

Unclassified

ENV/EPOC/GSP/BIO(2001)5/FINAL



Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

29-Mar-2002

English - Or. English

ENVIRONMENT DIRECTORATE
ENVIRONMENT POLICY COMMITTEE

Cancels & replaces the same document of 25 January 2002

Working Party on Global and Structural Policies
Working Group on Economic Aspects of Biodiversity

THE BIODIVERSITY BENEFITS OF CORAL REEF ECOSYSTEMS:
VALUES AND MARKETS

by
Herman CESAR
Cesar Environmental Economics Consulting, Amsterdam, The Netherlands

Contact for comments: Herman CESAR, Cesar Environmental Economics Consulting, Amsterdam, The Netherlands - Tel. (+31-20) 444 95 77; email: herman.cesar@ivm.vu.nl. For copies: Philip BAGNOLI, OECD, ENV/GSP: Tel. (+33-1) 44 24 76 95; email: philip.bagnoli@oecd.org

JT00123420

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

ENV/EPOC/GSP/BIO(2001)5/FINAL
Unclassified

English - Or. English

Copyright OECD, 2002

Applications for permission to reproduce or translate all or part of this material should be addressed to Head of Publications Service, OECD, 2 rue André-Pascal, 75775 Paris CEDEX 16, France.

FOREWORD

This report was prepared by Herman Cesar of Cesar Environmental Economics Consulting, Amsterdam, The Netherlands.

This document is made available to the public as a consultant's report. The opinions expressed and the arguments employed in this document are the sole responsibility of the author and do not necessarily reflect those of the Working Group on the Economic Aspects of Biodiversity or the governments of OECD Member countries.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 7

1. INTRODUCTION 8

2. GOODS AND SERVICES OF REEFS, THEIR MARKET AND ECONOMIC VALUE 10

3. CASE STUDY 1: MARINE MARKET TRANSFORMATION OF THE LIVE REEF FISH FOOD TRADE 14

 3.1 Introduction..... 14

 3.2 The Market and Trade in Live Reef Fish..... 15

 3.3 Marine Market Transformation 16

 3.4 Steps Toward a Market Transformation of the LRFT 18

4. CASE STUDY 2: ECONOMIC ANALYSIS FOR TAKA BONE RATE MARINE PROTECTED AREA (INDONESIA) 20

 4.1 Introduction..... 20

 4.2 Data and Trends 22

 4.3 Results of the Economic Analysis 24

 4.4 Financial Analysis of Village Micro-Enterprise Activities 25

 4.5 Economic Justification for Village Subsidies 26

5. CASE STUDY 3: COSTS AND BENEFITS OF CORAL MINING IN LOMBOK, INDONESIA..... 28

 5.1 Introduction..... 28

 5.2 Financial Analysis: The Coral Mining Business 29

 5.3 Financial Economic Analysis: Societal Costs of Coral Mining..... 29

 5.4 Discussion Coral Mining 32

6. OVERALL DISCUSSION 33

REFERENCES..... 35

THE BIODIVERSITY BENEFITS OF CORAL REEF ECOSYSTEMS: VALUES AND MARKETS

by

Herman Cesar

Cesar Environmental Economics Consulting, Amsterdam, The Netherlands

EXECUTIVE SUMMARY

In most tropical countries, coral reef ecosystems provide many goods and services to coastal populations, such as subsistence and commercial fishery, tourism, coastal protection and biodiversity. A variety of anthropogenic practices threatens reef health and therefore jeopardizes the benefits flowing from these services and goods. These threats range from local pollution, sedimentation, destructive fishing practices and coral mining to global issues like coral bleaching. Economic valuation can help to shed light to the importance of the services and goods by 'getting some of the numbers on the table'. Creating markets for sustainable resource utilization can enhance the value captured by the local population from these goods and services.

This paper gives some background to economic valuation (Total Economic Value, Cost Benefit Analysis) and market creation as well as three case studies. These case studies illustrate: (i) the creation of a market for sustainably caught/reared reef fish as an alternative to cyanide fishing; (ii) the economic valuation of marine protected areas; and (iii) the economic valuation of a threat to coral reefs (coral mining).

1. INTRODUCTION

Coral reefs form a unique ecosystem, richer in marine biodiversity than any other in the world. Reefs are also 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 both the productivity of reefs and the rather strict environmental requirement of corals.

Coral reefs have important ecosystem functions which provide crucial goods and services to hundreds of millions of people. The goods and services 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. And coral reefs form a natural protection against wave erosion.

Currently, however, coral reefs are being depleted rapidly in many locations in the world due to destructive fishing practices (poison fishing, blast fishing, muro-ami, etc.), coral mining, marine pollution, sedimentation and coral bleaching among others. Often, these threats are the result of externalities: people causing the threat benefit from unsustainable economic activities, but the costs are borne by others depending in some way or another on coral reefs. Economists argue that this is often due to the absence of a well-functioning market for environmental goods and services. Hodgson and Dixon (1988) describe a clear externality situation with 'no-market' where logging causes sedimentation resulting in reef degradation (tourism) and fishery losses. For the logging company, these tourism and fishery losses are not part of their profit calculation. In the absence of government policy and/or public outcry, logging would continue even if the external costs to society were much higher than the net profits of the logging industry, as was the case in the example of Hodgson and Dixon.

This example shows two points: (i) it highlights the fact that in the absence of markets for environmental goods and services, an optimal allocation of these goods and services can only be obtained through some form of intervention; (ii) it shows the importance of obtaining economic values for the various reef goods and services, e.g. a fishery value and a coastal protection value. These goods and services can deal with concrete marketable products, such as shell fish, for which the value can be determined based on the demand, supply, price and costs. Other services depend on the possible future uses of yet unknown biodiversity on reefs for which sometimes markets can be created. The values of all these goods and services together forms the Total Economic Value (TEV) of reefs ecosystems (e.g. Spurgeon, 1992). This TEV can be calculated for a specific area or for alternative uses (e.g. preservation area, tourism area, multiple use area, etc.). We can also use economic valuation to calculate the economic losses due to destruction of reef functions, as in blast fishing (Pet-Soede et al. 1999) or coral mining (Berg et al., 1998).

This paper deals with economic valuation and market creation with respect to coral reef ecosystems. First, the goods and services of coral reefs are described and basic concepts of economic valuation and markets are discussed in Section 2. The next three sections describe case studies on market

creation for sustainable grouper capture, on economic valuation of a marine protected area and on economic valuation of coral mining. The paper ends with a discussion in Section 6.

2. GOODS AND SERVICES OF REEFS, THEIR MARKET AND ECONOMIC VALUE¹

Ecosystems provide a great many functions, goods and service. The terms ‘functions’, ‘goods’ and ‘services’ have, in this context, slightly different meanings, though these terms are used interchangeably by many in the environmental economics literature. Costanza et al. (1997, p.253) define functions, services and goods in the following way: “Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem services”. For example, a forest provides the function of storage and retention of water, with the associated service of water supply.

In a recent paper by Moberg and Folke (1999), the most important goods and services of coral reef ecosystems are systematically presented (see Table 1). The authors distinguish goods into renewable resources (fish, seaweed, etc.) and mining of reefs (sand, coral, etc.). The services of coral reefs are categorised into: (i) physical structure services, such as coastal protection; (ii) biotic services, both within ecosystems (e.g. habitat maintenance) and between ecosystems (e.g. biological support through mobile links); (iii) biogeochemical services, such as nitrogen fixation; (iv) Information services (e.g. climate record); and (v) social and cultural services, such as aesthetic values, recreation and gaming. Note that this categorisation is slightly different than that of Costanza et al. (1997). Besides, Moberg and Folke additionally identify information services, such as climate and pollution records.

Table 1. Goods and ecological services of coral reef ecosystems identified in Moberg & Folke (1999)

----- Goods -----		----- Ecological services -----					
Renewable resources	Mining of reefs	Physical structure services	Biotic services (within ecosystem)	Biotic services (between ecosystems)	Bio-geo-chemical services	Information services	Social and cultural services
Sea food products	Coral blocks, rubble / sand for building	Shoreline protection	Maintenance of habitats				
Raw materials and medicines	Raw materials for lime and cement production	Build up of land	Maintenance of biodiversity and a genetic library	Biological support through ‘mobile links’	Nitrogen fixation	Monitoring and pollution record	Support recreation
Other raw materials (e.g. seaweed)	Mineral oil and gas	Promoting growth of mangroves and seagrass beds	Regulation of ecosystem processes and functions	Export organic production etc. to pelagic food webs	CO ₂ / Ca budget control	Climate control	Aesthetic values and artistic inspiration
Curio and jewellery		Generation of coral sand	Biological maintenance of resilience		Waste assimilation		Sustaining the livelihood of communities
Live fish and coral collected for aquarium trade							Support of cultural, religious and spiritual values

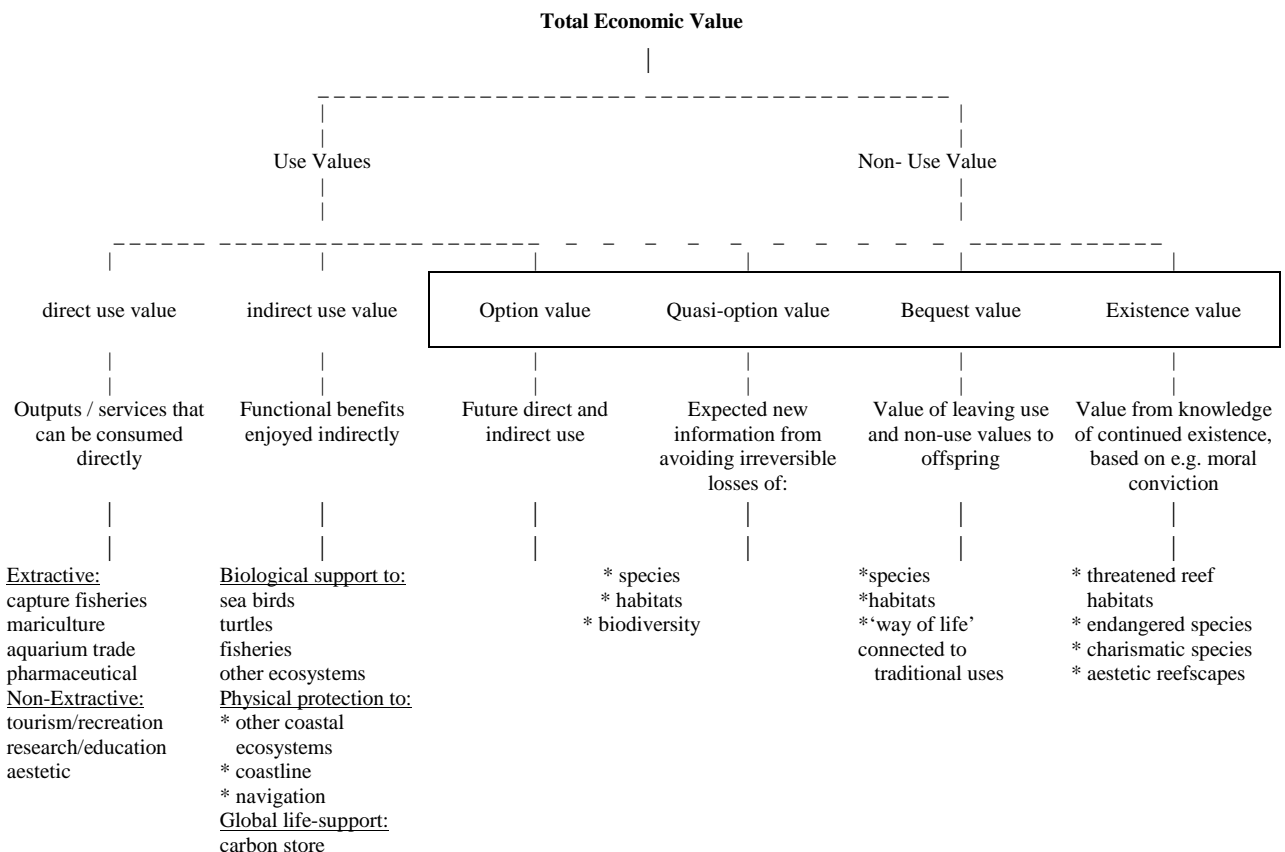
Source: adapted from Moberg and Folke (1999).

1. This section is an abbreviated version of Cesar (2000).

For a reef ecosystem, the economic value is often defined as the total value of its instruments, that is the goods and ecological services that an ecosystem provides. We therefore need to know the major goods and services of reef ecosystems as well as their interactions with other ecosystems. Next, these goods and services need to be quantified and monetized. For goods sold in the market place, this is straightforward by looking at their market price, but for ecological services, this is not the case. Therefore, complex valuation techniques are used to arrive at an economic value of these services. Note also that for each of the goods and ecological services where no markets exist at present, markets could be established in principle, although this might be very costly and impractical.

The value of all the compatible goods and services combined gives the Total Economic Value (TEV) for an ecosystem. The neo-classical foundations of economic value and its relationship with willingness to pay and consumer surplus are not discussed here (see Pearce and Turner, 1990 for a general discussion and Barton, 1994 and Pendleton, 1995 for a specific discussion on the economic value of coral reefs). Each of the goods and services of coral reefs presented in Table 1 above generate economic value. Fishery resources can be harvested and sold, creating value added and likewise, the coastal marine area enables sea transportation that creates profits. Similarly, preservation and eco-tourism create value. The mapping between the goods and services on the one hand and their values on the other hand is straightforward, as is shown in Figure 1.

Figure 1. Total Economic Value and Attributes of Economic Values for Coral Reefs



Source: Barton (1994).

As indicated in Figure 1, there are six categories of values: (i) direct use value; (ii) indirect use value; (iii) option value; (iv) quasi-option value; (v) bequest value and (vi) existence value. Direct use

values come from both extractive uses (fisheries, pharmaceuticals, etc.) and non-extractive uses. Indirect use values are, for example, the biological support in the form of nutrients and fish habitat and coastline protection. The concept of option value can be seen as the value now of potential future direct and indirect uses of the coral reef ecosystem. An example is the potential of deriving a cure for cancer from biological substances found on reefs. Bio-prospecting is a way of deriving money from this option value. The quasi-option value is related to the option value and captures the fact that avoiding irreversible destruction of a potential future use gives value today. The bequest value is related to preserving the natural heritage for generations to come where the value today is derived from knowing that the coral reef ecosystem exists and can be used by future generations. The large donations that are given to environmental NGOs in wills is an example of the importance of the bequest concept. The existence value reflects the idea that there is a value of an ecosystem to humans irrespective of whether it is used or not.

These values all are quite abstract and theoretical. Measuring these values in monetary ways is not straightforward, and in some cases (nearly) impossible. For an overview of different techniques, see Barton (1994), Pearce & Turner (1990), Dixon et al. (1988), etc. Yet, it is important to take these values into account. As Dixon (1989) states: "Whether a coastal resource is a good or service, marketed or nonmarketed, is not important in terms of its function in the coastal ecosystem. The extent to which coastal resources represent easily marketed goods, however, heavily influences resource management decisions. Nonmarketed goods and environmental or ecosystem services are frequently overlooked or their importance played down. This is one of the factors leading to resource management conflicts and poor decisions". Therefore, creation of non-existing markets and transformation of markets that do not function well can be a solution to environmental problems and overextraction of resources, as is shown in the first case study. The background to the other two case studies will also be briefly discussed here to finish this section.

Case 1: Market transformation live food reef fish trade Current practices in the live reef fish trade pose a critical threat to global marine biodiversity. The trade also imperils the food security and income provided by traditional reef fisheries in Southeast Asia. This case study describes today's trade and its underlying destructive and unsustainable fishing practices, which include both the use of cyanide to stun fish as well as harvesting of spawning aggregations and overharvesting of juveniles. Though cyanide use is widely banned for fisheries in most, if not all countries, high profits and enforcement problems require policy makers to look for innovative ways to manage the supply of live reef fish. To this end, the concept of a marine market transformation is introduced and applied to reef fisheries. In particular, current wild-caught supply mechanisms are described and the potential for mariculture and sustainable wild-catch are evaluated. Sustainable management of the live reef fish trade requires active participation from both importing and exporting economies. However, action to date has been one-sided, with demand countries shifting responsibility for environmental damage to supply nations. The paper provides suggestions as to how this situation can be remedied and discusses creative market and policy solutions for achieving transformation of the current trade to one which is non-destructive and sustainable.

Case 2: Economic Valuation of Take Bone Rate Marine Protected Area Establishment of marine protected areas (MPAs) is a costly affair and a government needs to be well-informed about the pros and cons of an additional MPA (McClanahan, 1999). Determining the economic value for an MPA and comparing the costs and benefits of establishing and running an MPA are two crucial steps for an economist involved in MPAs. The net benefits of establishing a park are defined as the net increase in the value of the ecosystem due to the establishment and management of the park minus the costs of managing the park. Pendleton (1995, p.119) states: "Past valuations of tropical marine parks inaccurately measure their economic value because they value the resource protected and not the protection provided". For the Take Bone Rate archipelago (South Sulawesi, Indonesia), these steps were carried out as part of project economic analysis for the Indonesian Coral Reef Rehabilitation and Management Project (COREMAP), an

ongoing project run by the Indonesian Government and supported by the World Bank, the Asian Development Bank, AusAid and others.

Case 3: Economic Losses due to Coral Mining in Lombok, Indonesia Coral mining for lime production is a source of income and subsistence in many developing countries. The associated damage to the reef is however significant, both in physical and monetary terms. Since the economic benefits from reef destruction are often used to justify continuation of this threat, quantifying the costs associated with coral reef degradation is important to make a balanced assessment of the benefits and costs of various threats. To do this, a Cost Benefit Analysis (CBA) is carried out where the net benefits of coral mining to the people causing the threat are compared with the net societal costs plus the enforcement costs of actually eliminating coral mining in a specific location. We discuss the cost-benefit analysis for Lombok, Indonesia.

3. CASE STUDY 1: MARINE MARKET TRANSFORMATION OF THE LIVE REEF FISH FOOD TRADE²

3.1 Introduction

Reef fish stocks have seen a dramatic decline over the last decades with growing fishing pressure. Their sedentary nature and the habit of some of the larger species of reef fish of congregating in spawning aggregations, make them easy to target. A relatively small but important segment of reef fisheries is the live reef fish trade (LRFT) which involves the capture of living coral reef fish from Indo-Pacific island nations such as Indonesia, the Philippines and Papua New Guinea. The trade has traditionally focused on ornamental fishes, but recently, the bulk of the trade has shifted to reef food fish principally to supply Hong Kong, Taiwan and mainland China (Johannes and Riepen, 1995). Global annual retail value of the LRFT was roughly US\$1.2 billion in 1995, of which US\$1.0 billion from live food fish (Barber and Pratt, 1998). This case study focuses on the live food fish segment, primarily comprising groupers (Family Serranidae, especially the genera *Epinephelus* and *Plectropomus*) and small volumes of humphead wrasse (*Cheilinus undulatus*, also referred to as Napoleon or Maori wrasse).

The substantial profits generated by the LRFT are counterbalanced by serious environmental impacts. The two most pressing problems are the use of cyanide and overfishing of target species. During the 1980s, destructive cyanide fishing techniques, which enable the capture and transport of live reef fish to distant markets, became widespread for the LRFT. The ecological and economic impacts of cyanide fishing have recently gained considerable popular as well as scientific attention (Johannes and Riepen, 1995; Erdmann and Pet-Soede, 1998; Cesar, 1996; Barber and Pratt, 1997 and 1998; Bryant et al., 1998; Mous et al, 2000)³. While cyanide is a very effective method to capture reef fish⁴, its effects reach beyond targeted fish to damage corals, other reef invertebrates and non-target fish. The Indo-Pacific region contains over 90% of the world's coral reefs and serves as the planet's central repository for marine species. The destruction of these reefs poses a critical threat to global marine biodiversity.

Overfishing for the LRFT also imposes severe constraints on sustainability (Mous et al, 2000). As a direct result of the live reef fish trade, catches of giant grouper and humphead wrasse are increasingly rare. Spawning aggregations are increasingly targeted often removing a significant proportion of spawning fish during the course of their brief annual spawning period (Johannes and Lam, 1999, Rhodes, 1999). Such fishing practice could compromise the reproductive potential of these species. Mariculture of grouper species may also be contributing to overfishing problems. With its heavy reliance on wild-caught breeding stocks and juveniles for grow-out and its use of so-called 'trash' fish (i.e., by-catch which consists of

2. This section is an abbreviated version of Cesar et al. (2000).

3. Up-to-date information on the LRFT can be found in the "Live Reef Fish Information Bulletin" (South Pacific Commission; <http://www.spc.org.nc/coastfish/>).

4. In the live reef fishery, cyanide is used to stun and remove fish from hard-to-reach crevices and coral heads.

normally non-commercial species and juveniles of a range of species), the grouper mariculture industry may in fact be intensifying rather than decreasing existing pressure on wild grouper stocks (Sadovy and Pet, 1998).

The degradation of coral reefs and overfishing for the LRFT threaten the livelihood of already marginalized fishing communities. Vast areas of Indonesian reefs are being exhausted to support the LRFT and the collapse of its grouper fishery is imminent (Erdmann and Pet, 1999). A recent economic analysis estimates quantifiable losses to Indonesia from cyanide fishing to be US\$280 million compared with profits from the fishery of US\$234 million, a net loss of US\$46 million. Sustainable live reef fisheries were estimated to have a net societal benefit of US\$322 million in present value terms (Cesar et al. 1997). The discrepancy between profits and societal losses due to the LRFT, as well as the potential for better alternatives to the trade, drive the fundamental research question of this case study: can the current destructive practices and unsustainable market for live reef fish in Southeast Asia be transformed into a trade that is both non-destructive and sustainable?

3.2 The Market and Trade in Live Reef Fish

Few reliable statistics exist for the total value or volume of the live reef fish food market, partly because cyanide fishing is illegal and therefore the market is inherently not transparent. Estimates reveal that in 1995, the total volume of the LRFT was 20,000 to 25,000 tonnes (Johannes and Riepen, 1995). This corresponds to some 38 million fish with a retail revenue of US\$1.0 billion (Barber and Pratt, 1998). Estimates by Lau and Parry-Jones (1999) reveal a much larger trade: in 1997, Hong Kong alone imported nearly 32,000 metric tons of live reef fish, of which 18,900 were groupers and humphead wrasse (see also Mous et al, 2000). The contribution of other Asian economies, such as Japan, Taiwan, Singapore and Malaysia, is relatively small when compared with that of Hong Kong or China.

The LRFT is a lucrative business due to high retail prices and strong market demand in Hong Kong. Wholesale prices for coral reef fish average about US\$ 20 per kg, but can reach over US\$200 dollars per kg for valued species such as the giant grouper and humphead wrasse (Lau and Parry-Jones, 1999; Sadovy 1998). This demand stems from the Chinese, especially Cantonese, style of cooking that favours steamed seafood dishes which are delicate in both taste and texture. Above all, the Cantonese value food that is fresh, believing that a dish's flavour is enhanced if the animal is kept alive until the moment it is cooked. Exotic and colourful live groupers meet these strict culinary requirements, and the associated heavy price-tag is happily accepted (see Table 2 for prices of some species). Groupers are favourites in Hong Kong for important social occasions such as wedding or business celebrations.

Table 2. Market Prices in Hong Kong Dollars for Selected Live Reef Fishes in Hong Kong in May 1999.

<i>Species name</i>	<i>English common name</i>	<i>Price HK dollar per kg (US\$ per kg)</i>
<i>Epinephelus coioides</i>	Green, orange-spotted grouper	117 (\$15)
<i>E. polyphkadion</i>	Camouflage/flowery grouper, cod	137 (\$18)
<i>E. fuscoguttatus</i>	Brown-marble, tiger grouper	120 (\$16)
<i>E. akaara</i>	Hong Kong, red grouper	341 (\$44)
<i>E. lanceolatus</i>	Giant grouper	161 (\$21) *
<i>Cromileptes altivelis</i>	Highfin, rat, mouse, humpback grouper	500 (\$65)
<i>Plectropomus leopardus</i>	Leopard coral grouper, trout	233 (\$30)
<i>Plectropomus areolatus</i>	Spotted coral grouper, trout	149 (\$19)
<i>Cheilinus undulatus</i>	Humphead, Napoleon, Maori wrasse	417 (\$54)

Source: AFD Hong Kong, 1999.

*The price reflects the combined average price for giant grouper.

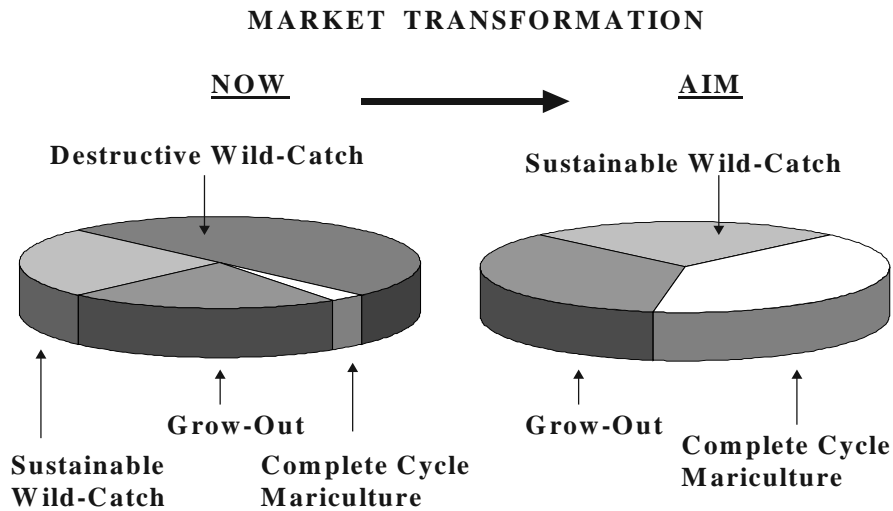
Major supply nations for the LRFT include Indonesia, the Philippines, Thailand and Malaysia. Australia, China (e.g., Pratas Islands), Vietnam, Taiwan (mariculture), Myanmar and Papua New Guinea also supply live reef fish to the trade, but their individual exports are relatively minor. However, the supply side is highly dynamic, with remote island nations in the Indo-Pacific such as Micronesia, the Maldives, the Solomon Islands, Fiji and Kiribati increasing production as other nations exhaust their fishing grounds. In general, Indonesia is thought to supply nearly 50% of the total volume of the regional LRFT trade (Barber and Pratt, 1997).

3.3 Marine Market Transformation

The LRFT is not sustainable in its current form, due to the use of cyanide, the catch of overexploited species (Erdmann and Pet, 1999; Pet and Djohani, 1998), the targeting of spawning aggregation (Johannes, 1997; Pet et al., 1999; Johannes and Lam, 1999) and the capture of juveniles from the wild. Yet, the harvesting of groupers as a renewable natural resource provides a food source to consumers, a livelihood for many fishers, and foreign exchange for developing countries. Therefore, if harvesting is done in a non-destructive and sustainable way, this trade could be a selective (i.e., reducing bycatch by selecting for groupers) and value-added fishery that needs not be discouraged.

The challenge is how to move from today's non-sustainable and habitat-destructive situation to a future trade that is both sustainable and non-destructive (Figure 2). This shift is problematic because: (i) the LRFT is very lucrative for some stakeholders; and (ii) traditional enforcement of customs and fisheries regulation is weak. To enable a shift toward sustainability requires that policy makers and NGOs 'go with' rather than 'go against' the market. This key concept underlies the Marine Market Transformation (MMT). In the grouper fishery case, given the existing demand for live reef fish, the MMT would 'unleash the market' by stimulating a sustainable substitute for cyanide-caught groupers and thereby undermine current destructive practices. Three potential ways of supplying groupers sustainably are: (i) sustainable wild-catch of marketable size fish; (ii) complete cycle mariculture; i.e. situation where juveniles originate from fish culture and (iii) grow-out based on sustainable wild-catch of fingerlings.

Figure 2. Current situation and future goal for the LRFT through a marine market transformation.



The concept of the MMT for groupers is similar to the idea behind two recent initiatives, the Marine Stewardship Council (MSC) and the Forest Stewardship Council (FSC). Their aim is to improve fishing and forestry practices respectively through eco-labelling (Holthus, 1999). The MSC-logo and the FSC-label show that these fish and wood products come from well managed sources. Each of these initiatives encourages the responsible use of renewable resources by offering a sustainable alternative to consumers. Whether the substitutes proposed are enough to supply the demand for live reef fish remains uncertain. However, failing concrete action, the alternative is the collapse of the LRFT in due course, with its correlative negative impact both on the regional economy and on biodiversity. The main ways of supplying groupers sustainably are:

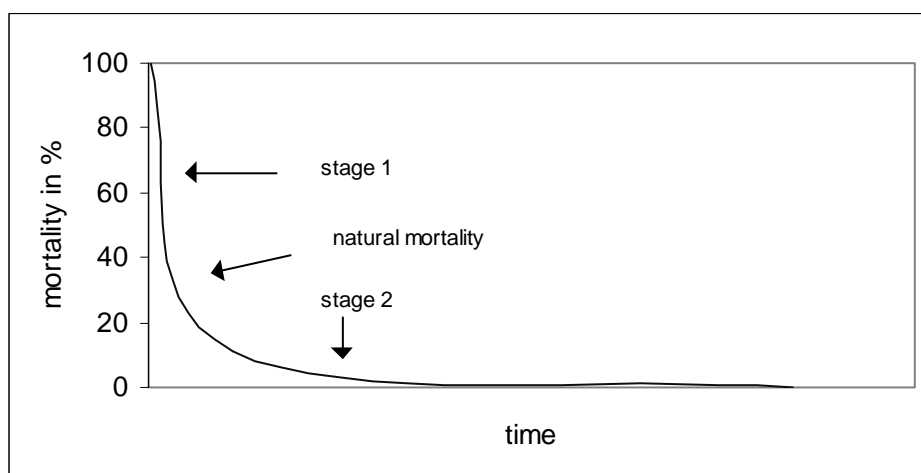
Wild-Caught Supply for the LRFT: Due to the cyanide issue, a non-destructive alternative to cyanide - hook-and-line grouper fishery - has become increasingly popular in countries such as the Philippines and the Maldives. Fish are caught using a variety of baits, which differ for individual grouper species, and are kept alive using needle decompression, which releases built-up pressure in a fish's air bladder to prevent death at the surface (Barber and Pratt, 1998). But even with hook-and-line, the environmental sustainability of the LRFT may still be threatened in the long-term, as groupers are vulnerable to overfishing due to their long life, large size at sexual maturity and predictable reproductive behaviour (Mous et al., 2000). However, even with proper regulations and enforcement, the wild-catch of groupers is likely to be insufficient to supply future demand for the LRFT. Therefore, alternatives to wild-catch have to be developed.

Full Cycle Mariculture for the LRFT Reef fish mariculture in Asia is still in its nascency, with the only major commercial activity in Taiwan with about 600 grow-out and hatchery farms producing 5,000 to 7,000 tons of marketable-sized groupers annually. Three species -- *Epinephelus coioides*, *E. tauvina* and *E. malabaricus* -- comprise about 90% of the total. Rearing of high-valued grouper species such as giant grouper in significant numbers is still problematic. Challenges in general include: (i) adult wild groupers are taken directly for brood stock (mature spawners); (ii) wild juveniles (fry and fingerlings) are caught for grow-out, even for full cycle mariculture because of seasonal periods of limited supply; (iii) non-target wild species are used as fish feed or wasted as bycatch - for each tonne of grouper, 8 tonnes of trash fish are needed; and (iv) high mortality is observed during transition to the sedentary life-stage, as

well as difficulties with starter feeders and cannibalism. See Cesar and Hempel (2000) for a recent description of grouper aquaculture in Asia.

Grow-Out Based on Sustainable Catch of Wild Fingerlings: The sustainability of wild capture of seed and juveniles for mariculture is still debated among scientists. The key issue centers on whether the capture of seed and juveniles for grow-out contributes to total mortality in wild grouper populations, or if it represents harvesting of young fish that would otherwise die of natural mortality. As illustrated in Figure 3, natural fish mortality rates decrease with time from egg production to settlement and post-settlement. Highest natural mortality rates occur early on (stage 1) prior to settlement or within a few weeks or months thereafter and then drop rapidly within a few weeks to months afterwards (Sadovy and Pet, 1998). Survivorship rapidly increases as individuals become established in nursery or adult habitats (stage 2) and quickly attain adult natural mortality levels (see also the discussion below).

Figure 3. **The Mortality of Fish over Time after Settlement**



3.4 Steps Toward a Market Transformation of the LRFT

Given the challenges and uncertainties that lie ahead for the LRFT, one cannot but wonder whether there will ever be a transformation towards a sustainable and healthy fishery. However, relatively small changes today can help to bring about a Marine Market Transformation (MMT) of the LRFT. In this section, the steps that can be taken, and some that are currently underway (Barber, 1999), to assist in this transformation are discussed.

At present rates, the harvesting of coral reef fish for the LRFT, irrespective of the cyanide fishing issue, is unsustainable. Numerous policy and market measures can be adopted to shift the LRFT towards a more sustainable future. (For further discussion of potential solutions to the LRFT, see Barber and Pratt, 1998; Cheung et al., 1998; Smith, 1997, and Bentley, 1999). In order to transform the LRFT market from an unsustainable and destructive business into one that is sustainable and non-destructive, several steps are needed: (i) elimination of cyanide use for wild catch, (ii) prevention of the overfishing of wild populations by closing spawning aggregation sites to all fishing, and (iii) stimulation of sustainable grouper mariculture as an alternative to wild supply. These options will only work when accompanied by applied research, strong government commitment and solid management efforts. The capture of wild juveniles for grow-out needs to be evaluated further, and the practice may need to be modified (to take only very young fish in pre-settlement or early post-settlement stages) before it can be promoted as a sustainable component of a

MMT. Together, these measures could supply the market for live reef fish in both sustainable and non-destructive ways.

Sustainable management of the live reef fish trade requires active participation on the part of both importing and exporting economies. However, action to date has been one-sided, with demand countries, most notably Hong Kong –which is the largest consumer of reef fish in the world --shifting responsibility for environmental damage to supply nations. With coordinated efforts on the part of both importing and exporting economies, particularly APEC members Hong Kong and China, I believe the live reef fish trade can move from a legacy in the late 20th century of ecological destruction and irresponsible economics and practices to a future that is cyanide-free and sustainable into the 21st century.

4. CASE STUDY 2: ECONOMIC ANALYSIS FOR TAKA BONE RATE MARINE PROTECTED AREA (INDONESIA)⁵

4.1 Introduction

There are significant management costs involved in the setting-up and management of Marine Protected Areas (MPAs), and a government may want to know whether these management costs are economically justified. In evaluating this, the economic value would need to outweigh the costs of management. This question will be addressed for the marine protected area of the Taka Bone Rate (TBR) archipelago in South Sulawesi, Indonesia.

The total area of TBR is around 2200 km², though the actual park area is around 530 km². The reef area up to 25 meter depth - the basis for the calculations - is estimated at around 500 km². The actual coast line area of the atoll is unknown. However, only 7 islands are inhabited. The total coastline of these 7 islands is estimated at around 25 km². The coastline is 100% rural with some village infrastructure and some agricultural area (palm trees). A brief site description is given in Box 1.

The analysis presented below has been used in the World Bank appraisal of the three-year first Phase of the Coral Reef Rehabilitation and Management Project (COREMAP) in Indonesia to compare the benefits of managing TBR as a MPA outway the considerable costs involved (World Bank, 1998).

5. This section is based on World Bank (1998) and background documents mentioned herein.

Box 1. Background Information on Taka Bone Rate

<u>Geographical:</u>		<u>Coral Reef Condition:</u>		
Location:	7°10'S to 7°20'S; 120°55'E and 121°20'E 21 islands in Flores Sea.		<u>Avg all stations</u>	<u>Range</u>
Size:	530,800 ha (national park area)	% Life Hard Coral (3 m):	21%	4-72%
Population:	4,200 in 7 inhabited islands.	% Soft Coral (3 m):	11%	0-33%
Status:	National Park since 1992.	% Dead Coral (3 m):	8%	0-34%
District:	Selayar, South Sulawesi	% Abiotic material (3 m):	22%	2-82%
Sub-Districts:	Pasimasunggu and Pasimarannu	Recovery Prospects: If damage eliminated, reef recovery could be evident in 5 years (<i>Acropora</i>).		
<u>Conservation Importance:</u>		<u>Key Threats:</u>		
Indonesia's largest atoll and world's third largest. Identified as first order conservation priority under <i>Indonesia's Marine Conservation Atlas</i> , and as a priority under <i>the Global Representative System of Marine Protected Areas</i> .		<u>Threat</u>	<u>Degree</u>	<u>Trend</u>
		<u>Bombing:</u> External Fishers	•••	Stable
		Internal Fishers	•••	Stable
		<u>Cyanide Fishing:</u> External Fishers	•••	Increase
		Internal Fishers	•••	Increase
<u>Ecological:</u>		Traps: External Fishers	•	Decrease
Coral:	200 species, 52 genera.	Overfishing	••	Stable
Reef habitats:	atoll, patch, barrier, fringing.	Wading	••	Increase
Dominant coral:	<i>Acropora</i>	Anchor Damage	•••	Stable
Fish genera:	325	Garbage/Waste	••	Stable
Gastropod species:	121			
Bivalve species:	78			

The methodology requires trends over 25 years in the 'with' and the 'without' scenario for the following eleven variables: (i) size of reef area; (ii) length of coast line; (iii) land use patterns in coastal area; (iv) current average level of 'coral cover' and 'coral mortality'; (v) site specific data on fish prices; (vi) costs of fishing gear used for different fishing methods; (vii) current percentage of catch through blast and poison fishing and its impact on corals; (viii) current level of fishing effort, catch per unit effort, maximum sustainable yield (MSY) at current level of coral cover; (ix) current sustainable level of high value species catch (grouper, lobster, etc.); (x) current level of coastal protection through coral reefs; and (xi) current level of tourism potential. These data are summarized below in the next section.

4.2 Data and Trends

Coral cover and coral mortality are reported for different sites in TBR. Blasting and other destructive fishing techniques have resulted in major damage. Coral destruction, as defined by the mortality index, is currently at around 60% with live coral cover ranging from poor to fair in nearly all places. The current fishing effort in TBR is not known. Around 70% of fishing pressure is from outside the Park while some people from TBR actually fish outside the Park area (Flores). There is a de facto open access situation. However, due to the large distance to the main market (24 hrs. to Makassar), and due to low population density in the Park (around 6,000 people), fishing pressure is not so high as elsewhere and catches are still higher than in many other places. Still, resource rents are assumed to be zero, except for destructive fishing. The MSY and open access equilibrium (OAE) at current level of coral destruction (60%; see above) is estimated at 6 and 3 mt/km²/yr respectively (Cesar, 1996, App.2). However, no data were available to confirm this, due to uncertain catches by external fishermen.

Due to lack of fresh water, the local population does not have ice to preserve fish caught. Therefore, most fish is either dried or used for home consumption. The exception is the catch of groupers. These are either caught by hook-and-line (e.g. in Rajuni Kecil), traps and/or cyanide (outsiders and some locals), and kept alive in floating cages. The larger scale operations by outsiders (blast fishing, etc.) use ice to bring to the markets in Makassar, Salayar and elsewhere. Prices are roughly US\$ 1 per kg of fresh fish, US\$ 0.66 per kg of blasted fish, US\$ 0.40 for dried fish. Groupers fetch around US\$ 5/kg, but this depends on the size and species, with top of the line, the Sunu 'super'. Costs of fishing are assumed to be as given in Cesar (1996).

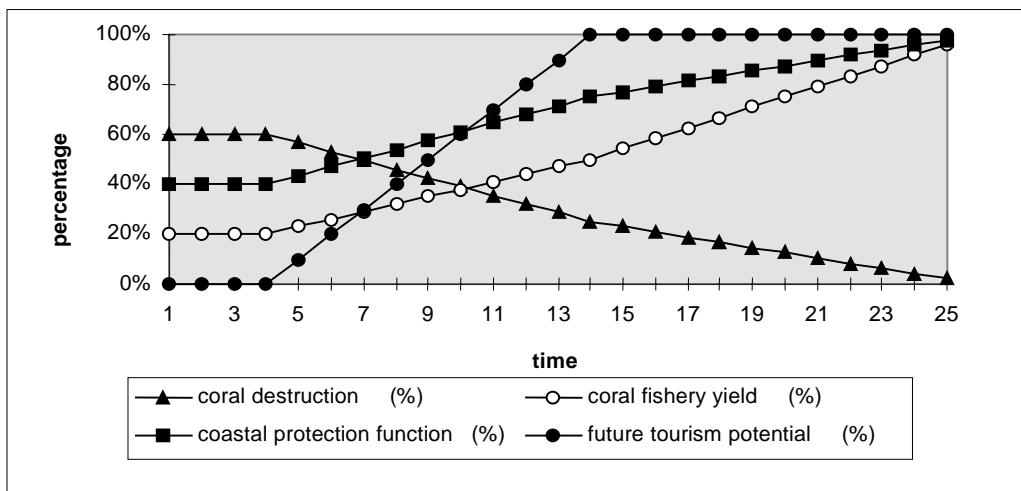
Though it was confirmed that blast fishing is extensively practised in TBR, the use of this gear as percentage of total catch is unclear. It is estimated that in Ujung Pandang, 10-40% of reef fish landings are from blast fishing (Lida Pet-Soede, pers. comm.). To be conservative, it is estimated here that 10% of catch is from blast fishing. Accounts of cyanide use for groupers vary enormously. It seems that the large scale operations (20 people) have moved on to Maluku and Irian Jaya. However, the medium-size operations (4-5 people) is still continuing in TBR. The stock of groupers in TBR seems to be rapidly depleting: three years ago, fishermen in Rajuni Kecil, using hook-and-line, would catch on average five groupers of each around 2 kg per day. Now, they are lucky with one grouper of around 0.6 kg average. This shows severe over-exploitation of the top reef predators. It is assumed here that 6.7 % of total yield is grouper catch (Cesar, 1996), though this has not been confirmed by TBR data. Of this catch, most is caught with cyanide, say 90%, though the percentage is not known exactly. This means that 6% of the total catch in TBR is cyanide-caught grouper. No data are known for other valuable species, such as lobster, teripang, turtle and shark-fin.

Probably due to past coral destruction, coastal erosion is occurring in TBR. In Rajuni Kecil, around 10 meters of coastline (or one row of houses) has been lost to the sea over the last 20 years. The common perception is that past blast fishing is responsible for this costly loss and extensive damage on the east side of Rajuni Kecil has been reported. Assumptions on the relationship between coral destruction and coastal erosion deviate from Cesar (1996) in the following ways: (i) it is assumed that extensive damage leads to a 50 cm destruction per year (rather than 20 cm); (ii) it is assumed that 1% loss in coral destruction leads to 1% coastal erosion without a threshold.

Due to the absence of fresh water, pristine reefs, and few non-reef related tourism attractions in TBR, it is assumed that the tourism potential in the Park is will be low. Yet, there is interest to attract game fishing tourists to TBR and some of this is already taking place through live-aboards. In Rajuni Kecil, there is one 'losmen' (homestay), but it is only used a few times per year. Though tourism will probably never be a large source of alternative income generation, it is currently at close to zero % of its potential.

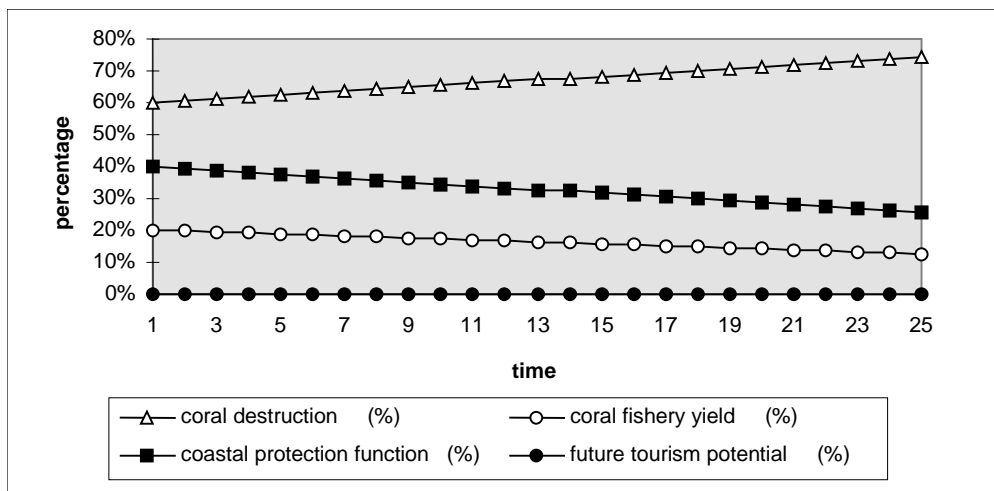
Trends for each of these key variables over 25 years are probably even harder to estimate than the current value of the variables (Figure 4-a and 4-b). It is assumed, over the three years of COREMAP I, that enforcement and surveillance will bring blast and poison fishing gradually to a near stand-still and that the current levels of coral destruction, fishing yields, coastal protection and tourism potential will stay put for 3 years. After this, corals will recover quickly to 25% coral destruction in 10 years time. This recovery is relatively quick due to abundance of fast growing branching corals (acropora) in TBR. Following Cesar (1996), this implies that fishery yield and coastal protection will return to 50% resp. 75% of their potential, up from 20% and 40% respectively. It is further assumed that blast fishing will stop complete 10 years after the end of COREMAP I. Also, it is assumed that grouper fishery will stay at 6 2/3% of total yield, but that it will be caught through non-destructive techniques. Tourism potential, though low, would gradually move to full capacity.

Figure 4-a. Assumed Trends Over Time in the ‘With’ Scenario for TBR



In the ‘without’ scenario, it is assumed that blast and cyanide fishing are continuing at present levels, leading to a increase in coral destruction of 75% in 25 years, up from 60%. This implies that the fishery yield would drop to 12.5% of its potential and coastal protection would also drop, to 25% of its capacity (for assumptions, see Cesar, 1996). Tourism potential would stay at 0%.

Figure 4-b. Assumed Trends Over Time in the ‘Without’ Scenario for TBR



4.3 Results of the Economic Analysis

Given these assumptions, the quantifiable incremental benefits are estimated at US\$ 13.5 million in net present value terms. This benefit is mainly due to a recovery of fish yield due to the establishment of sanctuaries and the eradication of destructive fishing practices. The total costs over 25 years are very difficult to measure, as heroic assumptions need to be made concerning the costs beyond the first phase of COREMAP. Two scenarios are considered. The first scenario assumes that the Global Environment Facility (GEF) will provide an amount of US\$ 500,000 over COREMAP II, consistent with current plans. The World Bank or International Bank of Reconstruction and Development (IBRD) would provide an additional US\$ 350,000, which would keep the GEF-IBRD ratio for Taka Bone Rate the same as in COREMAP I. It is assumed that the Government of Indonesia (GOI) would take over aerial surveillance, the reef watchers program and legal prosecutions, while keeping its staff involvement at provincial and district level in place. Note that GOI has additional costs both in COREMAP I and beyond for park rangers and their transportation, not included in project costs but still part of the economic analysis. Also, for the calculations, only a part of district and provincial costs are attributed to the costs of managing Taka Bone Rate. In the 'higher cost' scenario, it is assumed that in order to achieve the eradication of illegal and/or destructive fishing, a doubling of enforcement expenditures are needed. In the 'standard' scenario, the net present value of net incremental benefits is US\$ 5.0 million with a modest ERR of 14%. In the 'higher' cost scenario, the net incremental benefits would drop to US\$ 3.5 million with an ERR of 12% (Table 3).

From the GOI perspective, its perceived rate of return could be thought of as not including GEF grant funds. Excluding GEF costs, the ERR would become 17% in the 'standard' scenario and 14% in the 'higher cost' scenario. This can be interpreted as the economic rate of return for Indonesian policy makers. It indicates the rationale for GEF involvement, as it would make the project more attractive for GOI: with scarce resources, a project with an ERR of 17% is more attractive than a project with a rate of return of 14%. This analysis excludes the biodiversity value and other non-quantifiable ecosystem functions of Taka Bone Rate atoll.

Table 3. **Summary of the Economic Analysis of Taka Bone Rate**
(US\$ million; 25 year horizon)

	standard scenario	higher cost scenario
Incremental Benefits (NPV; @10%)	13,500	13,500
Costs (Coremap I; sum)		
GEF	2200	2200
IBRD	700	700
GOI	2600	2600
Costs (Coremap II; sum)		
GEF	500	1000
IBRD	350	700
GOI	4300	5400
Costs (after II; annual)		
GEF	0	0
IBRD	0	0
GOI	700	900
Net Benefits (NPV; @10%)	5000	3400
ERR	14%	12%
ERR (excl. GEF funds)	17%	15%

4.4 Financial Analysis of Village Micro-Enterprise Activities

A detailed financial analysis was performed on prospective alternative income generation (AIG) activities supported by the project. Eight representative microenterprise models were identified as possible AIGs. These include: (i) bag-making; (ii) brick-making; (iii) *kerupuk ikan* (fish crackers) processing; (iv) *terasi* processing; (v) pearl oyster culture; (vi) seaweed culture and drying; (vii) snorkelling and fishing equipment rental; and (viii) seabass floating cage culture. The details of the financial analysis of each microenterprise are included in the Project Implementation Plan. Since the project is demand driven, other alternative livelihood projects not included in the analysis could be chosen by beneficiaries after review by the project team. Hence, the enclosed analysis should be regarded as indicative.

The financial analysis of each of the microenterprises covered a period of six years, including an establishment period of one year and an operation period of five years. The financial assessment was based on several financial indicators which included: (i) investment costs; (ii) working capital requirements; and (iii) annual operating costs. Operating cost items included wages, production materials, repair and maintenance costs, depreciation and interest payments. The results of the financial analysis are summarised in the Tables 4 and 5 below. Table 4 summarises the analysis of individual micro-enterprises. The aggregate results of Table 5 took into account the total costs and benefits weighed by the assumed adoption rate for individual enterprises, as displayed on the “# of activities” column of Table 4. The results indicate financial rates of return (FRR) from 28 percent to 59 percent, well above the estimated weighted average capital cost of 18 percent. The benefit-cost ratios for the activities range from 1.08 to 1.26. The Net Present Values (NPV) for the various activities varies considerably from US\$748 to US\$4,380. For the assumed aggregate package of a total of 50 microenterprises and an investment of US\$35,000 by a group of 387 investors, the FRR is 39 percent, the benefit-cost ratio is 1.17 and the NPV is US\$ 21,600.

Table 4. Financial Analysis of Representative AIGs

Microenterprise	Investment (US\$)	FRR (%)	NPV (@12%; US\$)	B/C ratio	# of activities	Switching Values [@]	
						Benefits (for 12%)	Investment Costs (for 12%)
Brick making	403	41%	249	1.19	10	16%	70%
Kerupuk ikan	230	59%	254	1.13	10	12%	125%
Terasi processing	682	31%	322	1.26	10	20%	53%
Bag making	1069	28%	388	1.08	5	7%	40%
Pearl oyster	1042	45%	757	1.24	5	19%	80%
Seaweed	1179	43%	780	1.21	5	18%	75%
Snorkeling	315	46%	266	1.09	3	9%	95%
Seabass culture	2309	44%	1460	1.24	2	19%	70%
Total Package:	35,166	39%	21,598	1.17	50	15%	70%

@: switching values here are the percentage changes in benefits (negative) and investment costs (positive) to make NPV=0.

Table 5. Financial Analysis for the Aggregate AIG Package

Item	Yr 0 (Rp million)	Yr 1 (Rp million)	Yr 2 (Rp million)	Yr 3 (Rp million)	Yr 4 (Rp million)	Yr 5 (Rp million)
Capital Costs						
Investment	78.9	0.0	0.0	13.7	1.9	2.3
Working Capital	26.6	0.0	0.0	0.0	0.0	0.0
Total Capital Costs	105.5	0.0	0.0	13.7	1.9	2.3
Variable costs						
Labor Costs	0.0	22.1	22.5	22.8	22.8	22.8
Other Costs	0.0	39.2	67.4	69.0	69.0	69.0
Total Variable Costs	0.0	61.3	89.9	91.9	91.9	91.9
Total Costs	105.50	61.31	89.90	105.57	93.79	94.13
Total Revenues	0.00	127.03	134.68	141.61	142.19	142.19
Net Benefits	-105.50	65.73	44.79	36.04	48.39	48.06
FRR	39.369%					
NPV @ 12% (Rp million)	64.795		(21,600 US\$)			
Benefit-Cost Ratio	1.17		:1			

4.5 Economic Justification for Village Subsidies

Reef sanctuaries and other fisheries management interventions can be expected to yield benefits relatively quickly in the form of increased fisheries productivity. Reef sanctuaries, for example, can typically replenish surrounding fishing grounds within a period of 3-7 years. The financial rate of return for average reef sanctuaries in the Philippines is 28 percent, indicating that recurrent expenditures are more than offset by the benefits of management. Nonetheless, reef sanctuaries involve an initial closure of 20-30 percent of the reef area, imposing short-term costs to traditional fishers, and hence a short-term subsidy is likely to be justified. The estimates below are for Taka Bone Rate: the calculations assume a closure of 30 percent of the area, leading to a short term drop in catch of 30 percent, which would rapidly recover to pre-sanctuary levels around year three. The catch would continue to gradually increase until leveling off after 7 years with a doubling of the initial catch. These assumptions are in line with recent studies of marine reserves in East Asia. The initial catch by local fishers is assumed to be worth US\$450,000 per year, based on the assumption that local fishers operate in 30 percent of the area (70 percent of the fishing effort in the park is external), or 150 km² of reef. There are five villages in the project site:

Table 6. Benefits from Sanctuaries to villagers in the Taka Bone Rate Park

years	0	1	2	3	4	5	6	7
fish yields ('000 \$)	360	252	330	408	486	564	642	720
benefits		-108	-30	48	126	204	282	360
benefits per village:		-22	-6	10	28	41	56	72

As indicated in Table 6, the losses in the first two years have been estimated at about US\$28,000 per village over a period of two years, using the conservative assumptions outlined above. Hence, an initial subsidy of US\$25-30,000 equivalent per village for alternative income generation activities and village infrastructure reef-saving investments, as determined by the project, is considered justified.

5. CASE STUDY 3: COSTS AND BENEFITS OF CORAL MINING IN LOMBOK, INDONESIA⁶

5.1 Introduction

One of the key threats to coral reefs is the extraction of corals for lime production and construction materials, which is carried out in many areas around the world including East Africa (Dulvy et al., 1995; Andersson and Ngazi, 1995), South Asia (Brown and Dunne, 1988; Rajasuriya et al., 1995; Berg et al., 1998), South-East Asia (Cesar et al., 1997) and in the Pacific (Salvat, 1987). In the Maldives 20,000 m³ of corals per year are collected mainly for construction material (Brown and Dunne, 1988; Brown et al., 1995).

Extraction of corals has a detrimental effect on the reef ecosystem. For instance, a study carried out by Dulvy et al. (1995) in Tanzania showed that live coral cover in mined areas was one third of that in the unmined sites. The abundance and diversity of fish species also decreased. Besides these direct effects, the loss of land and increased sedimentation have also been reported (e.g. Salvat, 1987; Dulvy et al., 1995). If corals are collected from a reef, recovery appears to be slow. In the Maldives, where coral mining had taken place, little recovery was noted 16 years after mining activity (Brown and Dunne, 1988). Dulvy et al. (1995) stated that recovery of the reefs to the pre-disturbance live coral cover could take up to 50 years.

Although coral extraction is destructive, it is a source of income and subsistence for a large number of people in the developing world. Yet, by adversely affecting the foundation of the reef, coral mining is likely to result in longer term costs to society due to the benefits foregone from other resources. This trade-off between current benefits and future losses is a classic problem in natural resource management. Destructive practices are often allowed to continue because policy makers are not fully aware of the long term adverse consequences. Or if they are, powerful stakeholders or lack of economic alternatives may encourage policy makers to turn a blind eye to this destruction. In this sense, coral mining is no different from unsustainable agricultural practices, logging of tropical forests and destructive fishing. In each of these cases, economic analyses have shown that the long term costs outweigh the benefits by a large margin (e.g. Hodgson and Dixon, 1988).

In this case study we analyse the cost and benefits of coral mining in Lombok, Indonesia. First, in a financial analysis we describe the mining business and estimate its net profits. Then, in an economic analysis we additionally consider the societal costs of coral mining in terms of associated losses to typical reef functions, specifically the fishery, tourism and coastal protection. The aim of the case study is to show that the societal costs far outway the private gains from a handful of individuals, even though these individuals themselves have a clear interest to continue with the activity, partly because of lack of other income generating activities in the area.

6. This section is based on Cesar (1996) and Ohman and Cesar (2000) and background documents herein.

5.2 Financial Analysis: The Coral Mining Business

Lombok is an island situated in the south central Indonesian archipelago between Bali and Sumbawa. Its population of 2.4 million people depends to a large extent on the island's coastal resources. Tourism is an important industry which is growing rapidly. Other activities include fishing and mangrove forestry (Subani and Wahyono, 1987; Cesar, 1996). Coral mining for lime production is a small-scale, but widespread, industry around the island where recently 500-1000 families were involved in the business.

A recent case study by Cesar (1996) described a small area in West Lombok where 60 families have practised mining, on a 2 km long stretch of reef, over a 10 year period⁷. The corals were collected, burnt and sold as lime. The lime was of poor quality and could be sold for one third of the price of cement. The lime was sold to the private sector and to the local government, mainly for housing construction and plaster for schools and other government buildings. Each year, a family produced and sold around 600 bags of lime, each weighing 25 kg at a total price of US\$ 818.

A crucial input for the mining process is locally harvested fuel wood. Each family used roughly 20 m³ of fuel wood taken from a secondary forest exploited in a non-sustainable manner. Another interesting expense in the production of lime for each family was the side-payments for protection, as coral mining is illegal in Indonesia. This is important to consider in the financial analysis as it is a real cost for the business. Finally, there are no labour costs, as coral mining in Lombok is a family business: father and sons are involved in the mining and the women are involved in breaking the corals as well as in the burning and sieving process.

Combining the revenues and costs gives the annual net profits, which are summarised at the village level in Table 7. As indicated above, this village takes 10 years to mine one km² of reef. Net profits for the village are US\$ 27,300 per year.

Table 7. **Annual Costs and Revenues of Coral Mining per km² in Lombok**
(1 km² of reef is fully mined in a 10 year period)

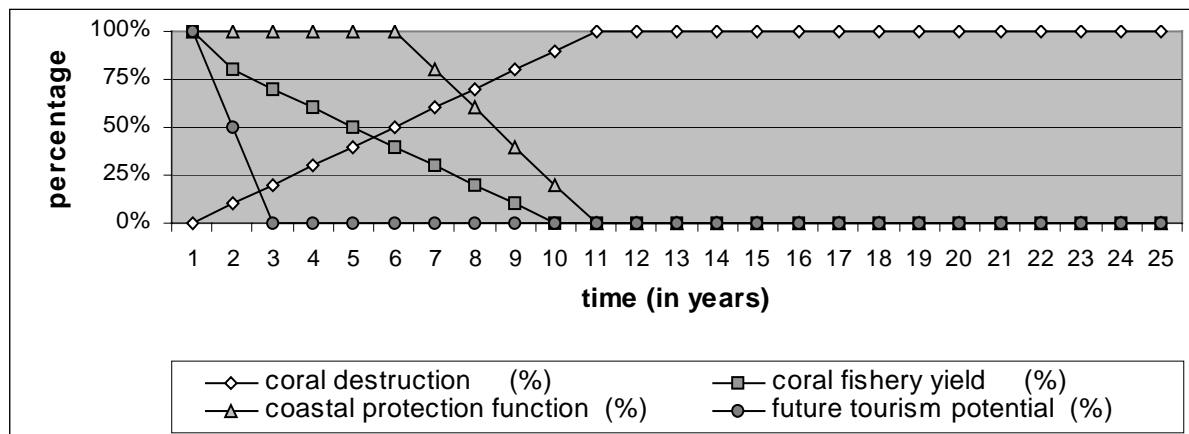
Costs of Mining (thousand US\$)		Revenues of Mining (thousand US\$)	
Fuel wood	10.9	Sale of Lime	49.1
Protection	8.7		
Labour	0		
Other costs	2.2		
Total costs	21.8	Total Revenues	49.1
<i>Net profits per year: 27,300 US\$</i>			

5.3 Financial Economic Analysis: Societal Costs of Coral Mining

Extraction of corals for lime production affects many valuable reef functions. In the Lombok case study (Cesar, 1996), three resources are discussed: fisheries, tourism and coastal protection. These three resources were selected, as they were considered to be among the most important and relatively easy to quantify. The sum of the quantifiable damages can be interpreted as a lower-boundary of total costs of reef destruction. Due to mining activities, the functions of coral reefs will decrease gradually over time. Figure 5 gives the assumed paths over time, as elaborated in Cesar (1996) and briefly explained below.

7. These data were based on field observations from Suharsono (pers. comm.) in the mid nineties.

Figure 5. Destruction of Coral Reefs and of its Functions over Time in the Lombok Case Study

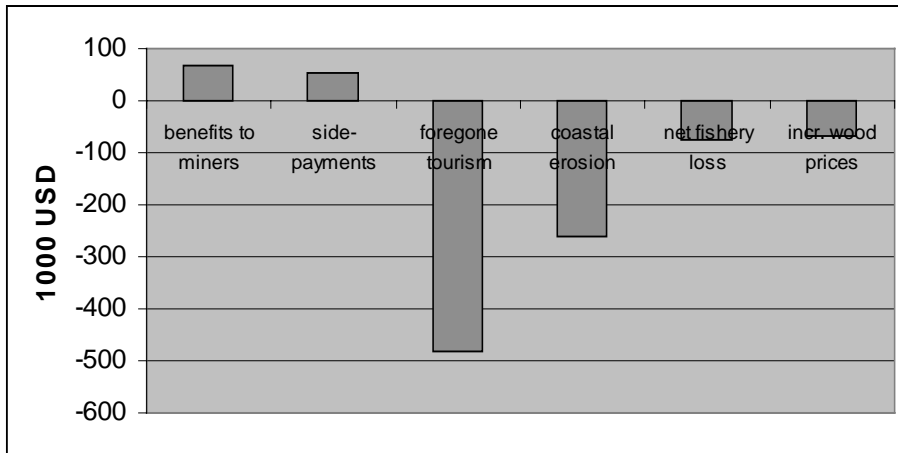


Fringing coral reefs act as natural wave breakers and protect against coastal erosion i.e. they have a coastal protection function. This has implications for the evaluation of reef degradation. In the Lombok study it was assumed that the coastal protection function would start breaking down gradually after five years of mining. It was suggested that tourism, on the other hand, would be affected directly. Since divers are sensitive to the aesthetic appearance, it is likely that other diving destinations will become more popular. Therefore, it was assumed that after two years, tourism will have vanished in that specific area. It was further suggested that no substantial recovery of the corals would take place within the time frame of the analysis. For fisheries, it was assumed that fish revenues would drop as a result of mining. Based on field data in Lombok, it was anticipated that reef fisheries would disappear and be replaced by a less valuable pelagic fishery.

For the economic valuation of the losses to these functions, the case study presents two scenarios, one in which there is limited tourism potential and little coastal construction (scenario ‘LOW’) and one in which there is high tourism potential and considerable coastal infrastructure (scenario ‘HIGH’). All costs are calculated in net present value terms (NPV) for a 30 year time horizon. The NPV expresses the discounted sum of annual costs over the 30 years. The net loss of the fishery function was valued at US\$ 74,900 in both scenarios. For the ‘LOW’ scenario, the loss in value of the tourism function is estimated at US\$ 2,900 and that of the coastal protection function at US\$ 12,000. In the ‘HIGH’ value scenario, erosion costs are estimated at US\$ 260,000 and loss of tourism at US\$ 481,900 (see Table 8 and Figure 6).

Table 8 also shows that there are three additional items in the economic analysis. First, labour costs were set to zero for the calculation of mining profits, because only family labour was involved. For the economic analysis, however, these costs need to be imputed in some way, as the mining family could have been employed elsewhere. This reflects the concept of ‘opportunity costs’ of labour, which is the family’s likely income in absence of coral mining. These costs were estimated at US\$ 101,000 in NPV terms. Secondly, the true costs of fuel wood were assumed to be larger than the price paid by the families, because of the unsustainable way in which the logging was carried out. The economic costs were assumed to be double the price. Thirdly, the side payment paid by the mining family for protection is a true cost to that family. However, from an economic point of view, it is merely a transfer of resources from one group in society (the miner) to another (the protector). These costs therefore were not incorporated into the economic analysis.

Figure 6. **Costs and Benefits of Coral Mining in 'High' Scenario Case**



Combining the net profits from mining with the societal costs, Table 8 shows that the economic loss of mining to society is US\$ 33,000 per km² for a 'LOW' value scenario (costs are US\$ 389,000 in NPV terms and benefits are US\$ 355,000). For the 'HIGH' scenario, the contrast between costs and benefits is even more pronounced: US\$ 1,117,000 versus US\$ 355,000. This means that the net present value of mining per km² is US\$ -762,000 in the 'HIGH' scenario. For both scenarios, therefore, coral mining constitutes a significant, long-term loss to society.

Table 8. **Costs and Benefits of Coral Mining Per Square Kilometre in NPV terms**

'LOW' Scenario (thousand US\$)				'HIGH' Scenario (thousand US\$)			
Costs		Benefits		Costs		Benefits	
Direct Costs		Direct Benefits		Direct Costs		Direct Benefits	
Labour	0	sales of lime	302	labour	0	sales of lime	302
Wood	67			wood	67		
Side-payments	54			side-payments	54		
Other costs	13			other costs	13		
		side-payments	54			side-payments	54
Indirect Costs		Indirect Benefits		Indirect Costs		Indirect Benefits	
Coastal erosion	12			coastal erosion	260		
Incr. wood prices	67			incr. wood prices	67		
Other functions	n/a			other functions	n/a		
Opportunity Costs				Opportunity Costs			
Foregone tourism	3			foregone tourism	482		
net fishery loss	75			net fishery loss	75		
Labour costs	101			labour costs	101		
Total Costs	389	Total Benefits	355	Total Costs	1117	Total Benefits	355
Costs miners	235	benefits miners	302	costs miners	235	benefits miners	302
Net Present Value (economic)			-33	Net Present Value (economic)			-762
Net Present Value (financial)			67	Net Present Value (economic????)			67

5.4 Discussion Coral Mining

The aim of this case study was to discuss ways of assessing the costs and benefits of coral mining. This type of (e)valuation of destructive reef harvesting practices provides information that is useful for management of the coral reef resource in two key ways (Hodgson and Dixon, 1988; Spurgeon, 1992; Dixon et al., 1993; Costanza et al., 1997; White et al., 1997). By comparing the mining profits with the associated societal costs, awareness can be raised about the long term detrimental impacts of coral mining. Furthermore, for the planning of management interventions, it is important to have an idea about the actual money made by coral mining, in order to understand the driving forces behind each stakeholder's behaviour. The case studies present useful methods for evaluating reef resources and analysing the coral mining business. However, in utilising these techniques, the various assumptions incorporated in the analysis have to be carefully considered. Also, the complexity characterising coral reefs has to be accounted for in the interpretation of the data.

6. OVERALL DISCUSSION

Why do economists want to value something as invaluable as coral reefs? The answer could well be: “because coral reefs are so beautiful that we want to make sure that our grandchildren can enjoy them as well”. Unfortunately, we see many coastal populations who are unaware of the goods and services that coral reef ecosystems provide and who are unable to see through the complex linkages of the natural world. Creation or transformation of markets for environmental goods might help in this respect. We also see people using coral reefs unsustainably and even destructively. And we see politicians unwilling to look beyond their short-sighted lenses, and consequently we see a lack of funds for coral reef management, even though the long-term costs of inaction are typically much higher than the funds needed.

One important issue in economic valuation studies is to whom the benefits will accrue and whether these are real or virtual. In travel costs studies, some of the costs are actually paid and accrue to local or foreign business operators. Most costs are, however, virtual. They describe a potential willingness-to-pay for a specific improvement in reef quality in a National Park. In the case of CVM, all values are virtual in the sense that there are no actual cash transactions associated. It is also important for the economic analysis of a specific area to distinguish between local and foreign tourists.

A second important issue is that valuing all the benefits of coral reefs is often frustrating and nearly impossible. The good news is, however, that valuing all benefits is not needed. Assume we show that net benefits to blast fishers is lower than societal losses in sustainable fishing income and tourism revenues combined. Then, no complicated techniques are needed and no major data collection on the value of bio-prospecting, biotic services and physical structure services are necessary: two services that can be possibly monetized easily already suffice to show the costs of inaction. Hopefully, economic valuation can help and raise the awareness to all those involved in order that we may enjoy the beauty of coral reefs forever.

A third important issue is that in the case of valuing reef-destructive activities like coral mining, the type of (e)valuation presented above provides information that is useful for management of the coral reef resource in two key ways. By comparing the mining profits with the associated societal costs, awareness can be raised about the long term detrimental impacts of coral mining. Furthermore, for the planning of management interventions, it is important to have an idea about the actual money made by coral mining, in order to understand the driving forces behind each stakeholder’s behaviour.

A last important issue is that in cases where enforcement proves difficult, transforming a lucrative market into one that is sustainable and non-destructive may be possible. So when we ask ourselves whether the current destructive practices and unsustainable market for live reef fish in Southeast Asia can be transformed into one that is both non-destructive and sustainable, our case study shows that the answer is, in principle, yes. Through numerous actions, a marine market transformation of the LRFT can be achieved through (i) elimination of cyanide use for wild catch, (ii) prevention of the overfishing of wild populations, and (iii) stimulation of sustainable grouper mariculture as an alternative to wild supply. These options will only work when accompanied by applied research, strong government commitment and solid management efforts. With coordinated efforts on the part of both importing and exporting economies,

particularly APEC members Hong Kong and China, we believe the live reef fish trade can move from a legacy in the late 20th century of ecological destruction and irresponsible economics and practices to a future that is cyanide-free and sustainable into the 21st century.

REFERENCES

- Andersson, J. and Z. Ngazi (1998), "Coastal Communities' Production Choices, Risk Diversification, and Subsistence Behaviour: Responses in Periods of Transition", *Ambio*, Vol. 27, pp. 686-693.
- Barber, C.V. (1999), "Recent Developments in Combating Cyanide Fishing: Much Talk but Little Action on the Ground." SPC Live Reef Fish Information Bulletin, No. 5, pp. 27-31.
- Barber, C.V. and V.R. Pratt (1998), "Poison and Profits: Cyanide Fishing in the Indo-Pacific", *Environment*, Vol.40, No. 8, pp. 5-34.
- Barber, C.V. and V.R. Pratt (1997), *Sullied Seas: Strategies for Combating Cyanide Fishing in Southeast Asia and Beyond*, World Resources Institute, Washington D.C., and International Marinelife Alliance, Manila, Philippines.
- Barton, D.N. (1994), "Economic Factors and Valuation of Tropical Coastal Resources", SMR-Report 14/94, Bergen, Norway, 128 pp.
- Bentley, N. (1999), "Fishing for Solutions: Can the Live Trade in Wild Groupers and Wrasses from Southeast Asia be managed?", TRAFFIC Southeast Asia, Petaling Jaya, Malaysia.
- Berg, H., M.C. Öhman, S. Troëng and O. Lindén (1998), "Environmental Economics of Coral Reef Destruction in Sri Lanka", *Ambio*, Vol. 27, pp. 627-634.
- Brown, B.E. and R.P. Dunne (1988), "The Environmental Impact of Coral Mining on Coral Reefs in the Maldives", *Environmental Conservation*, Vol. 15, No. 2, pp. 159-166.
- Brown, B.E., R.P. Dunne and T.P. Scoffin (1995), "Coral Rock Extraction in the Maldives, Central Indian Ocean – Limiting the Damage", *Coral Reefs*, Vol. 14, p. 236.
- Bryant, D., Burke, L., McManus, J. and M. Spalding (1998), *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs*, World Resources Institute, Washington, D.C..
- Cesar, H. (1996), *Economic Analysis of Indonesian Coral Reefs*. The World Bank, Washington, D.C.
- Cesar, H., Lundin, C., Bettencourt, S. and J. Dixon (1997), "Indonesian Coral Reefs: An Economic Analysis of a Precious but Threatened Resource." *Ambio*, Vol. 26, No. 6, pp. 345-350.
- Cesar, H. (2000) "Coral Reefs: Their Functions, Threats and Economic Value", in H. Cesar (ed.) "Collected Essays on the Economics of Coral Reefs", CORDIO, Kalmar University, Kalmar, Sweden.

- Cesar, H. and E. Hempel (2000), *Opportunities and Constraints of Grouper Aquaculture in Asia*, The World Bank, Washington, DC.
- Cesar, H., K. Warren, Y. Sadovy, P. Lau, S. Meijer & E. van Ierland (2000), "Marine Market Transformation of the Live Reef Fish Food Trade in Southeast Asia", in H. Cesar (ed.) "Collected Essays on the Economics of Coral Reefs", CORDIO, Kalmar University, Kalmar, Sweden.
- Cheung, M., Li, Z., Young, C., Sham, C., Wong, Y., Ni, I., Qian, P., and Y. Sadovy (1998), *Proceedings of the APEC "Workshop on Destructive Fishing Practices on the Marine Environment,"* 16-18 December 1997, Hong Kong. Published by the Agriculture and Fisheries Department, Hong Kong, APEC #98MR-01.1.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V.O., Paruelo, J., Raskin, R.G., Sutton, P. and M. van den Belt (1997), "The Value of the World's Ecosystem Services and Natural Capital", *Nature*, Vol. 387, pp. 253-260.
- Dixon, J.A., Fallon Scura, L., and T. van't Hof (1993), "Meeting Ecological and Economic Goals: Marine Parks in the Caribbean", *Ambio*, Vol. 22, pp. 117-125.
- Dixon J.A., L. Fallon Scura, R.A. Carpenter, P.B. Sherman (1988), *Economic analysis of environmental impacts*, 3rd ed., Earthscan, London.
- Dixon J.A. (1989), "Coastal resources in Kosrae: an undeveloped economic resource", *Kosrae Island Management Plan*, Vol. II, background paper, East-West Center.
- Dulvy, N.K., Stanwell-Smith, D., Darwall, W.R.T. and C.J. Horill (1995), "Coral Mining at Mafia Island, Tanzania: A Management Dilemma", *Ambio*, Vol. 24, pp. 358-365.
- Erdmann, M. and J. Pet (1999), "Krismon and DFP: Some Observations on the Effects of the Asian Financial Crisis on Destructive Fishing Practices in Indonesia." SPC Live Reef Fish Information Bulletin, No. 5, pp. 22-26.
- Erdmann, M. and J. Pet-Soede (1998), " $B^6 + M^3 = DFP$: An Overview of Destructive Fishing Practices in Indonesia," Proceedings of the APEC "Workshop on Destructive Fishing Practices on the Marine Environment," 16-18 December 1997, Hong Kong, pp. 25-34.
- Hodgson, G. and J.A. Dixon (1988), "Logging Versus Fisheries and Tourism in Palawan: An Environmental and Economic Analysis", Occasional Paper No.7, East-West Environment Institute.
- Holthus, P. (1999), "The Marine Aquarium Council, Certifying Quality and Sustainability in the Marine Aquarium Industry." SPC Live Reef Fish Information Bulletin, No. 5, pp. 34-35.
- Johannes, R. and M. Lam (1999), "The Live Reef Food Fish Trade in the Solomon Islands." SPC Live Reef Fish Information Bulletin, No. 5, pp. 8-15.
- Johannes, R. (1997), "Grouper Spawning Aggregations Need Protection." SPC Live Reef Fish Information Bulletin, No. 3, pp. 13-14.
- Johannes, R. and M. Riepen (1995), *Environmental, Economic, and Social Implications of the Live Reef Fish Trade in Asia and the Western Pacific*, The Nature Conservancy, Jakarta.

- Lau, P. and R. Parry-Jones. (1999), *The Hong Kong Trade in Live Reef Fish for Food*, TRAFFIC-East Asia and World Wide Fund for Nature (WWF), Hong Kong.
- McClanahan, T.R. (1999), "Perspective: Is there a future for coral reef parks in poor tropical countries?" *Coral Reefs* Vol. 18, No. 4, pp. 321-325.
- Moberg, F. and C. Folke (1999), "Ecological Goods and Services of Coral Reef Ecosystems", *Ecological Economics*, Vol. 29, pp. 215-233.
- Mous, P., L. Pet-Soede, M. Erdmann, H. Cesar, Y. Sadovy & J. Pet (2000), "Cyanide fishing on Indonesian coral reefs for the live food fish market — What is the problem?", *SPC Live Reef Fish Information Bulletin*, Issue 7 (May 2000), pp.20-27.
- Öhman, M. & H. Cesar (2000), "Costs and Benefits of Coral Mining", in H. Cesar (ed.) "Collected Essays on the Economics of Coral Reefs", CORDIO, Kalmar University, Kalmar, Sweden.
- Pearce, D.W. and K.R. Turner (1990), *Economics of natural resource and the environment*, 1 ed., London: Harvester Wheatsheaf.
- Pendleton, L.H. (1995), "Valuing Coral Reef Protection", *Ocean & Coastal Management*, Vol. 26, No. 2, pp. 119-131.
- Pet-Soede, C., H.S.J. Cesar and J.S. Pet (1999) 'An Economic Analysis of Blast Fishing on Indonesian Coral Reefs', *Environmental Conservation*, **26** (2), pp. 83-93.
- Pet, J., Squire, L., Subagyo, C. and A. Mulyadi (1999), "Grouper and Napoleon Wrasse Spawning Aggregation Sites, Komodo National Park." Monitoring Report 1998-1999. The Nature Conservancy, Jakarta.
- Pet, J. and R. Djohani (1998), "Combating Destructive Fishing Practices in Komodo National Park: Ban the Hookah Compressor!" *SPC Live Reef Fish Information Bulletin*, No. 4, pp. 17-28.
- Rajasuriya A, DeSilva M.W.R.N., and M.C. Öhman (1995), "Coral Reefs of Sri Lanka: Human Disturbance And Management Issues", *Ambio*, Vol. 24, pp. 428-437.
- Rhodes, K. L. (1999). "Grouper aggregation protection in proactive Pohnpei", South Pacific Commission, *Live Reef Fish Information Bulletin*, Vol.6, pp. 14-15.
- Sadovy, Y. (1998), "Marketing and Monitoring Live Reef Fishes in Hong Kong, an Update." *SPC Live Reef Fish Information Bulletin*, No. 4, pp. 47-51.
- Sadovy, Y. and J. Pet (1998), "Wild Collection of Juveniles for Grouper Mariculture: Just Another Capture Fishery?" *SPC Live Reef Fish Information Bulletin*, No. 4, pp. 36-39.
- Salvat, B. (ed.) (1987), *Human Impacts on Coral Reefs: Facts and Recommendations*, Antenne de Tahiti Museum, E.P.H.E.
- Smith, A. (1997), "Management Suggestions for the Sustainable Development of Live Reef Fish Food Fisheries in the Pacific Islands Region." *SPC Live Reef Fish Information Bulletin*, No. 3, pp. 47-51.
- Spurgeon, J.P.G. (1992), "The Economic Valuation of Coral Reefs", *Marine Pollution Bulletin*, Vol. 24, pp. 529-536.

Subani, W and M.M. Wahyono (1987), "Study on Destruction of Coastal Ecosystem and its Impact on the Fishery Resources in the South Coast of Bali, West and East Coast of Lombok, and Jakarta Bay", *Journal of Marine Fisheries Research* (Jakarta), Vol. 42, pp. 53-70.

White, A.T., Barker, V. and G. Tantrigama (1997), "Using Integrated Coastal Management and Economics to Conserve Coastal Tourism Resources in Sri Lanka", *AMBIO*, Vol. 26, No. 6, pp. 335-344.

World Bank, (1998), "Project Appraisal Document; Indonesia Coral Reef Rehabilitation and Management Project", Washington DC.