will remain after the 10 years. Therefore, these costs will be calculated for a 25 year time period. This gives both for miners and for society an idea of the net present value of the mining activity of one km^2 of reef (see Appendix 7 for calculations). First, the costs and benefits will be discussed in remote and sparsely populated areas.

The table shows that coral mining is a truly marginal activity. The financial analysis (shaded blocks) show that the net present value of mining for the miners is US$ 67,000 over the ten year period. This will be further discussed in the stakeholder analysis below. The economic analysis

Table 3.4.1: COSTS AND BENEFITS OF CORAL MINING PER KM^2 (in 1000 US$) (assuming 0.5 km reef flat and 2 km of shore line, it takes 60 families 10 years to mine 1 km^2, sparsely populated)							
Mining				**No Mining**			
costs		*benefits*		*costs*		*benefits*	
direct costs		**direct benefits**		**direct costs**	**0**	**direct benefits**	0
labor	0	sales of lime	302				
wood	67						
protection	54						
other costs	13						
		protection	54				
indirect costs				**indirect costs**	0		
sand erosion	0.4						
increm. wood price	67						
other functions	na						
opportunity costs				**opportunity c.**	0		
foregone tourism	0.0						
incremental fishery	75						
labor	101						
total costs	377	**total benefits**	355	**total costs**	0	**total benefits**	0
costs miners	235	**benefits miners**	302	**costs miners**	0	**benefits miners**	0
Net Present Value (economic):			-22	*Net Present Value (economic):*			0
Net Present Value (financial):			67	*Net Present Value (financial):*			0

shows the loss of mining to society in net present value terms of US$ -33,000 per km^2 even for 'LOW' value scenario. The fishery function has value US$ 75,000, the incremental wood price is US$ 67,000, the value of the tourism function is US$ 2,900 and that of the coastal protection function is US$ 12,000[xciv]. This means that even if the foregone fishery benefits and the indirect external costs of fuel wood are considerably less than assumed, mining would still imply a net loss to society.

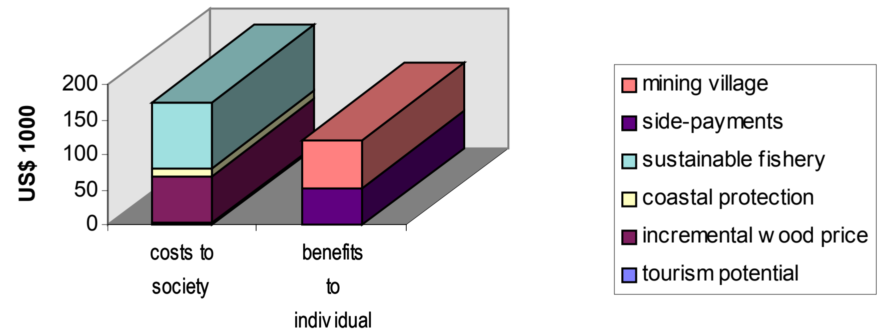
In the 'HIGH' value scenario (with discounted erosion costs of US$ 260,000 and loss of tourism worth US$ 481,9)[xcv], the contrast between costs and benefits will be even more pronounced: US$ 637,000 versus US$ 355,000. This means that the net present value of mining is US$ -281,000. Note also that the miners themselves have again a net revenue of only US$ 67,000, and that the fishery function and the incremental wood price are US$ 75,000 and US$ 67,000 respectively. The difference between the benefits to miners and the cost of wood is the present value of side-payments (US$ 54,000), which form a cost for the miners but not to society, as discussed above.

Stakeholder analysis

Miners and Loggers

The 60 mining families make their living out of coral destruction. Each of these families earns around 1 million Rp. (US$ 455 per year) per year[xcvi]. From the above analysis, it is clear that with all externalities included in the price, this would not be a viable livelihood. The financial analysis shows, however, that for the village, the benefits of mining are higher than the costs, if we assume that no sustainable fishery would not be an alternative for the miners: US$ 302,000

Figure 3.4.3: Costs to Society and Benefits to Individuals from Mining
(LOW-scenario; Present Value; 25 year; 10% discount rate)



versus US$ 235,000. If fishery were an option for the rest of the family, while one person would work outside as day labor, the cost of mining would actually exceed the benefits (US$ 328,000 against 302,000). The village's lack of affinity with fishing, as well as the lack of alternative income opportunities cause the mining activity to continue even though it does not make sense from a national or provincial point of view.

It is not clear how many fuel wood loggers and other people are indirectly employed as a result of the mining activity, but it would probably not involve more than 20. This would mean that a total of some 80 families would have to be offered alternative income generation, where each family would have to earn at least US$ 455 per year. For 80 families, this amounts to US$ 36,400 per year, assuming that the 20 non-mining families have comparable income as the miners.

Fishermen

Local fishermen will be one of the gainers of enforcement of the ban. We assumedabove that sustainable fishery could produce as much as 15 mt of fish per km^2 per year. As discussed in Chapter 2, the optimal effort would be 10 menyears. Mining would displace these fishermen, either pushing them into off-coastal pelagic fishery (tuna, etc.) or into a different livelihood altogether (or into poverty).

Tourism Industry

As mentioned above, some resorts in Bali and Lombok are spending over US$ 100,000 per year to prevent sand erosion to take place in previously mined areas. This is far more than the income of the miners that caused the destruction. Hotel owners along a stretch of beach in Bali have found an interesting Coasian solution to stop mining by offering employment to all miners or their sons in the hotels as gardeners or otherwise. The tourism industry, aware of the potential costs of sand erosion, are now also making the quality of coral reefs one of the main criteria in new resort site selection.

3.5 Sedimentation and Pollution

Sedimentation (or siltation) and pollution from the effluent discharge of industrial

Table 3.5.1: Temporal Comparison of Average Nutrient Concentration in the Jakarta Bay Area (years: 1964-1992; standard deviations in parentheses; units in μg-at/l)				
Nutrients\Year	*1964-1973*	*1975-1978*	*1985*	*1992*
phosphates	*0.67 ± 0.32*	*0.36 ± 0.15*	*1.09 ± 0.93*	*1.36 ± 1.35*
nitrates	*0.48 ± 0.22*	*0.62 ± 0.63*	*1.41 ± 1.00*	*2.71 ± 2.70*

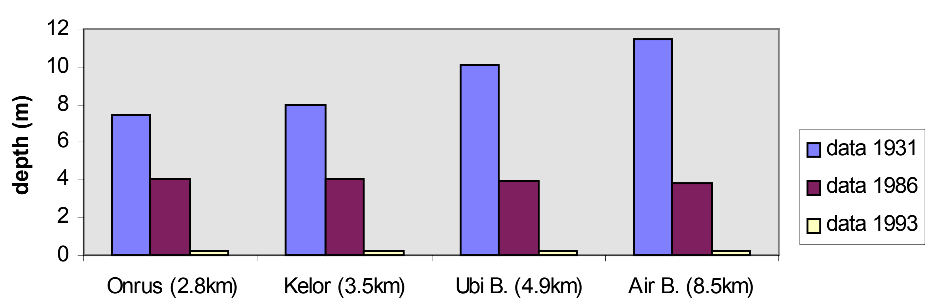
Source: Tomascik et al. (1993); references to primary data sources are given there.

waste, domestic waste, agricultural sources (erosion and agro-chemicals) and logging practices do great harm to corals. Sedimentation smothers corals, as they prevent coral from capturing sun light and plankton - their primary sources of energy and nutrition. Contrary to the acute stress caused by destructive fishing practices, chronic stress of sedimentation leads to slow and gradual decline of the health of reefs. This, in turn, impedes growth and makes corals more susceptible to disease and death.

Sedimentation and pollution is particularly problematic close to large urban areas (Jakarta, Manado) and close to areas with erosion, logging and mining. As Indonesia is very spread out with more than 17,000 islands and population is concentrated to a large extend in Java (around 60%) and in urban pockets elsewhere, sedimentation and pollution might not be as much of a problem in Indonesia as it is in many other countries. However, locally it might be very severe. Table 3.5.1 shows an increase in the nutrient concentration in Jakarta Bay, originating mainly from human and industrial waste of Jakarta and from erosion in close-by rivers (Citarum, etc.).These increases in nutrients have led to algae blooms and associated water turbidity and eventually to death of many of the corals in the Bay area. This is illustrated in Figure 3.5.1 showing the maximum depth of living coral reef among four islands in the Bay area at different distances from Jakarta[xcvii].Note that at the moment, there is virtually no coral left in the islands close to Jakarta.

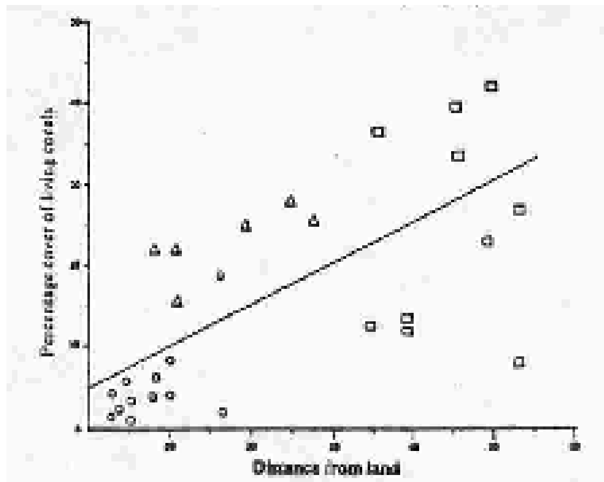
This is confirmed by Hutomo (1987) and Harger (1988) who both give data of distances from mainland Java and percentage of live coral cover. Hutomo's data, based on 28 islands (Pulau Seribu) are presented in Figure 3.5.2[xcviii].

Figure 3.5.1: Temporal and Spatial Comparison of Maximum Depth of Living Coral Reef for 4 Islands in Jakarta Bay
(names and distance in km from coast are given for each island)



Source: Tomascik et al. (1993); reference to primary data sources are given there.

Figure 3.5.2 The Relationship between Live Coral Cover and Distance from Land
(28 observations from islands of the Pulau Seribu group off Jakarta; 1986 data; distance in km)



Source: Hutomo (1987); reference to primary data source is given there.

Harger (1988) also correlates distance from mainland Java with abundance of fish and coral species diversity with similar results. These relations are confirmed by Rogers (1990), who gives an extensive literature review of responses of coral reef and associated reef organisms to sedimentation. Hodgson & Dixon (1988) present assumptions of relationships between coral cover, coral species, total fish catch and sedimentation, indicating similar trends as described above. Their assumptions are based on observations in the Bacuit Bay (Palawan, Philippines), where a diving resort was being threatened by sediments from a nearly logging operation.

In order to do an economic analysis of this threat, it is useful to separate between the following types of sedimentation and pollution, arising as a result of:

type 1: logging and mining (erosion; heavy metals, etc.);
type 2: general agricultural land-use (erosion; agro-chemicals);
type 3: urban areas (sewage, industrial waste, pollution, etc.).

The first type is discussed in Hodgson & Dixon (*op. cit.*), who present an economic analysis of continued logging, taking into account foregone benefits from tourism and fishery in the Bacuit Bay (some 120 km^2; 15-20 km^2 of coral reefs)[xcix]. They show that present value of gross revenues of a logging-ban are some 70% higher than gross revenues of continued logging (see Table 3.5.2). For sedimentation and pollution in rural areas with general agricultural practices (type 2), we have not come across an economic analysis of consequences of erosion and agro-chemicals on coral reefs.

An economic analysis of sedimentation and pollution in urban areas (type 3) is presented by Russell (1992). He describes the costs and benefits of coastal waste management in urban areas. As stated above, human and industrial waste are responsible for much of the sedimentation in urban coastal areas. Russell takes tourism (diving and other coastal recreation), fishery and health (decreased incidence of dysentery and other water-borne diseases) as prime benefits of coastal waste management. Annual costs presented of additional waste management

Table 3.5.2 Present Value of Gross Revenue from Logging, Tourism and Fishery in case of a Logging-ban versus Continued Logging ***(data for Bacuit Bay, Philippines; million US$; 10 year period; 10% discount rate)***		
	logging-ban	*continued logging*
Tourism	*25.5*	*6.3*
Fishery	*17.2*	*9.1*
Logging	*0.0*	*9.8*
Total	*42.7*	*25.2*

Source: Hodgson & Dixon (1988); Note: Data on fishery do not include tuna fishery

(sewage and solid waste) for urban centers in Indonesia is US$ 987 million. The benefits are: tourism (US$ 101 million), fishery (US$ 221), health (US$ 4.8). Hence total annual benefits are US$ 327 million, or one-third of the costs.

DMI (1996) has carried out an economic analysis of different threats to coastal resources in 6 areas of Indonesia (e.g. Jakarta Bay and Ambon). Also, a valuation is done for all coastal resources in Indonesia. Total costs of intervention are estimated at US$ 2,600 million and the value of the coastal resources at risk is assessed at US$ 56,000 million (more than 20 times higher)! A summary of these figures is given in Table 3.5.3.

These coastal resources at risk include the value of coral reefs, but also of mangrove areas and many other coastal resources. Besides, sedimentation is only one of the threats, even though in Jakarta Bay and Ambon Bay it might be the major one. Therefore, it is difficult to use these data for our analysis. However difficult it is to compare the presented results of Russell (1992) and DMI (1996), it seems that the figures are at odds at each other.

Generally, an economic calculation of the impacts of sedimentation and pollution on coral reefs is extremely difficult, with the possible exception of type 1 threats. In those cases (logging, mining), there is typically one specific activity leading to erosion, and one or two major impacts as in the analysis of Hodgson & Dixon (1988)[c]. In other cases, typically many small point sources at different locations linked to different economic activities by many individuals and sometimes far away from the coast are responsible for sedimentation and pollution. Impacts depend crucially one such site-specific factors as composition of waste, ocean currents, etc. Besides, integrated

Table 3.5.3: Value of Coastal Resources at Risk and Costs of Intervention *(total value figures in million US$ in medium growth, do nothing scenario)*		
Area	*Value of coastal resources*	*Cost of Intervention*
Jakarta Bay	*407*	*18*
Brantas Delta	*276*	*97*
West Lombok	*76*	*13*
South Sulawesi	*852*	*109*
Ambon Bay	*275*	*59*
Bintuni Bay	*970*	*3*
Total Indonesia	*56,000*	*2,600*

Source: DMI Volume I (CEPM Final Report; 1996)

management of waste reduction, sewage treatment, etc. have many other benefits (health; more efficient land use; fishery; water supply). Together, these issues will complicate the economic analysis enormously. Therefore, we will not attempt to estimate costs and benefits of pollution and sedimentation per km^2 in urban area. For mining areas, we take the calculations of Hodgson & Dixon (1988), and adjust them on a per km^2 basis for our purposes.

3.6 Overfishing

This section describes the economic and ecological consequences of overfishing and looks at marine reserves as a way of coping with fishing pressure. In a way, overfishing is different from the other threats described above, in that it does not have the same type of direct destructive impacts. Modest forms of non-destructive overfishing will, in fact, have very little impact on corals. Extreme forms of non-destructive overfishing could, on the other hand, alter the ecosystem balance, ultimately leading to a reef dominance by sea urchins and resulting in a dramatic drop in fishery yields and reduced algal and coral biomass and productivity (McClanahan, 1995).

Typically, overfishing occurs in combination with other threats, such as destructive fishing methods (blasting, etc.) or ill-use of potentially benign techniques (traps). Overfishing is often a result of population pressure, fishing technology and open-access problems. The latter is brought about by a lack of legal or practical possibilities for local communities to protect their common property resources. For some statistics on population growth in coastal areas, fishing techniques, fishing pressure and fishery yields in reef areas, see Pauly (1989).

This section briefly describes the costs and benefits of overfishing at the level of open access (OA) vis-à-vis sustainable fishing at the maximum sustainable yield level (MSY). Data and assumptions on the yield-effort relationship are presented in Chapter 2 (especially Table 2.2.1 and Figure 2.2.1), based on Munro & Williams (1985) and others. The only assumption discussed so far deals with the dynamics of overfishing from an initial situation (assumed to be at MSY) to the open access equilibrium (OA). Evidence from reefs where protective fishery management was discontinued, suggest that fishery yields can drop very quickly after resource access is re-opened. Alcala & Russ (1990) mention a decline of US$ 54 in the total yield of reef fishes off Sumilon Island (Philippines) after breakdown of protective management. In the absence of a multi-species dynamic fishery model, we make the following conservative assumptions with respect to a hypothetical example. (See Box.)

Assumptions for Overfishing:

- In year one, the fishing effort is increased from 10 full time fishermen (the effort in case of the MSY) to 25 (the effort of OA in equilibrium);
- The total yield will drop after 3 years with 50% (from 15 mt/km^2/yr to 7.5 mt/km^2/yr). This corresponds to a decline in the daily catch per person from 5 kg to 1 kg;
- In the interim period, the catch will be higher than the sustainable catch. In year one, the catch is 30 mt/km^2/yr (twice the MSY). In year two and three, this amount drops to 22.5 and 15 mt/km^2/yr, respectively. Finally, from year four onwards, the yield will be in equilibrium at 7.5 mt/km^2/yr, the open access level.

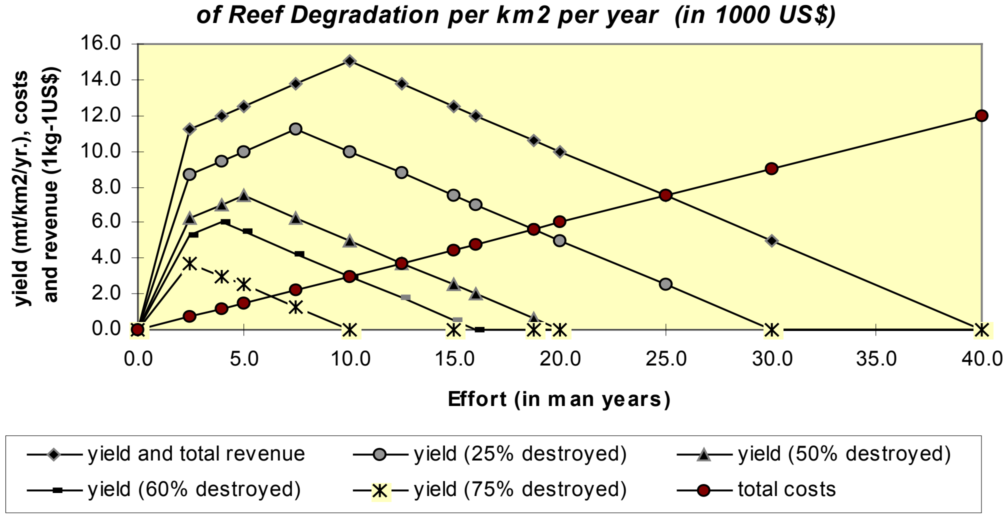
Table 3.6.1: The Economics of Overfishing vis-a-vis Sustainable fishing
(25 years; 10% discount rate; in 1000 US$)

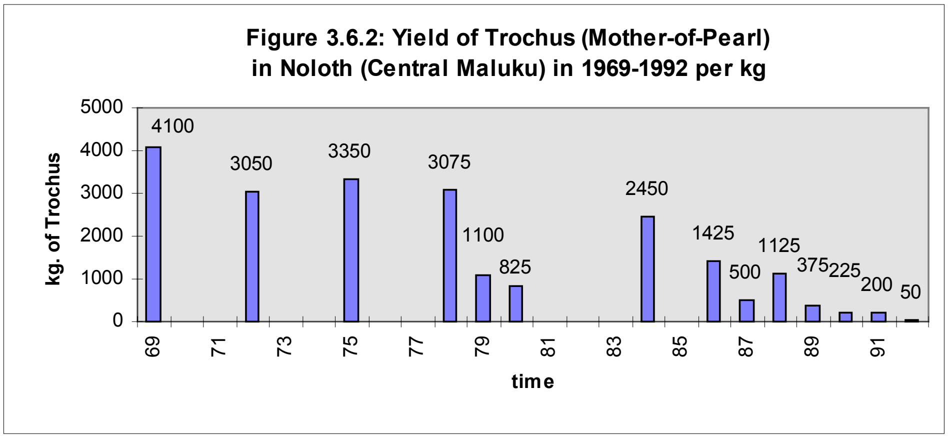
	no overfishing					***overfishing***				
	effort	***yield***	***value***	***costs***	***net benefit***	***effort***	***yield***	***value***	***costs***	***net benefit***
units	MAN/YEAR	MT/KM2/YR	US$/KM2/YR	US$/KM2/YR	US$/KM2/YR	MAN/YEAR	MT/KM2/YR	US$/KM2/YR	US$/KM2/YR	US$/KM2/YR
year 1	10.0	15.0	15.0	3.0	12.0	25.0	30.0	30.0	7.5	22.5
year 2	10.0	15.0	15.0	3.0	12.0	25.0	22.5	22.5	7.5	15.0
year 3	10.0	15.0	15.0	3.0	12.0	25.0	15.0	15.0	7.5	7.5
year 4	10.0	15.0	15.0	3.0	12.0	25.0	7.5	7.5	7.5	0.0
year 5-25	10.0	15.0	15.0	3.0	12.0	25.0	7.5	7.5	7.5	0.0
NPV					**108.9**					**38.5**

On the basis of these assumptions, the present value of overfishing (at OA) and sustainable fishery (at MSY) can be compared. Assumptions with respect to the value of the yield and the costs are presented in Chapter 2. The results are summarized in Table 3.6.1. The net present benefit, with a 10% discount rate over a 25 year time horizon is US$ 109.9 thousand in case of the MSY and US$ 38.5 thousand in the case of open access. This difference is large, as is to be expected, and clearly indicates that OA would not be attained as long as property rights are clearly defined and enforced, unless a very large rate of time preference is assumed: the net present value of OA and MSY coincide at a discount rate above 50%. However, if entry of other fishermen cannot be prevented, the OA will be the equilibrium outcome, at an economic cost of US$ 70.4 thousand (the difference between US$ 108.9 for MSY and US$ 38.5 for OA).

Similar analyses can be carried out for situations where the reef has been partly destroyed. In these cases, both the MSY and the OA are lower. The assumptions on yields, efforts, costs and benefits are given in Appendix 1, and is summarized in Figure 3.6.1 for 25%, 50%, 60%, and 75% destruction (See also Chapter 2).

Figure 3.6.1: Yield-Effort Curves and Cost Curve for Different Levels of Reef Degradation per km2 per year (in 1000 US$)





Source: Data gathered from the village head in Noloth

Marine reserves

There is a growing body of literature suggesting that the establishment of a small marine reserve in an area greatly enhances the fishery productivity in the remaining areas (Alcala, 1988; White, 1989; Alcala & Russ, 1990; Polunin & Roberts, 1993; Roberts, 1995; Russ, 1989 and 1994, etc.). For instance, Alcala (1988) on three Philippine islands with yields ranging from 10.94 to 24 mt/km2/year in years that no marine reserve was in place. In one of the three islands, Sumilon, fish yields of 14-24 mt/km2/year have been reported (White, 1989) from the time before the sanctuary, with catches increasing to 36 mt/km2/year when the marine reserve was in place. Fish yields fell back to about 20 mt/km2/year when island management broke down. In another island, Apo, catches rose from 17 to 32 mt/km2/year once the sanctuary had come in place.

White (1989) argues that the sanctuary is probably a recruitment area for many reef dwellers moving around the fringe reefs inside and outside the sanctuary area. These findings suggest that the maximum sustainable yield may be well above the upper bound of 20 mt/km2/year that was suggested by Russ (1989) and Munro (1984). Based on this information, we assume that the maximum sustainable yield for a km^2 of reef can be doubled when a portion (15-30%) of this area is set aside as refugia. This is illustrated in Appendix 2).

For some invertebrates, like mother-of-pearls (*Trochus spp*.), a closed season would be a more appropriate means raising yield. One village in Central Maluku has a traditional management scheme (sasi) for trochus. Data were collected for the years 1969-1992, and are presented in Figure 3.6.2.

Interestingly, in the periods with a long-term cycle, where harvesting was only allowed every three years, yields were far higher than with a short-term cycle, with collection during several weeks every year. The three year closed season till 1978 gave an average yield of some 3400 kg or more than 1100 kg per year. In the annual collection since 1987, the average per year of just over 400 kg.

3.7 Conclusions of the Economic Analysis

In this chapter, net losses to society and gains to individuals have been calculated for the most important human -induced threats to reef destruction in Indonesia. Table 3.7.1 summarizes the results per square kilometer of reef, indicating that overall benefits of destruction are always lower than the overall quantifiable losses. The benefits and costs are calculated in present value terms with a 10% discount rate and a 25-year time horizon. Sedimentation due to logging, for instance, has total quantifiable losses of US $273 thousand per km^2, nearly three times higher than the benefits (US$ 98 thousand).

Net losses of destruction to society are especially high in areas with considerable tourism potential and coastal infra-structure. In case of coral mining, net benefits of destruction in this high value scenario are more than 7 times lower than corresponding costs. And for poison and blast fishing, the ratio of costs to benefits is even 14 and 52 respectively (US$ 33.3 thousand vs. US$ 475.6 thousand for poison fishing; US$ 14.6 vs. US$ 761.2 for blast fishing). Finally, for overfishing, the economic rent involved in sustainable fishery is lost due to the additional effort.

The difference between benefits and corresponding costs is US$ 70.4 (US$ 108.9 thousand vs. US$ 38.5 thousand), can be interpreted as the economic cost of open access fishing. With this economic analysis in mind, Chapter 4 will specifically look at the management options to arrest the reef threats.

Table 3.7.1: Total Net Benefits and Losses due to Threats of Coral Reefs
(Present value: 10% discount rate; 25 y. time-span; in 1000 US$; per km^2

	Net Benefits to Individuals	**Net Losses to Society**						
Function / **Threat**	*Total Net Benefits*	*Fishery*	*Coastal Protection*	*Tourism*	*Food Security*	*Bio-diversity*	*Others*	*Total Net Losses (quantifiable)*
Poison Fishing	33.3	40.2	0.0	2.6 -435.6	n.a	n.a.	n.a.	42.8 -475.6
Blast Fishing	14.6	86.3	8.9 - 193.0	2.9 -481.9	n.a.	n.a.	n.a.	98.1 - 761.2
Mining	121.0	93.6	12.0 - 260.0	2.9 - 481.9	n.a.	n.a.	5.7	175.5, - 902.5
Sediment.-logging	98.0	81.0	-	192.0	n.a.	n.a.	n.a.	273.0
Sediment.-urban	?	?	?	?	?	?	?	?
Overfishing	38.5	108.9	-	n.a.	n.a.	n.a.	n.a.	108.9

4. Coral Reef Management: An Economic Perspective

Introduction

The management of coral reefs is often highly complex and very site-specific. There are typically many different issues and stakeholders involved. Besides, there is a diverse set of interactions and linkages between coral reefs and their environments, both of ecological, geographical, social, economic and political character. This requires an interdisciplinary and multi-sectoral approach.

In this chapter, we do not intend to cover the whole array of challenges involved in reef management. Instead, we will focus on what an economic analysis can contribute to managing coral reefs effectively. To this aim, we look at the benefits to individuals and the losses to society for each of the threats discussed in chapter 3. Next we look at the benefits per person: this gives a good feel of how important each of the stakeholders is. It also gives a first handle on what is the magnitude of compensation required to change stakeholders' incentives from resource destructive to conservation oriented. An important management issue is whether the stakeholders that use the coastal resources unsustainably are insiders (locals) or outsiders (from different region or country). Finally, we will look at various types of management options depending on the size of the individual stakeholders' incentives and on the relationship to the area (insider vs. outsider).

Economic Considerations in Coral Reef Management

Coral reef management is by its nature site-specific. This implies that it is crucial for management to have a thorough understanding of the threats in the site of interest. This can vary dramatically. In one area, there may be one single threat, such as sedimentation from a logging concession, as was the case in the Bacuit Bay in Palawan (the Philippines), discussed in Section 3.5. In other areas, there may be a whole array of threats, from bombing and poison fishing to sewage and pollution and even diver-induced threats, as is the case in the Bunaken area (Manado, Indonesia).

Once the specific threats are known, management options can be developed for each of the issues. It is crucial that the threats are ranked in their contribution to the overall impacts. The economic analysis

Table 4.1: Total Net Benefits and Losses Due to Threats of Coral Reefs
(Present value: 10% discount rate; 25 y. time-span; in 1000 US$; per km^2

	Net Benefits to Individuals	Net Losses to Society						
Function / Threat	Total Net Benefits	Fishery	Coastal Protection	Tourism	Food Security	Bio-diversity	Others	Total Net Losses (quantifiable)
Poison Fishing	33.3	40.2	0.0	2.6 -435.6	n.a	n.a.	n.a.	42.8 -475.6
Blast Fishing	14.6	86.3	8.9 - 193.0	2.9 -481.9	n.a.	n.a.	n.a.	98.1 - 761.2
Mining	121.0	93.6	12.0 - 260.0	2.9 - 481.9	n.a.	n.a.	>67.0	175.5, - 902.5
Sediment.-logging	98.0	81.0	-	192.0	n.a.	n.a.	n.a.	273.0
Sediment.-urban	?	?	?	?	?	?	?	?
Overfishing	38.5	108.9	-	n.a.	n.a.	n.a.	n.a.	108.9

of the last chapter can give guidance as to where the key impacts might be and what the loss is in money terms to some of the impacted functions.

This can be confronted with the net benefits associated with the threat to see how the losses and benefits relate to each other. This is shown in Table 4.1, where the net benefits to individuals of a threat are compared with the net losses to society per km^2 of reef. Note that in all cases, the net losses to society are much higher than the gains to the individuals responsible for the threat[ci]. Also, note that the net benefits to individuals seem to be highest for coral mining and for logging-induced sedimentation.

Knowing the net benefits to the stake-holders, however important they are, might not give a clear understanding of the magnitude of the incentives. For that, we have to know what are the stakes per threat per person. Table 4.2 uses the data presented in Table 4.1 above but adds in parentheses the net benefits per person/family/boat/company. Interestingly, poison fishing and logging-induced sedimentation have by far the highest private incentives, ranging from US$ 1.9 million the case of logging[cii] to US$ 317,000 - US$ 1,585,000 in the case of poison fishing.[ciii] At the other extreme, mining is a very marginal activity for the families involved. Note that side-payments, such as political rents, are not negligible in the case of mining, but are nowhere close to the magnitude of these payments involved in poison fishing.

With respect to the table above, some caveats apply. The stakes per person are calculated on the basis of man-years. For mining, where families are involved nearly full-time with this activity, this approach represents the real stakes per person probably rather well. But in case of blast fishing in part-time subsistence fishery, the actual stakes involved per person are much lower than the stakes given above which are computed on a man-year basis. In the case of poison fishing, the stakes per diver are high: US$ 23,400. This is based on the assumption that the divers will carry out this activity full time over several years. Often, however, divers are recruited for short periods of time only. This again probably overestimates the real stakes per person significantly. At the same time, the overall picture that incentives differ dramatically per threat remains valid and that types of management interventions differ accordingly. In the case of urban sedimentation, especially when some large industries are involved, the stakes are probably high, though we have not been

Table 4.2: Net Benefits to Individuals: Amount per km^2 and per Stakeholder (latter in parentheses; present value; 10% discount rate; 25 y. time-span; in 1000 US$; per km^2)			
Threat \ Individuals	Fishermen	Miners, Loggers	Others (payments)
Poison Fishing	29.3 (468.6 per boat) (23.4 per diver)	-	4.0 (317-1585 per person)
Blast Fishing	14-6 (7.3 per fisherman)	-	?
Mining	-	67 (1.4 per mining family)	54.0 (18.0 - 54.0 per person)
Sedimentation -logging	-	98.0 (1990 per logging family)	98.0
Sediment.- urban	?	?	?
Overfishing	38.5 (0.2 per fisher)	-	38.5

able to estimate specific stakes per person for this situation.

Another interesting difference between the stakeholders for the different threats is whether they live in the area where the threat is posed (insiders) or not (outsiders). For instance, in the case of large scale poison fishing operations, the captain and his crew are outsiders, as if often the case with logging-induced sedimentation. Overfishing can both come from local fishermen as well as from outsiders. Population pressure and open-access problems respectively are often responsible for this situation. Urban sedimentation stems often from the coastal towns, but can also come from upland areas. Mining and blast fishing are typically activities carried out by the local population, though large scale explosives fishery operations do exist (Erdmann, 1995). The insider vs. outsider issues and the size of the stakes per person are combined in a two-by-two matrix present in Table 4.3. These are general tendencies, and there will inevitably be site-specific circumstances that form exceptions to this framework.

The matrix elements each require a different management approach. In general, zone management is more appropriate if the stakeholders are insiders. If, however, one deals with large fishing operations in Eastern Indonesia that get licenses from Jakarta, local stakeholder consultations are not very useful. If the stakes are small and there is one dominant threat, such as coral mining in some locations on West Lombok, integrated coastal zone management

Table E-4: Size of Economic Stake and Location of Stakeholder

		Size of Economic Stakes		
		small	**big**	
location of Individual causing the threat	**insider**	coral mining, blasting, overfishing	sediment.	INTEGRATED COASTAL ZONE MANAGEMENT
	outsider	overfishing	cyanide, logging	
	LOCAL THREAT BASED APPROACH			NATIONAL THREAT BASED APPROACH

seems an overkill and a very direct approach might be the easiest way to resolve the threat. Based on these features, the following three types of management approaches are defined:

Local Threat Based Approach (LTBA)

If the dominant threat(s) in a specific site fall under the categories 'Small-Insider' and/or 'Small-Outsider,' a local threat based approach is probably appropriate. This takes typically the form of community-based management. Examples are villages with a combination of overfishing and some blasting fishing. Alternative income generation, enforcement of anti-explosives regulation, establishment of cooperatives or other types of fishermen groups, etc. could be appropriate options in such a situation. Re-introduction of traditional common property resource management (e.g. 'Sasi'-system in Maluku) is another possibility. In some situations provincial regulation need to be adjusted to allow for common property resource management. In cases like coral mining, ad hoc solutions might be appropriate. An example is one village in Bali, that has stopped coral mining completely after a hotel offered employment as gardeners to all the mining families.

National Threat Based Approach (NTBA)

In situations where the categorization 'Big-Outsider" applies for the main threat(s) in a specific location, action at the national level is required. The clearest example is large scale poison fishing operations, that often take place in remote and unpopulated areas. Strong initiatives at the highest national levels, involving the Navy and the Policy are the only way to arrest this threat, as local and provincial officials are powerless in the face of these operations. Likewise, sedimentation from large scale logging and mining operations can only be dealt with nationally, as it is at that level that the concessions are negotiated.

Integrated Coastal Zone Management (ICZM)

When sites cope primarily with 'Big-Insider' type situations, or if the site is confronted with an array of different threats that cannot be dealt with separately, ICZM seems appropriate. This is for instance the case in Manado, with a large thriving diving tourism industry, that is more and more threatened by a variety of threats, from sewage to poison fishing. Other examples might include Jakarta Bay and Ambon Bay, also with a variety of threats, related to urbanization and population pressure.

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Appendices

Appendix 1: Bibliography of Man-Made Coral Reef Destruction

Authors	Title	Description	Threats
A.C. Alcala (1988)	Effects of Marine Reserves on coral Reef Abundances and Yields of Ph. Coral Reefs	description of 3 islands in Ph. with data of reserve and non-reserve period; yield/effort data are striking	**overfishing**
J. Alder et al. (1994-b)	A Comparison of Management Planning and Implementation in 3 Indonesian MPAs	comparison of P. Seribu, TBR + Bunaken in mngt., issues and implementation; commercial & subsistence exploitation, urban areas, econ. development	**overfishing blasting urbanization**
A.A. Alvarez (1995)	Dead Corals in Exchange for Live Fish Exports	short description of live fish trade in Phil. and effects on corals	**poison**
J. Andersson (1995)	Marine resource Use in the Proposed Mafia Island Marine Park	valuation of benefits of Mafia park, looking at TEV	**blasting overfishing coral mining**
J.D. Bell & R. Galzin (1984)	Influence of live coral cover on coral reef fish communities	empirical study in French Polynesia on effect of differences in % live cover on number of fish species and individuals	**general**
B.E. Brown & R.P. Dunne (1988)	The Environmental Impact of Coral Mining on Coral Reefs in the Maldives	description of current coral mining in Maldives and resulting environmental damage; projected extraction of coral and discussion of alternatives	**coral mining**
J.N. Butler et al. (1993)	The Bermuda Fisheries: A Tragedy of the Commons Averted?	description of decline in fish stock and changing mix of fish in Bermuda islands and measures taken	**overfishing pollution**
J. Caldecott (1994)	Dead in the Water: Threats to Indonesia's Dive-Tourism Industry	story of massive upsurge of destructive fishing practices in Indonesia in 1994.	**poison blasting**
G. Cambers (1992)	Coastal Zone Management: Case Studies from the Caribbean	discussion of coastal zone management and illustration of case studies (sewage pollution; beach erosion, etc.)	**pollution construction**
W.L. Campos et al. (1994)	Yield Estimates, catch, effort and fishery potential of the reef flat in Cape Bolinao, Philippines	description of catch, fishing effort and yield estimates specified by types of gear (spear, traps, corrals, grill nets)	**overfishing**
P. Christie et al. (1994)	Community-Based Coral Reef Management on San Salvador Island, the Philippines	description of Marine Conserv. Project showing that comm. based mngt. can stop coral threats	**blasting poison finemesh**
D. Davis et al. (1995)	Conflicts in a marine protected area: Scuba Divers, Economics, Ecology and Management in Julian Rock Aquatic Reserve	general information on economic/envir. issues in the Julian Rocks Aquatic Reserve (Australia)	**tourism**
D. Davis & C. Tisdell (1995)	Recreational SCUBA Diving and Carrying Capacity in Marine Protected Areas	analysis of conflicts between recreation and conservation	**tourism**
G.D. Dennis & T.J. Bright (1988)	The Impact of a Ship Grounding on the Reef Fish Assemblage at Molasses Reef, Key Largo Nat. Mar. Sanctuary, FA.	see title: reef fish recolonization (species composition, community structure, biomass)	**grounding**
J.A. Dixon (1993)	Economic Benefits of Marine Protected Areas	description of costs and benefits of MPAs, with specific reference to Saba, Virgin Islands, Bonaire	**mooring tourism**
J.A. Dixon et al. (1995)	Ecology and Microeconomics as "Joint Products": The Bonaire Marine Park in the Caribbean	econ. analysis of costs and benefits of protection and the physical limits of tourism!	**tourism**
M. Erdmann (1995)	The ABC Guide to Coral Reef Fisheries in Southwest Sulawesi, Indonesia (+letter)	short anecdotal directory to the major fisheries, techniques and problems in Spermonde reef fisheries	**poison blasting coral collection**

Erdmann, M.V. & K. Pet-Soede (1996)	"How Fresh is Too Fresh: The Live Reef Food Fish Trade in Eastern Indonesia."		
FAO (1979)	Report on a Preliminary Survey of the P.Pombo and P.Kassa marine reserves, Maluku.	description of quick appraisal of two MPAs in Maluku with recommend. on legal status	**dynamiting overfishing tourism**
C. Gabrie' et al. (1994)	Study of the Coral Reefs of Bora-Bora for the Development of a Conservation and Management Plan	quick appraisal of Bora-Bora with discussion of multiple-use conflicts and management solutions	**overfishing tourism urbanization**
R. Galvez et al. (1989)	Sociocultural Dynamics of Blast Fishing and Sodium Cyanide Fishing in Two Fishing Villages in the Lingayen Gulf Area	detailed description of blast and cyanide fishing in two villages in the Phil.; focus on ethnography; interesting observations on why?, how? and how much? of activities	**blasting poison**
E.D. Gomez & H.T. Yap (1985)	Coral Reefs in the Pacific - Their Potential and their Limitations	description of coral reefs in pacific states and man's relation to the coral reefs	**overfishing population**
E.D. Gomez et al. (1994)	Assessment of *Tridacna Crocea* in an Exploited Philippine Reef	see title (Tridacna Crocea is burrowing giant clam)	**overfishing**
E.D. Gomez et al. (1994)	A Review of the Status of Philippine Reef	description of status of reefs (coral cover, mortality index) and discussion of the causes of degradation, reef functions, etc.	**all**
S.R. Gittings et al. (1988)	The Recovery Process in a Mechanically Damaged Coral Reef Community: Recruitment and Growth	effect of ship grounding on coral recruitment and tissue regeneration	**grounding**
J.R.E. Harger (1988)	Community Displaced. in Stressed Coral Reef Systems and the Implicatations for a Compreh. Mngt. Strat. for Coastal & Offshore Productiv. Enrichment	analysis of coral coverage (live and hard)/ and fish species/ etc. in Palau Seribu (Indonesia) in relation to the distance to mainland (Jakarta Bay area)	**sedimentation sewage pollution**
A.L. Hatcher et al. (1990)	Resolving the conflict between conservation values and extractive use of the Abrolhos coral reefs	detailed study of 3 little island groups in Australia showing that ecological and fishery values differ per zone so that actual area of conflict is limited.	**tourism**
J.P. Hawkins & C.M. Roberts (1994)	The Growth of Coastal Tourism in the Red Sea: Present and Future Effects on Coral Reefs	description of coral reef damage due to tourists and possibilities for sustainable tourism in Red Sea	**tourism econ. devel.**
T.G. Hinggo & R. Rivera (1991)	Aquarium Fish Industry in the Philippines: toward Development or Destruction	description of aquarium fish industry in Bolinao, the why of cyanide use and marketing of alternatives	**poison**
G. Hodgson & J.A. Dixon (1988)	Logging Versus Fisheries and Tourism in Palawan: An Environmental and Economic Analysis	see title	**sedimentation**
T.P. Hughes (1994)	Catastrophies, Phase Shifts, and Large-Scale Degradation of a Caribbean Coral Reef	description of coral reef degradation following hurricanes and diseases of algae eating fish	**overfishing hurricanes disease**
M. Hutomo (1987)	Coral Fish Resources and their Relation to Reef Condition: Some Case Studies in Indonesian Waters	see title; relationship between live coral and number of fish species	**sedimentation, etc.**
R.E. Johannes & M. Riepen (1995)	Environmental, Economic and Social Implications of the Live Reef Fish Trade in the Asia and the Western Pacific	see title; excellent description of live food fish trade for Asian market and their impacts on reefs and humans	**poison**
A. Lillie &	Trade in Ornamental Fish and	see title (Indonesia)	**poison coral**

Suharsono (1995?)	Coral		**collection**

Marinelife (1995)	IMA Promotes Hook-and-Line as an Alternative to Cyanide Fishing	description of use of hook-and-line for live fish catch	**poison**
D.E. McAllister (1988)	Environmental, Economic and Social Costs of Coral Reef Destruction in the Ph.	estimation of costs of coral reef destruction (diff. threats) and econ. & social consequences (tourism rev., malnutrition)	**sedimentation poison blasting agriculture**
J.W. McManus (1993)	Managing Seagrass Fisheries in Southeast Asia: An Introductory Overview	discussion of seagrass fishery and potential for community based management in those areas	**blasting**
J.W. McManus (1994)	The Spratly Islands: A Marine Park?	threats for Spratly Isl. (military; potential oil) and possibility for international marine park	**military oil drilling**
J.W. McManus (forthcoming 1996)	Social and Economic Aspects of Reef Fisheries and their Management	description of the why and how of the 'tragedy of the common reef'; description of management options and some case histories;	**overfishing muro-ami**
J.W. McManus & J.J. Wenno (1988)	Coral Communities of Outer Ambon Bay: A General Assessment Survey	see title; also discussion of fishery and of present and potential threats to the corals	**pollution sedimentation**
J.W. McManus et al. (1992)	Resource Ecology of the Bolinao Coral Reef System	description of results of large research program on harvest methods and yield in Phil. location; recommendation to reduce fishing effort with 60% and suggestions for alternative livelihoods	**overfishing poison blasting anchoring**
M.K. Moosa et al. (1993)	Coastal Zone Management of Small Island Ecosystem (Proceedings)	papers on coral reefs, seagrass and mangrove II-4:Coast.Z.Mngt Maluku; II-7 role/functions cor.reefs; III-2: Aru Tenggara M.Res.	**various**
M.C. Ohman, et al. (1993)	Human Disturbances on Coral Reefs in Sri Lanka: A Case Study	study of life coral cover, species richness and coral rubble in 3 Sri Lankan sites	**mining nylon nets**
D. Pauly (1988)	Fisheries Resources Management in Southeast Asia: Why Bother	discussion on marine fishery development over time in ASEAN countries (incl. Indon.); discussion on increase of effort (pop. growth; inv. in fleet) and call for lower fleet investments	**population**
D. Pauly & T-E. Chua (1988)	The overfishing of marine resources: socio-economic background in southeast Asia	description of marine fishery development from 60s to now, stressing fishery techn. change and human population growth as most important factors	**type of gear population**
N.V.C. Polunin & C.M. Roberts (1993)	Greater biomass and value of target coral reef fishes in two small Caribbean marine reserves	discussion of difference in biomass and abundance in protected marine areas vs. non-protected areas in two Caribbean coral reefs	**overfishing**
J. Purwanto (1986)	The Stress Effect on coral Reef Econsystems of Pari Island, Indonesia	see title; human induced stresses have greater impact than natural stresses	**pollution waste overfishing coral mining**
R. H. Richmond (1993)	Coral Reefs: Present Problems and Future Concerns Resulting from Anthropogenic Disturbance	discussion on natural vs. anthropogenic stress (esp. sedimentation, sewage) on reef viability	**sedimentation pollution starfish**
J.M. Riopelle (1995)	The Economic Valuation of Coral Reefs: A Case Study of West Lombok, Indonesia	calculation of Total Economic Value (TEV) of coral reefs in the Kabupaten of West Lombok	**various**
C.M. Roberts	Damage to Coral Reefs in Virgin	see title: study on physical damage to reefs	**tourism**

(1993)	Islands National Park and Biosphere Reserve from Recreational Activities	due to anchors, boat groundings and careless snorkelers	

C.M. Roberts (1995)	Rapid Build-up of Fish Biomass in a Caribbean Marine Reserve	see title: study on fish biomass over time in and around reserves, showing that reserves as well as reduction in fishing pressure increase biomass	**overfishing**
C.M. Roberts (1995)	Effects of Fishing on the Ecosystem Structure of Coral Reefs	discussion of effects of overfishing of specific species on ecosystem equilibrium; overfishing is also shown to interact with other threats	**overfishing**
C.S. Rogers (1990)	Responses of coral reefs and reef organisms to sedimentation	literature review of effects of sedimentation (dredging, sewage, natural runoff) on coral reefs and associated organisms	**sedimentation pollution dredging sewage**
P.J. Rubec (1988)	The need for conservation and management of Philippines coral reefs	description of threats to biological diversity and productivity of Ph. reefs; conservation methods and village-based management	**muro-ami poison blasting overfishing sedimentation coral collection trawling**
H.J. Ruitenbeek (1992)	Mangrove Management.: An Economic Analysis of Management Options with a focus on Bintuni Bay, IJ.	ec. analysis (with househ. survey) of diff. mangrove policies given shrimp industry under different linkage assumptions	**sedimentation**
G.H. Russ (1989)	Distribution and Abundance of Coral Reef fishes in the Sumilon Isl. Reserve, Centr. Phil., after 9 Yrs. of Protection from Fishing	see title	**overfishing**
G.H. Russ (1991)	Coral Reef Fisheries: Effects and Yields	literature review of effects of fishing on catch and catch per unit of coral reef fisheries	**overfishing**
G.H. Russ (1994xx)	The Use of Refugia for Fishery Resource Management on Coral Reefs	discussion of advantages and disadvantages of long term spatial closures; discussion of larval and adult fluxes of fish	**overfishing**
K.D. Russell (1992)	The Economics of Coastal Waste Management	analysis of costs and benefits (tourism, fishery, etc.) of waste management	**sedimentation waste**
C. Safina (1995vv)	Phil. Shark Fisheries in a Global Contexzt and a Recommendation to end Fin Exports	see title; description of shark fin overfishing	**overfishing**
B. Salvat (Ed.) (1987)	Human Impacts on coral Reefs: Facts and Recommendations	edited volume with contrib. by Salvat, Gomez, Yap, Munro, White et al. on all human impacts on coral reefs!!!	**blasting coral collection overfishing poison muro-ami pollution, dredg./mining tourism**
G.C. Savina & A.T. White (1986)	A Tale of Two Islands: Some Lessons for Marine Resource Management	comparison of fishery data for two islands in Philippines with coral reef; discussion marine protected areas	**overfishing blasting**
D.A. Sawyer (1992)	TBR: Management Development and Resource Valuation of an Indonesian Atoll	socio-economic household survey and cost-benefit analysis of MPA, using env. productivity figures	**overfishing**
R. Soekarno (1989)	Comparative Studies on the Status of Indonesian Coral Reefs	discussion of human impacts on coral reefs over time (coral cover, fishery)	**sedimentation pollution**
R. Soekarno (1987)	The Effect of Environmental Trends and Associated Human Damage on coral Reefs in the Seribu Islands, Jakarta	presentation of data on benthic lifeforms (coral cover, abiotic, algae, other fauna) in 4 zones in P. Seribu (depending on distance to Jakarta)	**sedimentation pollution**

J.P.G. Spurgeon (1992)	The Economic Valuation of Coral Reefs	descr. of TEV of coral reefs with direct use value (extract.:fishery; non-extract: tourism, etc), indirect use value (coastal erosion), intrinsic value, aggragation and double counting	**mining others**

L. Sya'rani (1987)	The Exploration of Giant Clam Fossils on the Fringing Reef Areas of Karimun Jawa Islands	discussion of consequences of giant clam gathering on the reefs	**collection**
J. Sybesma (1988)	Marine Resource Protection versus Marine Tourism in Curacao: a Management Problem	discussion of the conflicting goals of nature conservation, recreation and exploitation	**tourism**
T. Tomascik (1993)	Coral Reef Ecosytems: Environmental Management Guidelines	guidelines for ecosystem maintenance/ development activities (e.g. mining) and its hazards; + good intro on (types of) coral reefs and measuring its health	**tourism mining sewage industry, etc.**
T. Tomascik et al. (1993)	Case Histories: A Histor. Perspective of the Nat. and Anthropogenic Impacts in the Indon. Archipelago with a Focus on the P. Seribu, Java Sea	analysis of historic and current data on anthropogenic eutrophication leading to major ecosystem shift and animal algal relation	**sedimentation; pollution**
G.F. Usher (WWF/IUNC) (1984)	Coral Reef Invertebrates in Indon.: Their Exploitation and Conservation Needs	detailed description of invertebrates (pearl oysters, greensnail, trochus, other shells, sea cucumber) in Ind.	**natural man-induced**
A.T. White (1979)	Sumilon Island: Philippine Marine Park Pilot Site Enjoys Early Success	success-story of Sumilon Island where marine park is well enforced	**overfishing**
A.T. White (1987)	Coral Reefs: Valuable Resources of Southeast Asia	Overview article on coral reef ecology, functions of reefs, its plants and animals, threats and conservation options	**all**
A.T. White (1989)	Two Community-based Marine Reserves: Lessons for Coastal Management	2 Phil. islands with coral reefs are compared with emphasis on fish yield under different management schemes	**overfishing**
A.T. White & G.C. Savina (1987)	Reef Fish Yield and Nonreef Catch of Apo Island, Negros, Philippines	detailed analysis of catch on-reef and off-reef in Apo and discussion of why yield vary much over different islands	**overfishing etc.**
C.R.Wilkinson et al. (1993)	Status of Coral Reefs in Southeast Asia: Threats and Responses	presentation of data on live coral cover in Southeast Asia	**all**
C.R.Wilkinson & R.W. Buddemeier (1995)	Global Climate Change and Coral Reefs: Implications for People and Reefs	Assessment of the potential and expected effects of global climate change on coral reef ecosystems and the peoples	**climate change population**
P.P. Wong (1991)	Coastal Tourism in Southeast Asia	see title; discussion of physical environment, beach resort sites, resort models, impacts of coastal tourism	**tourism**
World Bank (1995)	Pacific Islands Economies: Sustainable Development of Fisheries	detailed description of off-shore and near-shore fisheries in Pacific Islands including policy recommendations	**overfishing**
M. G. Wright (1994)	An Economic Analysis of Coral Reef Protection in Negril, Jamaica	calculation of the costs and benefits of coral reef protection using CVM and travel cost methods	**general**

Appendix 2: Assumptions for Yields, Costs, Income and Net Benefits etc. in Reefs of Various Quality

	effort	yield	value yield	opp.cost labour	other costs	total costs	total net benefit	yield	net income	net income	Rp. net income
UNITS	MAN/YEAR	MT/KM2/YR	US$/KM2/YR (IN 1000US$)					KG/MAN/DAY	US$/MAN/YR.	US$/MAN/DAY	RP./MAN/YR
	A	B	C	D	E	F	G	H	I	J	K
ASSUMPTIONS			1KG=US$1	(RP.2000/D)	(RP.60000/YR)	D + E	C - F	1000*B/A/300	1000*((C-F)/A	I/300	J*2,200
prestine reef with reserve area											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0	0.00	0
	5.0	22.50	22.50	1.36	0.14	1.50	21.0	15.00	4473	14.91	32,800
	10.0	25.00	25.00	2.73	0.27	3.00	22.0	8.33	2473	8.24	18,133
	15.0	27.50	27.50	4.09	0.41	4.50	23.0	6.11	1806	6.02	13,244
MSY	20.0	30.00	30.00	5.45	0.55	6.00	24.0	5.00	1473	4.91	10,800
	30.0	25.00	25.00	8.18	0.82	9.00	16.0	2.78	806	2.69	5,911
	40.0	20.00	20.00	10.91	1.09	12.00	8.0	1.67	473	1.58	3,467
OPEN ACCESS	50.0	15.00	15.00	13.64	1.36	15.00	0.00	1.25	273	0.91	2,000
	80.0	0.00	0.00	21.82	2.18	24.00	-24.0	0.00	-27	-0.09	-200
in tact reef											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0	0.00	0
	2.5	11.25	11.25	0.68	0.07	0.75	10.5	15.00	4473	14.91	32,800
	5.0	12.50	12.50	1.36	0.14	1.50	11.0	8.33	2473	8.24	18,133
MSY	10.0	15.00	15.00	2.73	0.27	3.00	12.0	5.00	1473	4.91	10,800
	15.0	12.50	12.50	4.09	0.41	4.50	8.0	2.78	806	2.69	5,911
	20.0	10.00	10.00	5.45	0.55	6.00	4.0	1.67	473	1.58	3,467
OPEN ACCESS	25.0	7.50	7.50	6.82	0.68	7.50	0.0	1.00	273	0.91	2,000
	30.0	5.00	5.00	8.18	0.82	9.00	-4.0	0.56	139	0.46	1,022
	40.0	0.00	0.00	10.91	1.09	12.00	-12.0	0.00	-27	-0.09	-200
25% destroyed											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0	0.00	0
	2.5	8.69	8.69	0.68	0.07	0.75	7.9	11.57	3443	11.48	25,247
	5.0	10.00	10.00	1.36	0.14	1.50	8.5	6.67	1973	6.58	14,467
MSY	7.5	11.25	11.25	2.05	0.20	2.25	9.0	5.00	1473	4.91	10,800
	10.0	10.00	10.00	2.73	0.27	3.00	7.0	3.33	973	3.24	7,133
	15.0	7.50	7.50	4.09	0.41	4.50	3.0	1.67	473	1.58	3,467
OPEN ACCESS	18.8	5.63	5.63	5.11	0.51	5.63	0.0	1.00	273	0.91	2,000
	20.0	5.00	5.00	5.45	0.55	6.00	-1.0	0.83	223	0.74	1,633
	25.0	2.50	2.50	6.82	0.68	7.50	-5.0	0.33	73	0.24	533
	30.0	0.00	0.00	8.18	0.82	9.00	-9.0	0.00	-27	-0.09	-200
50% destroyed											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0	0.00	0
	2.5	6.25	6.25	0.68	0.07	0.75	5.5	8.33	2473	8.24	18,133
MSY	5.0	7.50	7.50	1.36	0.14	1.50	6.0	5.00	1473	4.91	10,800
	7.5	6.25	6.25	2.05	0.20	2.25	4.0	2.78	806	2.69	5,911
	10.0	5.00	5.00	2.73	0.27	3.00	2.0	1.67	473	1.58	3,467
OPEN ACCESS	12.5	3.75	3.75	3.41	0.34	3.75	0.0	1.00	273	0.91	2,000
	15.0	2.50	2.50	4.09	0.41	4.50	-2.0	0.56	139	0.46	1,022
	20.0	0.00	0.00	5.45	0.55	6.00	-6.0	0.00	-27	-0.09	-200
60% destroyed											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0	0.00	0
	2.5	5.25	5.25	0.68	0.07	0.75	4.5	7.00	2073	6.91	15,200
MSY	4.0	6.00	6.00	1.09	0.11	1.20	4.8	5.00	1473	4.91	10,800
	5.0	5.50	5.50	1.36	0.14	1.50	4.0	3.67	1073	3.58	7,867
	7.5	4.25	4.25	2.05	0.20	2.25	2.0	1.89	539	1.80	3,956
OPEN ACCESS	10.0	3.00	3.00	2.73	0.27	3.00	0.0	1.00	273	0.91	2,000
	15.0	0.50	0.50	4.09	0.41	4.50	-4.0	0.11	6	0.02	44
	16.0	0.00	0.00	4.36	0.44	4.80	-4.8	0.00	-27	-0.09	-200
75% destroyed											
	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0	0.00	0
MSY	2.5	3.75	3.75	0.68	0.07	0.75	3.0	5.00	1473	4.91	10,800
	5.0	2.50	2.50	1.36	0.14	1.50	1.0	1.67	473	1.58	3,467
OPEN ACCESS	6.3	1.88	1.88	1.70	0.17	1.88	0.0	1.00	273	0.91	2,000
	7.5	1.25	1.25	2.05	0.20	2.25	-1.0	0.56	139	0.46	1,022
	10.0	0.00	0.00	2.73	0.27	3.00	-3.0	0.00	-27	-0.09	-200

Appendix 3

Destruction of coral reefs and its functions due to explosive fishing per km2 (1000 US$**); (Scenario: 'LOW' Value)

	Coral destruction (%)	Coral fishery yield (%)	Coastal protec-tion function (%)	Future tourism potential (%)	Gross revenue sust. fishery	Other costs sust. fishing	Opport cost labour (sust.)	Net revenue sustain fishery	Gross revenue blast fishing	Cyanide costs blast fishing	Other costs blast fishing	Opp. cost labour (blast)	Net revenue blast fishing	Gross revenue other fishery	Other costs other fishing	Opp. cost labour (other)	Net revenue of rest fishery	Net revenue of total fishery w.blast	Value loss of coastal protec.	Value loss of tourist potential	Net revenue sustain. fishery	Net value of total fishery w.blast
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	H	U
	Percentage for functions								Cost & ben. per yr. for poison fishers*								Annual data*		NPV figures*			
Year:					15.0	0.3	2.7	E-F-G	6.0	0.3	0.65	0.55	I-J-K-L	6.00	0.11	1.09	N-O-P	M+Q	25.4	3.0	E-F-G	N-O-P-H
YR 0	0%	100%	100%	100%	15.0	0.3	2.7	12.0	0.00	0.00	0.00	0.00	0.00	15.00	0.27	2.73	12.00	12.0	0.0	0.0		
YR 1	8%	93%	100%	50%	15.0	0.3	2.7	12.0	5.55	0.30	0.65	0.55	4.1	5.55	0.10	1.01	4.44	8.49	0.0	0.2	12.0	-3.7
YR 2	15%	85%	100%	0%	15.0	0.3	2.7	12.0	5.10	0.30	0.65	0.55	3.6	5.10	0.09	0.93	4.08	7.68	0.0	0.3	12.0	-4.7
YR 3	23%	78%	100%	0%	15.0	0.3	2.7	12.0	4.65	0.30	0.65	0.55	3.2	4.65	0.09	0.84	3.72	6.87	0.0	0.3	12.0	-5.5
YR 4	30%	70%	93%	0%	15.0	0.3	2.7	12.0	4.20	0.30	0.65	0.55	2.7	4.20	0.08	0.76	3.36	6.06	0.2	0.3	12.0	-6.5
YR 5	38%	63%	83%	0%	15.0	0.3	2.7	12.0	3.75	0.30	0.65	0.55	2.3	3.75	0.07	0.68	3.00	5.25	0.5	0.3	12.0	-7.6
YR 6	45%	55%	70%	0%	15.0	0.3	2.7	12.0	3.30	0.30	0.65	0.55	1.8	3.30	0.06	0.60	2.64	4.44	0.8	0.3	12.0	-8.7
YR 7	53%	48%	56%	0%	15.0	0.3	2.7	12.0	2.85	0.30	0.65	0.55	1.4	2.85	0.05	0.52	2.28	3.63	1.0	0.3	12.0	-9.7
YR 8	60%	40%	43%	0%	15.0	0.3	2.7	12.0	2.40	0.30	0.65	0.55	0.9	2.40	0.04	0.44	1.92	2.82	1.3	0.3	12.0	-10.8
YR 9	68%	33%	29%	0%	15.0	0.3	2.7	12.0	1.95	0.30	0.65	0.55	0.5	1.95	0.04	0.35	1.56	2.01	1.6	0.3	12.0	-11.9
YR 10	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 11	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 12	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 13	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 14	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 15	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 16	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 17	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 18	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 19	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 20	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 21	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 22	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 23	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 24	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
YR 25	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	1.9	0.3	12.0	-13.0
net present value year 1 to 25**					136.2	2.5	24.8	108.9	28.2	2.7	5.9	5.0	14.6	28.2	0.5	5.1	22.6	37.1	8.9	2.9	108.9	-83.6

* 15.00 is maximum sustainable yield in mt/km2/yr (reefflat 20mt/km2/yr and
0.27 are other costs of fishing (nets; out-rigger boats (w/o motor), nets, etc.)
2.73 is opportunity costs of labour (10 people; Rp. 2000 per day; 300 days);
6.00 is value of blast yield (US$ 0.67 per kg) and 30kg per day for 300 days;
0.30 is total costs of explosives (US$ 1.0 for beer bottle-sized bomb; 1 bomb per day during 300 dyas);
0.65 are other costs of blast fishing (Rp.4800 per day per boat (two people); 300 days a year);
0.55 is opportunity costs of labour (2 people; Rp. 2000; 300 days);
6.00 is value of yield from remaining fishery (US$ 1 per kg; yield corresponds to the optimal level of effort as function of reef-destruction);
0.11 are other costs of fishing (see above), depending here on optimal level of effort;
1.09 is opportunity costs of labour (Rp. 2000 per day; 300 days; number of people is optimal level of effort as function of destruction);
25.40 NPV of coastal protection function (cf. text for assumptions);
3.00 NPV of tourism protection function in current scenario (cf. text for assumptions);

** NPV is taken over 25 years; discount rate = OCC = 10%; 1 US$ is 2,200 Rp.

Appendix 4

Destruction of coral reefs and its functions due to explosive fishing per km2 (1000 US$**); (Scenario: 'HIGH' Value)

	Coral destruction (%)	Coral fishery yield (%)	Coastal protection function (%)	Future tourism potential (%)	Gross revenue sust. fishery	Other costs sust. fishing	Opport cost labour (sust.)	Net revenue sustain fishery	Gross revenue blast fishing	Cyanide costs blast fishing	Other costs blast fishing	Opp. cost labour (blast)	Net revenue blast fishing	Gross revenue other fishery	Other costs other fishing	Opp. cost labour (other)	Net revenue of rest fishery	Net revenue of total fishery w.blast	Value loss of coastal protec.	Value loss of tourist potential	Net revenue sustain. fishery	Net value of total fishery w.blast
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	H	U
	Percentage for functions								Cost & ben. per yr. for poison fishers*								Annual data*		NPV figures*			
Year:					15.0	0.3	2.7	E-F-G	6.0	0.3	0.65	0.55	I-J-K-L	6.00	0.11	1.09	N-O-P	M+Q	550.0	503.0	E-F-G	N-O-P-H
YR 0	0%	100%	100%	100%	15.0	0.3	2.7	12.0	0.00	0.00	0.00	0.00	0.00	15.00	0.27	2.73	12.00	12.0	0.0	0.0		
YR 1	8%	93%	100%	50%	15.0	0.3	2.7	12.0	5.55	0.30	0.65	0.55	4.1	5.55	0.10	1.01	4.44	8.49	0.0	27.9	12.0	-31.5
YR 2	15%	85%	100%	0%	15.0	0.3	2.7	12.0	5.10	0.30	0.65	0.55	3.6	5.10	0.09	0.93	4.08	7.68	0.0	55.9	12.0	-60.2
YR 3	23%	78%	100%	0%	15.0	0.3	2.7	12.0	4.65	0.30	0.65	0.55	3.2	4.65	0.09	0.84	3.72	6.87	0.0	55.9	12.0	-61.0
YR 4	30%	70%	93%	0%	15.0	0.3	2.7	12.0	4.20	0.30	0.65	0.55	2.7	4.20	0.08	0.76	3.36	6.06	4.1	55.9	12.0	-65.9
YR 5	38%	63%	83%	0%	15.0	0.3	2.7	12.0	3.75	0.30	0.65	0.55	2.3	3.75	0.07	0.68	3.00	5.25	10.2	55.9	12.0	-72.8
YR 6	45%	55%	73%	0%	15.0	0.3	2.7	12.0	3.30	0.30	0.65	0.55	1.8	3.30	0.06	0.60	2.64	4.44	16.3	55.9	12.0	-79.7
YR 7	53%	48%	63%	0%	15.0	0.3	2.7	12.0	2.85	0.30	0.65	0.55	1.4	2.85	0.05	0.52	2.28	3.63	22.4	55.9	12.0	-86.7
YR 8	60%	40%	53%	0%	15.0	0.3	2.7	12.0	2.40	0.30	0.65	0.55	0.9	2.40	0.04	0.44	1.92	2.82	28.5	55.9	12.0	-93.6
YR 9	68%	33%	43%	0%	15.0	0.3	2.7	12.0	1.95	0.30	0.65	0.55	0.5	1.95	0.04	0.35	1.56	2.01	34.6	55.9	12.0	-100.5
YR 10	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 11	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 12	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 13	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 14	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 15	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 16	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 17	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 18	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 19	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 20	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 21	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 22	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 23	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 24	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
YR 25	75%	25%	33%	0%	15.0	0.3	2.7	12.0	1.50	0.30	0.65	0.55	0.0	1.50	0.03	0.27	1.20	1.20	40.7	55.9	12.0	-107.4
net present value year 1 to 25**					136.2	2.5	24.8	108.9	28.2	2.7	5.9	5.0	14.6	28.2	0.5	5.1	22.6	37.1	193.0	481.9	108.9	-746.7

* 15.00 is maximum sustainable yield in mt/km2/yr (reefflat: 20mt/km2/yr and
0.27 are other costs of fishing (nets; out-rigger boats (w/o motor), nets, etc.)
2.73 is opportunity costs of labour (10 people; Rp. 2000 per day 300 days);
6.00 is value of blast yield (US$ 0.67 per kg) and 30kg per day for 300 days;
0.30 is total costs of explosives (US$ 1.0 for beer bottle-sized bomb; 1 bomb per day during 300 dyas);
0.65 are other costs of blast fishing (Rp.4800 per day per boat (two people); 300 days a year);
0.55 is opportunity costs of labour (2 people; Rp. 2000; 300 days);
6.00 is value of yield from remaining fishery (US$ 1 per kg; yield corresponds to the optimal level of effort as function of reef-destruction);
0.11 are other costs of fishing (see above), depending here on optimal level of effort;
1.09 is opportunity costs of labour (Rp. 2000 per day; 300 days; number of people is optimal level of effort as function of destruction);
550.00 NPV of coastal protection function (cf. text for assumptions);
503.00 NPV of tourism protection function in current scenario (cf. text for assumptions);

** NPV is taken over 25 years; discount rate = OCC = 10%; 1 US$ is 2,200 Rp.

Appendix 5

Destruction of coral reefs and its functions due to small scale poison fishing per km2 (1000 US$**); (Scenario: some tourism potential)

	Coral destruction (%)	Coral fishery yield (%)	Coastal protec-tion function (%)	Future tourism potential (%)	Gross revenue sust. fishery	Other costs sust. fishing	Opport cost labour (sust.)	Net revenue sustain. fishery	Gross revenue poison fishing	Cyanide costs poison fishing	Other costs poison fishing	Opport cost labour (pois.)	Net revenue poison fishing	Gross revenue other fishery	Other costs other fishing	Opport cost labour (other)	Net revenue of rest fishery	Net revenue of total fishery w.poison	Value loss of coastal protec.	Value loss of tourist potential	Net revenue sustain. fishery	Net value of total fishery w.poison	Gross revenue hook&line live-fish	Gross revenue other fishery	Other costs fishing (with H&L)	Opport cost labour (with H&L)	Net revenue of total fishery with H&L
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	H	U	V	W	X	Y	Z
	Percentage for functions								Cost & ben. per yr. for poison fishers*								Annual data*		NPV figures*				Annual sustainable fishery data*				
Year:					15.0	0.3	2.7	E-F-G	15.0	0.2	0.6	2.4	I-J-K-L	6.0	0.2	2.2	N-O-P	M+Q	0.0	40.5	E-F-G	N-O-P-H	5.0	14.0	0.8	2.7	V+W-X-Y
Yr 0	0%	100%	100%	100%	15.0	0.3	2.7	12.0																			
Yr 1	50%	70%	100%	0%	15.0	0.3	2.7	12.0	15.0	0.2	0.6	2.4	11.8	6.0	0.2	2.2	3.6	15.4	0.0	4.5	12.0	-1.1	5.0	11.7	0.8	2.7	13.1
Yr 2	50%	40%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	6.0	0.2	2.2	3.6	3.6	0.0	4.5	12.0	-12.9	5.0	14.0	0.8	2.7	15.5
Yr 3	48%	42%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	6.3	0.2	2.2	3.9	3.9	0.0	4.5	12.0	-12.6	5.0	14.0	0.8	2.7	15.5
Yr 4	47%	44%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	6.6	0.2	2.2	4.2	4.2	0.0	4.5	12.0	-12.3	5.0	14.0	0.8	2.7	15.5
Yr 5	45%	46%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	6.9	0.2	2.2	4.5	4.5	0.0	4.5	12.0	-12.0	5.0	14.0	0.8	2.7	15.5
Yr 6	43%	48%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	7.2	0.2	2.2	4.8	4.8	0.0	4.5	12.0	-11.7	5.0	14.0	0.8	2.7	15.5
Yr 7	42%	50%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	7.5	0.2	2.2	5.1	5.1	0.0	4.5	12.0	-11.4	5.0	14.0	0.8	2.7	15.5
Yr 8	40%	52%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	7.8	0.2	2.2	5.4	5.4	0.0	4.5	12.0	-11.1	5.0	14.0	0.8	2.7	15.5
Yr 9	38%	54%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	8.1	0.2	2.2	5.7	5.7	0.0	4.5	12.0	-10.8	5.0	14.0	0.8	2.7	15.5
Yr 10	37%	56%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	8.4	0.2	2.2	6.0	6.0	0.0	4.5	12.0	-10.5	5.0	14.0	0.8	2.7	15.5
Yr 11	35%	58%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	8.7	0.2	2.2	6.3	6.3	0.0	4.5	12.0	-10.2	5.0	14.0	0.8	2.7	15.5
Yr 12	33%	60%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	9.0	0.2	2.2	6.6	6.6	0.0	4.5	12.0	-9.9	5.0	14.0	0.8	2.7	15.5
Yr 13	32%	62%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	9.3	0.2	2.2	6.9	6.9	0.0	4.5	12.0	-9.6	5.0	14.0	0.8	2.7	15.5
Yr 14	30%	64%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	9.6	0.2	2.2	7.2	7.2	0.0	4.5	12.0	-9.3	5.0	14.0	0.8	2.7	15.5
Yr 15	28%	66%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	9.9	0.2	2.2	7.5	7.5	0.0	4.5	12.0	-9.0	5.0	14.0	0.8	2.7	15.5
Yr 16	27%	68%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	10.2	0.2	2.2	7.8	7.8	0.0	4.5	12.0	-8.7	5.0	14.0	0.8	2.7	15.5
Yr 17	25%	70%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	10.5	0.2	2.2	8.1	8.1	0.0	4.5	12.0	-8.4	5.0	14.0	0.8	2.7	15.5
Yr 18	23%	72%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	10.8	0.2	2.2	8.4	8.4	0.0	4.5	12.0	-8.1	5.0	14.0	0.8	2.7	15.5
Yr 19	22%	74%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	11.1	0.2	2.2	8.7	8.7	0.0	4.5	12.0	-7.8	5.0	14.0	0.8	2.7	15.5
Yr 20	20%	76%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	11.4	0.2	2.2	9.0	9.0	0.0	4.5	12.0	-7.5	5.0	14.0	0.8	2.7	15.5
Yr 21	18%	78%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	11.7	0.2	2.2	9.3	9.3	0.0	4.5	12.0	-7.2	5.0	14.0	0.8	2.7	15.5
Yr 22	17%	80%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	12.0	0.2	2.2	9.6	9.6	0.0	4.5	12.0	-6.9	5.0	14.0	0.8	2.7	15.5
Yr 23	15%	82%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	12.3	0.2	2.2	9.9	9.9	0.0	4.5	12.0	-6.6	5.0	14.0	0.8	2.7	15.5
Yr 24	13%	84%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	12.6	0.2	2.2	10.2	10.2	0.0	4.5	12.0	-6.3	5.0	14.0	0.8	2.7	15.5
Yr 25	12%	86%	100%	0%	15.0	0.3	2.7	12.0	0.0	0.0	0.0	0.0	0.0	12.9	0.2	2.2	10.5	10.5	0.0	4.5	12.0	-6.0	5.0	14.0	0.8	2.7	15.5
net present value year 1 to 25**					136.2	2.5	24.8	108.9	13.6	0.2	0.5	2.2	10.7	72.3	1.9	19.8	50.6	61.3	0.0	40.8	108.9	-88.4	45.4	125.0	7.4	24.8	138.1

* 15.0 is maximum sustainable yield in mt/km2/yr (reefflat 20mt/km2/yr and
0.3 are other costs of fishing (nets; out-rigger boats (w/o motor), nets etc.)
2.7 is opportunity costs of labour (10 people; Rp. 2000 per day; 300 days);
15.0 is 2 mt/km2 of catcheable biomass of groupers with price US$7 for live grouper and US$1 for dead grouper and 33% mortality rate
0.2 is total costs of cyanide (US$ 0.1 for cyanide per grouper and 2 mt of grouper with average size 1 kg);
0.6 are other costs of poison fishing (5 out-board motor boats with each annual costs of US$ 300)
2.4 is opportunity costs of labour (5 people; US$ 480 each)
6.0 is net revenue from fishery in partly destroyed reef with 8 people (the optimal level of effort in non-destroyed reef);
0.0 NPV of coastal protection function (cf. text for assumptions);
40.5 NPV of tourism protection function in current scenario (cf. text for assumptions);
5.0 is gross revenue of hook-and-line fishery (1 mt/km2 of sust. grouper yield with prices as above and the same 33% mortality rate)
14.0 is gross revenue of other fishery (14/15 of normal yield; the rest is groupers, treated separately)
0.8 are the other costs (Rp. 180,000 per year)

2.7 is opportunity costs for 10 persons (Rp. 2000 per day; 300 days a year)

** NPV is taken over 25 years; discount rate = OCC = 10%; 1 US$ is 2,200 Rp.

Appendix 6 Destruction of coral reefs and its functions due to large scale poison fishing (in Million US$)

	gross revenue poison fishing	labor costs poison fishing	other costs poison fishing	cyanide costs poison fishing	SCUBA costs poison fishing	side-payments cyanide fishing	net revenue poison fishing	value loss of coastal protec.	value loss of tourist poten-tial	net value of total poson fishery	gross revenue hook&! live fish	labor costs hook& 1 live fish	other costs hook& 1 live-fish	net revenue of hook&1 live-fish	other income poison fisher-men	net gains to society of switching to hook&1
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	cost & benefit per year for poison fishers *						Total A B	npv figures *		Total	annual sust. fishery data			Total		Total
year	150.0	34.1	25.0	2.0	5.0	10.0	C D E F	0.0	323.6	G H I J	75.0	17.0	22.5	K L M	2.7	N J G
yr. 0																
yr. 1	150.0	34.1	25.0	2.0	5.0	10.0	73.9	0.0	9.0	64.9	75.0	17.0	22.5	35.5	0.0	-29.5
yr. 2	150.0	34.1	25.0	2.0	5.0	10.0	73.9	0.0	18.0	55.9	75.0	17.0	22.5	35.5	0.0	-20.5
yr. 3	150.0	34.1	25.0	2.0	5.0	10.0	73.9	0.0	27.0	46.9	75.0	17.0	22.5	35.5	0.0	-11.5
yr. 4	150.0	34.1	25.0	2.0	5.0	10.0	73.9	0.0	36.0	38.0	75.0	17.0	22.5	35.5	0.0	-2.5
yr. 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7
yr. 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-36.0	75.0	17.0	22.5	35.5	2.7	68.7

Appendix 7: Destruction of Coral Reefs and its Functions due to Coral Mining

("LOW" value scenario; in 1000 US$; values per km2 of reef)

	Coral destruction (%)	Coral fishery yield (%)	Coastal protec. funct. (%)	Future tourism potent. (%)	Muddy fishery yield (%)	Gross revenue of coral mining	Costs of wood imput	Costs of bribes	Other costs for miners	Opportunity cost labour	Village benefits of coral mining	Net revenue sustain. fishery	Net revenue remain. fishery	Net revenue muddy fishery	Increm. loss of fishery yield	Value loss of coastal protec.	Value loss of tourist potent	Extern. costs wood inputs	Net value coral mining
	A	B	C	D	E	F	G	H	I	J	F-G-H-I-J	H	I	J	J-H-I	K	L		O
	49.09	15.00	2.82	0.33	3.75	49.09	10.91	8.73	2.18	16.36						25.4	3	10.91	
0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	15.0	0.0	0.0	0.0	0.0	0.00	
1	0.1	0.8	1.0	0.5	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	12.0	0.0	3.0	0.0	0.2	10.91	5.6
2	0.2	0.7	1.0	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	10.5	0.0	4.5	0.0	0.3	10.91	3.9
3	0.3	0.6	1.0	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	9.0	0.0	6.0	0.0	0.3	10.91	2.4
4	0.4	0.5	1.0	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	7.5	0.0	7.5	0.0	0.3	10.91	0.9
5	0.5	0.4	1.0	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	6.0	0.0	9.0	0.0	0.3	10.91	-0.6
6	0.6	0.3	0.8	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	4.5	0.0	10.5	0.6	0.3	10.91	-2.7
7	0.7	0.2	0.6	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	3.0	0.0	12.0	1.1	0.3	10.91	-4.7
8	0.8	0.1	0.4	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	1.5	0.0	13.5	1.7	0.3	10.91	-6.8
9	0.9	0.0	0.2	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	0.0	0.0	15.0	2.3	0.3	10.91	-8.9
10	1.0	0.0	0.0	0.0	0.0	49.1	10.9	8.7	2.2	16.4	10.9	15.0	0.0	0.0	15.0	2.8	0.3	10.91	-9.4
11	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	15.0	2.8	0.3	0.00	-18.2
12	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	15.0	2.8	0.3	0.00	-18.2
13	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	15.0	2.8	0.3	0.00	-18.2
14	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	15.0	2.8	0.3	0.00	-18.2
15	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	15.0	2.8	0.3	0.00	-18.2
16	1.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.4	14.6	2.8	0.3	0.00	-17.8
17	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.8	14.3	2.8	0.3	0.00	-17.4
18	1.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	1.1	13.9	2.8	0.3	0.00	-17.0
19	1.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	1.5	13.5	2.8	0.3	0.00	-16.7
20	1.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	1.9	13.1	2.8	0.3	0.00	-16.3
21	1.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	2.3	12.8	2.8	0.3	0.00	-15.9
22	1.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	2.6	12.4	2.8	0.3	0.00	-15.5
23	1.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.0	12.0	2.8	0.3	0.00	-15.2
24	1.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.4	11.6	2.8	0.3	0.00	-14.8
25	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
26	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
27	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
28	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
29	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
30	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	3.8	11.3	2.8	0.3	0.00	-14.4
						301.6	67.0	53.6	13.4	100.5	67.0	136.2	40.0	2.6	93.6	12.0	2.9	67.0	-54.8

Endnotes

i The coral area of Indonesia is commonly estimated at 50-100,000 km^2.
ii Some claim that a lower discount rate than the opportunity cost of capital is called for given the intergenerational character of the problem: however, this would not qualitatively change the results. Note that a 10% discount rate does not imply that all stakeholders will have this rate of time preference the discount rate is only used for the welfare economic analysis. The issue of rates of time preference for stakeholders will be discussed in the main text.
iii In the text, both the point estimate (75,000 km^2) and the range (50,000 - 100,000 km^2) will be used. The estimates will be justified below.
iv The primary goal of the proposed COREMAP project is to *improve the management of coral reef ecosystems and rehabilitate degraded coral reefs*, for the protection of biodiversity and the sustainable use of marine resources. The preliminary project components have been identified as follows: (i) Locally-based Management of Priority Coral Reef Sites: this component would, through a process of intersectoral and participatory planning with relevant Government agencies, NGOs, private sector representatives and local communities, identify viable solutions for improving coral reef management which address the socio-economic needs of coastal communities; (ii) Establishment of a Coral Reef Information Network: this component would develop and/or strengthen the management information network and manpower capabilities in a number of regional Coral Reef Centers (COREMACs); (iii) Strengthening the Human Resources Capacity, Planning, and Policies affecting coral reef ecosystems: this component would provide support to on-site management by improving relevant policies, regulations, and legislation influencing coral reef ecosystems; devise cost-effective enforcement mechanisms; and improve human resources capacity of project stakeholders through the provision of strategic education and training programs, and on-the-job skill development; (iv) Public Awareness and Participation: this component would aim to generate public support for conserving Indonesia's marine biodiversity by directing communication and education efforts at strategic audiences and decision makers.
COREMAP is expected to become a national program involving multiple donors and multiple projects. The project, which is expected to be financed by the World Bank and by the Global Environmental Facility, would be carried out an area encompassing five provinces in Eastern Indonesia of high biodiversity importance. The provinces have been tentatively identified as Maluku, Irian Jaya, South Sulawesi, East and West Nusa Tenggara. The project implementation will involve multiple agencies. It is expected that a steering committee will be created at the national level, coordinated by Bappenas, and that implementation will be carried out through local governments (for on-site activities), and through the Oceanology Centre of the Indonesian Institute of Science (LIPI-P3O) for monitoring and research activities.
v See Brown *et at.* (1993) for an literature review of valuation studies on, among others, coral reefs. Hoagland *et at.* (1995) give an overview of net benefit evaluations for marine reserves (esp. USA).
vi This is the net present value at a 10% discount rate. See McManus et al. (1992) for a very extensive site-survey of catch of various types of fishery in Bolinao (Philippines).
vii See McManus et al. (1992) for a very extensive site-survey of catch of various types of fishery in Bolinao (Philippines).
viii These techniques will be explained in Chapter 3 below.
ix Munro & Williams (1985) give a yield effort curve with fishing intensity expressed in persons in local population per hectare of reef. The maximum sustainable yield is around 11-12 kg per person per year. This either means that most people have other income generation most of the time or that hectares and km^2 are mixed up in the paper.
x McManus et al. (1992) also quotes a study of coral reef fish catch vs. fishing intensity for 11 American Samoa villages. The derived yield-curve shows a maximum sustainable yield (MSY) of around 30 mt/km2/year and a yield of around 15 mt/km2/year when fishing intensity is increased two to threefold.
xi See Hanig et al. (1988) gives costs of various types of capital.
xii See economic survey of subsistence farming in NTT (Indonesia), World Bank (1995)
xiii Riopelle (1992) assumes that 10% of hotel revenues are from directly reef-related tourism. This gives a net present value of total rent of US$ 17.8 million from 19 thousand divers and some 50 thousand snorkelers. Net present value of rental of diving and snorkeling equipment (with profit margin of 20% resp. 80%) is US$ 5.7, so that NPV of total reef-related rent is US$ 23.5 million.
xiv The mid-point between US$ 1,000,000 (major tourism) and US$ 6,000 (some tourism) is US$ 503,000.
xv Data on agriculture are from Hendrik van Voorthuizen, EA3AG, World Bank (pers. comm.).

[xvi] The discount rate is 10%, the opportunity cost of capital for Indonesia (in World Bank projects).

[xvii] Data on roads are from Joris van
Ven, EA3IN (World Bank) and data on houses are from Heinz Unger, ASTEN (World Bank), private communication.

[xviii] Anonymous manager of resort-chain; personal communication.

[xix] In Lombok, average annual costs are US$ 125,000. Taking a discount rate of 10% and a time-frame of 25 years, this means total costs of US$ 1.25 million (if costs are made at the beginning of each year). The hotel has a stretch of beach of 250 meter, so that the total costs are US$ 5.0 million per km. For the hotel in Bali, costs are US$ 1 million for an area of 500 meter, or US$ 2.0 million per km of coastline.

[xx] The objectives of the proposed 'Urgent Bali Beach Conservation Project' are (i) to prevent beach erosion; (ii) to protect coastal tourism resorts; (iii) to protect coastal places of worship. Source: Bappenas Bluebook 1995/96.

[xxi] For fishery, only one scenario is taken. The net benefits are, as discussed above, US$ 12,000 per km^2. This means that the present value at 10% discount rate is US$ 108,000 per km^2.

[xxii] The stone often pounds on the corals, thereby destroying them (Gomez et al; 1988).

[xxiii] Cyanide is bought in the form of Sodium cyanide ($NaCN$) or potassium cyanide (KCN). This is dissolved into water to obtain hydrocyanic acid (HCN) (cf. Rubec, 1988).

[xxiv] Anonymous, pers. comm. (1995)

[xxv] Dr. Johannes, pers. comm. (1996)

[xxvi] Johannes & Riepen (1995) give 50-70 tablets per kg and 2-6 tablets per one-liter squirt bottle; another account gives 50 tablets per kg and 1-2 tablets per bottle (pers. comm. Dr. V.R. Pratt).

[xxvii] Johannes & Riepen (1995).

[xxviii] data on kg/week are from Dr. V.R. Pratt (pers. comm.).Dr. R.E. Johannes suggested that daily catch per fisherman are around 9-10 live fish per day. This is in line with an account stating that a boat with a crew of 20 catches 3 tonnes per month (av. weight 1kg) (anonymous, pers. comm.). Assuming they fish 5-6 days a week, this gives 16-22 gr. of cyanide per live-fish provided they use one kg per week.

[xxix] For the Philippines, it is estimated that 150,000kg of cyanide is used per year (McAllister, 1988), though Dr. V. Pratt estimated the total cyanide use there to be 150-400 tons (Johannes & Riepen, 1995).

[xxx] McAllister (1988) also reports accounts of the use of 5 kg of cyanide per fisherman per week.

[xxxi] Pers. comm from Dr. R.E. Johannes and anonymous expert.

[xxxii] Johannes & Riepen (1995) and pers. comm from anonymous expert.

[xxxiii] McAllister (1988) reports US$ 6/kg; 1995 figures are the same (pers. comm. Dr. V.R. Pratt);

[xxxiv] Accounts for the Philippines state that in remote areas, retail prices might be as high as US$ 12.2 (in the villages of Jolo and Tawi-Tawi; Alvarez, 1995), whereas one account states that in a large drug store in Manila, cyanide is available for a mere US$ 3.5/kg.

[xxxv] Pratt (pers. comm. 1995).

[xxxvi] Anonymous source in Indonesian fishery industry (pers. comm. 1995).

[xxxvii] Wild-caught live food-fish is rubricated as 'ikan liannya' (other fish) in the category 'ikan hidup' (live fish), which further contains various fresh water fishes. The number 1,522 mt is the total number for 'other fish'. Probably, wild-caught live food-fish is the bulk of this category.

[xxxviii] This is the largest species (max. size is over 2 m!) of the fam *Labridae*. The Napoleon wrasse is also referred to as Humphead wrasse, Maori wrasse and giant labrid.

[xxxix]

[xl] Total maximum sustainable yield (MSY) of finfish is taken to be 10 mt/km^2/yr for moderately fished reefs and 20 mt/km^2/yr for pristine reefs (like reserves) (see Chapter 2 for assumptions).

[xli] This is a very rough estimate. Johannes & Riepen (1995) report that growth rates in aquaculture ponds in Taiwan for Malabar groupers (*Epinephelus malabaricus*) are as follows:

fertilised eggs to 8 cm fingerlings:	about three months
fingerlings to 600-800 gr. groupers	about 1 year
fingerlings to 2.0 kilograms	about 1.8-2 year.

Sexual maturity is reached after the first year, though sex conversion makes generalisations difficult. Besides, aquaculture data are often significantly different from reef-data. The data together give a general indication that the ratio biomass/catchable yield is somewhere between 1 and 3.

[xlii] Indonesia is assumed to have a reef area of 75,000 km^2 (see Chapter 1). Most of cyanide fishing is going on in Sulawesi, NTT,NTB, Maluku, Irian Jaya, with around 70% or total reefs. In these areas, 40% of coral cover was up to recently in good or excellent condition (Wilkinson *et al., 1993)*. This gives an area of 21,000 km^2 of relatively pristine reefs.

[xliii] With an annual export of 15,000 mt, and a mortality rate during collection and transport of some 50% (ADB, 1992; Johannes & Riepen, 1995) as well as a total catch of 10 mt/km^2, this would mean that grouper populations are wiped out in some 3,000 km^2 per year. If the catch takes place primarily in good and excellent reefs (total area is 21,000 km^2), and is destroyed by cyanide, this catch can last for some 7 years. Given its recent start, some 3 years ago, there are 4 more years to go.

[xliv] Allegedly, one large scale operator was seized by locals in the Marine National Park of Cenderawasih (Irian Jaya), but freed by the authorities after a ransom had been paid (anonymous, pers.comm, 1995).

[xlv] This is a conservative guestinate. One anonymous record mentioned that these payments are a lot and that they for a huge income to the Navy and the police.

[xlvi] The particular examples were for teripang and lobster fishing. However, for groupers, it seems that similar situation occur.

[xlvii] Estimates of Mark Erdmann are that there are fewer boats, but more trips. The overall number of boattrips, might be similar.

[xlviii] Actually, assuming that the effort will continue at a level of 10 menyears, the sustainable level of yield at that level of effort is 6 mt/km^2/yr (See Appendix 2 for detailed calculation).

[xlix] Pers. comm., anonymous expert.

[l] Johannes & Riepen (1995) state that with middlemen, village fishermen receive "approximately one-third of the price live fish agents pay to those who contract the fishermen. The standard markup between the fishermen contractor and the export agent [.....] was around 100%. Combining this information with the mark-ups, this means in the case of coral trout that the middleman gets around US$ 8-10 and the fisherman gets about US$ 2.5-3 (for highfin grouper and Napoleon wrasse, the amounts are more than twice as high).

[li] In the Philippines, distance-wise twice as close to the Hong Kong market as Indonesia, the fishermen get a higher share, as can be expected. Air-freight transport is extensively used, where the exporter gets the fish directly from the middlemen. The latter flies the live-fish from the provinces to Manila. In this case, Alvarez (1995) reports that fishermen are paid P 350/kg of grouper (US$ 14/kg) and twice as much for Napoleon wrasse (*i.e*. US$ 28/kg). Their middlemen sell the fish to Manila-based exporters for an average of P 900/kg (US$ 36/kg). The middleman delivers it transport-ready in special air-freight packages. The middlemen (*alias* export agent) make a net profit of US$ 8/kg. Alvarez (1995) states that "after deducting the cost of air freight, packing and other handling expenses, the middlemen make a per kilo net profit of P 200" (i.e. US$ 8). In the Philippines, live fish are in this case transported by air from the regions to Manila by plane and then from Manila to Hong Kong and other places. In other countries, the prices may also be different. For instance, Australia with a small but capital intensive live-fish trade (no cyanide) to the Asian market, gross return to the fishermen is around US$ 18 (see Johannes & Riepen, 1995). The other extreme is Papua New Guinea: fishermen get no more than US$ 1 per kg.

[lii] Hannig et al. (1988) give precise values for out-rigger boats and outboard motors: maximum prices for boats are Rp. 650,000 (average depreciation: 11 years); for out-board motors are Rp. 1 million (average depreciation: 6-7 years). This would give total average annual costs of around Rp. 400,000. Daily fuel costs are Rp. 4,000. If it takes them about a two month to catch all the groupers (i.e. they catch 8 groupers a day), then total fuel costs are around Rp. 200,000. Hence, total costs are around Rp. 600,000 (US$ 272) per year. With inflation over the years, we assume that currently, the costs will be US$300.

[liii] According to Dr. R.E. Johannes (pers. comm.), in one specific instance, fishermen using cyanide catch around 8-9 groupers a day and those using hook-and-line catch 4-5 a day. In more depleted reefs, the difference is probably larger in percentage terms.

[liv] It is assumed that the remaining catch can be harvested within the available time frame for two reasons: first, around the maximum sustainable yield, a marginal decrease in effort does not significantly decrease the yield

(assuming that the yield-effort curve is parabola-shaped); second, with 25 full time fishermen, catching 15 mt/km^2/yr, 500 days for 1mt of groupers is close to the average catch per effort.

[lv] All of the data are explained above and presented in Appendix 4 or can be inferred from the discussion above; other costs and opportunity costs for group B and C is split up between items I and II for convenience in a proportion of 1:15. Other costs of live fish grouper catch totals 7.4, of which 2.3 comes from other fishery (as in B-II). Hence, the rest (5.2) are a cost item for C-I.

[lvi] Thus it is assumed that the area has a 5% chance of having high tourist potential, a 15% change of have some recreational possibilities and a 80% chance of having no tourist potential at all.(*cf.* large scale operations).

[lvii] See above: 5% high tourism potential, 15% some possibilities and 80% no tourism potential.

[lviii] A.A. Alvarez (1995) presents estimates of 4,000 cyanide-using aquarium fish gatherers and 2,000 people involved in live food fish. McAllister (1988) reports 1,000 full time aquarium fish collectors. Rubec (1988) reports a lower number: 1500 aquarium fishers and 1500 live food fishers.

[lix] It is not easy to confirm this on the basis of the Indonesian annual fisheries statistics. Uncertainty exists about whether the fish are counted per piece or per kg, and if the volume is taken, it is not clear whether these are gross figures (including the water), or net weights. Value figures for 1993 in these statistics are US$ 2.84 million (category: 'ikan hias' or aquarium fish), less than 10% of our estimate.

[lx] Prices in Ambon (Maluku) range from Rp. 400 to 10,000 (US$ 0.18-4.5). The highest priced species are the Majestic angelfish (Pomacanthus xanthometapon) and the Striped triggerfish (Balistapus undulatus). Most of the catch, though, are damsels and other pomacentrids at the bottom of the price range.

[lxi] Galves et al. (1989) state that in San Roque (Philippines), blast fishing was already introduced after WW-I. FAO (7979) gives a short history of dynamiting in Ambon (Maluku, Indonesia). The idea that blast fishermen want to "earn money the easy way" is often heard (see Galvez et al, *op.cit.*).

[lxii] See Rubec (1988), Alcala & Gomez (1987) and Galvez et al. (1989) for accounts on the Philippines.

[lxiii] McManus et al. (1992) reports that within a listening radius of 2-3 km, some 10 explosions per hour could be heard in Bolinao Bay (Philippines).

[lxiv] Alcala & Gomez (1987) report this diameter figure for gallon sized bombs, but take 3 m for beer bottle bombs. McManus et al. (1992) quotes a range of 2-3 m. Therefore, we have taken 2.5 m as mid-point estimate.

[lxv] Blast overpressure doubles with an eight fold (2^3) increase of explosive charge in open water. Shock waves are reflected by the bottom depending on the type of substratum (Alcala & Gomez, 1987). A 4 kg charge corresponds to some two gallon seized bombs (assuming that ca. 50% is sand). As stated above, a gallon-sized bomb shatters an area of 10 m diameter to pieces, so two such bombs would destroy an area of around 12.5-14 meter, depending on the substratum. If this kills 4 of 5 genera of fish with air-bladders ca. 16 meters away, this means that most such fish are killed in a area with a diameter of 32 meters. Therefore, a gallon sized bomb destroys fish in a diameter-range more than twice as large as the range of shattered corals. Generalising this, we get the result in the text.

[lxvi] Rubec (1988) quotes two intact reefs with yields of 31.8-36.9 mt/km^2/yr and destroyed reefs (blasting; muro-ami) with yields of 5-5.9 mt/km^2/yr. Note that both figures should be taken with some caution as it is not clear whether the levels of effort differ.

[lxvii] Note that in the case of coral mining, we assumed that coastal erosion starts at 50% coral destruction. The reason for this difference is that in coral mining, the activities start on the reef flat, and gradually move out towards the crest. Therefore, the coastal protection function will be maintained longer. Needless to say, both are very rough generalisations, and site-specific conditions might be vastly different;

[lxviii] See Christie et al. (1994) for accounts on blasted areas on San Salvador's reef, compared to Apo Island, both in the Philippines.

[lxix] Alcala & Gomez (1987).

[lxx] Total live coral cover and mortality index for Apo are calculated using data in Savina & White (1986).

[lxxi] We assume a price some US$ 0.5-0.6/kg and a high profit margin (large rents); Erdmann (pers. comm. states that the range is probably between 3-8 tons, close to our outcomes.

[lxxii] Galvez et al. (1994) that blast fishers spend at most eight hours at sea. McManus (pers. comm.) states that the blast fishermen often spend only two hours at sea. Here we have taken a rough figure in between.

[lxxiii] Pauly et al. (1989) gives number of blasts per 10-16 hp. boat involved in dynamite fishing. Some 56% of boats have one blast per day; around 29% have two blasts and only 15% use three or more bombs. Own observations and interviews in Indonesia confirmed that most blast fishermen use one bomb per day.

[lxxiv] Dr. J.W. McManus, and Dr. V. Pratt, pers. comm.

lxxv Galvez et al. (1989) state that gunpowder costs around *P*150 (US$ 7.15 in 1988 prices) per kg. Sand and explosives charge are mixed half-half, so around 0.10 kg of gunpowder is used for a beer bottle. A blasting cap costs *P*10 (US$ 0.48). So . This means that the bomb costs around US$ 1.2. In Indonesia, we heard one account of 200 bottle bombs, made from a large WWII bomb, which was traded for Rp. 150,000-250,000 (US$ 68-114). This would mean that the explosives charge per bottle would only cost around US$ 0.34-0.57. Pratt (pers. comm.) conveyed that a softdrink bottle costs around US$ 0.5-1. From this combined information, we take as a rough point-estimate a price of a beer-bottle bomb to be US$ 1.

lxxvi Data LIPI (Jakarta), 1995.

lxxvii For the crew of two, the costs are US$ 1 for the bomb and Rp. 4,800 for the 'other' costs. With a price of fish of US$ 0.67 per kilo, this gives profits of

lxxviii The offical indonesian fisheries export statistics lump corals and shells together and gives kg and US$, but it is very difficult to relate these back to pieces.

lxxix Information from Dr. Soeharsono, LIPI, Jakarta (personal communication).

lxxx Data are for the Maldives quoted from Brown & Dunne (1988), p. 162.

lxxxi For an overview of impacts of dredging on coral reefs and off-site, see Salvat (1987). For an interesting account of coral rock mining in the Maldives, see Brown & Dunne (1988). Rubec (1988) gives an account of the extent of coral rock mining for construction and ornamental coral trade in the Philippines.

lxxxii It is known that coral rocks for construction are typically gathered by families building their own house. The alternative - bricks - cost around Rp.20-35 per bricks. For a simple house, around 5,000- 10,000 bricks might be used (data: Heinz Unger (ASTEN, World Bank) and the World Bank COREMAP team (pers. comm.);. It is not clear, though, how much reef is mined for the construction of one house.

lxxxiii Data on mining in Lombok are from Dr. Soeharsono, LIPI, as well as from field observations of members of the World Bank COREMAP-team (personal communication).

lxxxiv The Rupiah-dollar exchange rate is taken to be 2,200 Rp. for 1 dollar.

lxxxv Onother village in North West Lombok has 120-150 families in an area of 15 km of shoreline. These people have mined since 1935 approximately in that area. (Joop de Schutter, pers. comm.). These data are in line with the data used here.

lxxxvi Data are from Dr. Soeharsono, LIPI, and from Jim Douglas, EA3AG, World Bank (personal communication).

lxxxvii If logging concessions are going on in the neighbourhood of a coral mining area, fire wood (left-overs of the logging) could be obtained without additional forest destruction;

lxxxviii Data are from Dr. Soeharsono, LIPI, and from Hendrik v.Voorthuizen, EA3AG, World Bank (pers. comm.).

lxxxix See World Bank Nusu Tenggara Agricultural Area Development Project, Report. 15043, 1995.

xc Note that we focus on alternatives for lime and not on coral rocks also used for houses that could be substituted for bricks or, sometimes, wood (see footnote above); Data are from Pak Soeharsono, LIPI (pers. comm.).

xci A five to ten fold increase in wood input would, *ceteris paribus*, increase the price 2-3 fold. Other costs (mining costs) are probably higher as well. Therefore, inland hard coral rock is not a viable alternative.

xcii An economic analysis has been carried out in the 1980s in Lombok of the use of oil burners, which appear to be economical (J. de Schutter, pers. comm.).

xciii Dr Johannes, pers. comm.

xciv The difference between the benefits to the miners and the costs to the functions and the additional costs of wood is the present value of side-payments, which form a cost for the miners but not to society, as discussed above. Note also that the value for coastal protection is different from the present values discussed above (US$820, because the damage - esp. to coastal protection - will only occur gradually.

xcv Note that these values are different from the present values discussed above (US$50,000 for sand erosion and US$ 3,000 for tourism), because the damage - esp. to coastal protection - will only occur gradually.

xcvi The annual earnings of the miners is 1,260,000 Rp., because monthly sales of lime are: 200,000 Rp.; costs of fuel wood costs: 33,000; costs of protection: 27,000 Rp. Mining takes place for 9 months a year. This means that on an average monthly basis per year, income is 105,000 Rp.

xcvii Tomascik et al. (1993) also give the relationship between the extinction coefficient (k) and distance of various islands from mainland Java (x): $k = 0.86\, x^{-0.58}$. The extinction coefficient, k, is related to the *secchi disk* depth (D) in the following way: $k = 1.7/D$.

xcviii The linear relationship between distance from mainland Java (D) and percentage of live coral cover (C) is: $C = 6.7290 + 0.4565*D$. The correlation coefficient is r=0.6549 (Hutomo, 1987).

[xcix] Dr. G. Hodgson (pers. comm.).

[c] Likewise, Ruiterbeek (1992) has carried out an economic evaluation of mangrove logging and corresponding losses to society (fishing, etc.) for Bintuni Bay, Irian Jaya (Indonesia). However, in that area, there are no coral reefs. Interestingly, Ruiterbeek has not assumed any *a priori* links between logging and fishery, but instead, has calculated costs and benefits for different linkage assumptions.

[ci] In the case of mining, there ae additional costs to society due to unsustainable logging (US$ 67,000 per km^2).

[cii] In the case of logging, the data are derived from Hodgson & Diuxon (1988). The Pagdanan Timber Products Inc. (PTPI) in Northern Palawan (Philippines) is the sole logging company in the Bacuit Bay.

[ciii] Data are based on large scale poison fishing operations (Chapter 3.2). It is assumed that for the large scale poison fishing, between 20-100 high ranking people receive side-payments. This is a rather wild guess, based on anecdotal information.