# The Biodiversity Benefits of Coral Reef Ecosystems: Values and Markets

**Herman Cesar**

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**(draft 1)**

**Abstract:**

In most tropical countries, coral reef ecosystems provide many goods and services to coastal populations. 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’. And 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 economic valuation of marine protected areas; (ii) the economic valuation of a threat to coral reefs (coral mining); and (iii) the creation of a market for sustainably caught/reared reef fish as an alternative to cyanide fishing.

## 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 Value[1]

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 aestetic 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)

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

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

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**

**Total Economic Value**

| Use Values | | Non- Use Value | | | |
|---|---|---|---|---|---|
| direct use value | indirect use value | Option value | Quasi-option value | Bequest value | Existence value |
| Outputs / services that can be consumed directly | Functional benefits enjoyed indirectly | Future direct and indirect use | Expected new information from avoiding irreversible losses of: | Value of leaving use and non-use values to offspring | Value from knowledge of continued existence, based on e.g. moral conviction |
| <u>Extractive:</u><br>capture fisheries<br>mariculture<br>aquarium trade<br>pharmaceutical<br><u>Non-Extractive:</u><br>tourism/recreation<br>research/education<br>aestetic | <u>Biological support to:</u><br>sea birds<br>turtles<br>fisheries<br>other ecosystems<br><u>Physical protection to:</u><br>* other coastal ecosystems<br>* coastline<br>* navigation<br><u>Global life-support:</u><br>carbon store | | * species<br>* habitats<br>* biodiversity | *species<br>*habitats<br>*'way of life' connected to traditional uses | * threatened reef habitats<br>* endangered species<br>* charismatic species<br>* aestetic reefscapes |

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 Trade[2]

### 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 fish[4], 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 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

[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.

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.*

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

Source: AFD Hong Kong, 1999.
*The price reflects the combined average price for giant grouper.

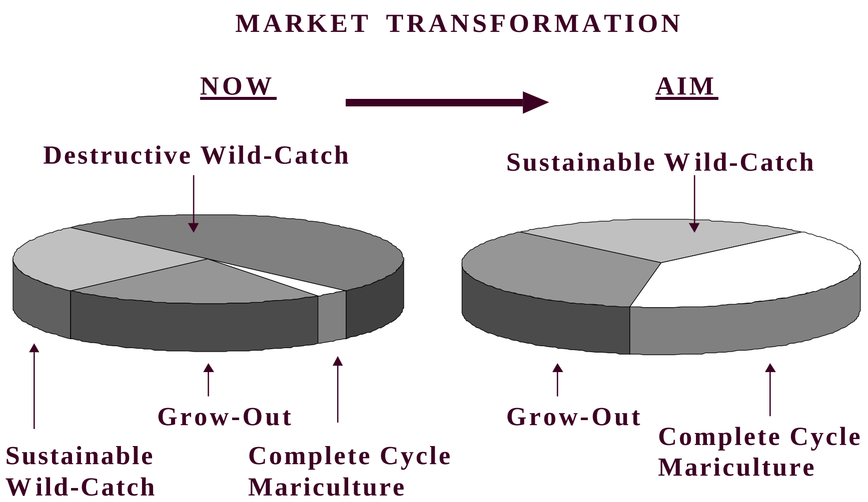
Major supply nations for the LRFT include Indonesia, the Philippines, Thailand and Malaysia. Australia, China (e.g., Pratas Islands), Vietnam, Taiwan (mariculture), Myanmar and Papua New Guinea also supply live reef fish to the trade, but their individual exports are relatively minor. However, the supply 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), the capture of juveniles from the wild, and the reliance on trash fish for food. 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 need 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.*



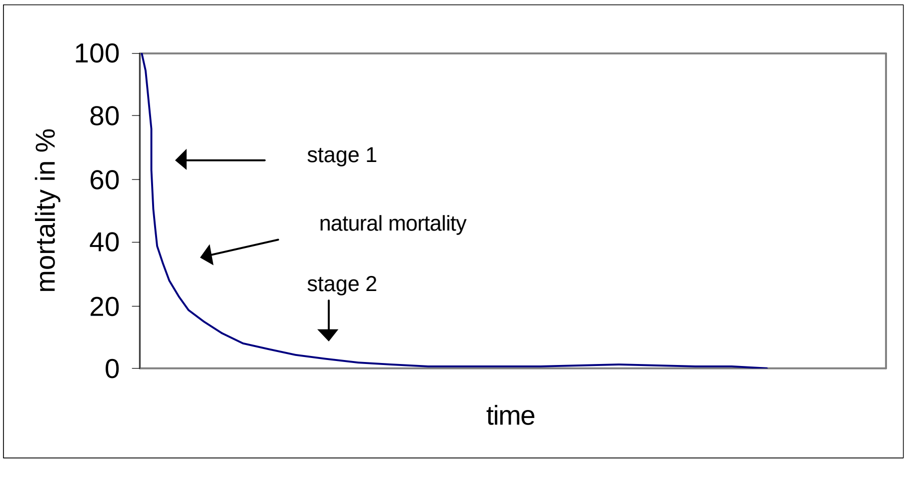

The concept of the MMT for groupers is similar to the idea behind two recent initiatives, the Marine Stewardship Council (MSC) and the Forest Stewardship Council (FSC). Their aim is to improve fishing and forestry practices respectively through eco-labelling (Holthus, 1999). The MSC-logo and the FSC-label 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.

*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.

*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 MPA (Indonesia)[5]

### 4.1 Introduction

There are significant management costs involved in the setting-up and management of 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 $km^2$. The reef area up to 25 meter depth - the basis for the calculations - is estimated at around 500 $km^2$. 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 $km^2$. 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).

*Box 1: Background Information on Taka Bone Rate*

***Geographical:***

| | |
|---|---|
| **Location:** | $7^o$10'S to $7^o$20'S; $120^0$55'E and $121^0$20'E |
| | 21 islands in Flores Sea. |
| **Size:** | 530,800 ha (national park area) |
| **Population:** | 4,200 in 7 inhabited islands. |
| **Status:** | National Park since 1992. |
| **District:** | Selayar, South Sulawesi |
| **Sub-Districts:** | Pasimasunggu and Pasimarannu |

***Conservation Importance:***

Indonesia's largest atoll and world's third largest. Identified as first order conservation priority under *Indonesia's Marine Conservation Atlas*, and as a priority under *the Global Representative System of Marine Protected Areas.*

***Ecological:***

| | |
|---|---|
| **Coral:** | 200 species, 52 genera. |
| **Reef habitats**: | atoll, patch, barrier, fringing. |
| **Dominant coral**: | *Acropora* |
| **Fish genera:** | 325 |
| **Gastropod spp**: | 121 |
| **Bivalve sps:** | 78 |

***Coral Reef Condition:***

| | ***Avg all stations*** | ***Range*** |
|---|---|---|
| **% Life Hard Coral (3 m):** | 21% | 4-72% |
| **% Soft Coral (3 m):** | 11% | 0-33% |
| **% Dead Coral (3 m):** | 8% | 0-34% |
| **% Abiotic material (3 m):** | 22% | 2-82% |

***Recovery Prospects:*** If damage eliminated, reef recovery could be evident in 5 years (*Acropora).*

***Key Threats:***

| Threat | Degree | Trend |
|---|---|---|
| Bombing: External Fishers | • • • | Stable |
| Internal Fishers | • • • | Stable |
| Cyanide Fishing: External Fishers | • • • | Increase |
| Internal Fishers | • • • | Increase |
| Traps: External Fishers | • | Decrease |
| Overfishing | • • | Stable |
| Wading | • • | Increase |
| Anchor Damage | • • • | Stable |
| Garbage/Waste | • • | Stable |

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

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, 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 Ujung Pandang), and due to low population density in the Park (around 6,000 people), catches are still higher than in many other places. Still, resource rents are assumed to be zero, except for destructive fishing. The MSY and 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 Ujung Pandang, 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).

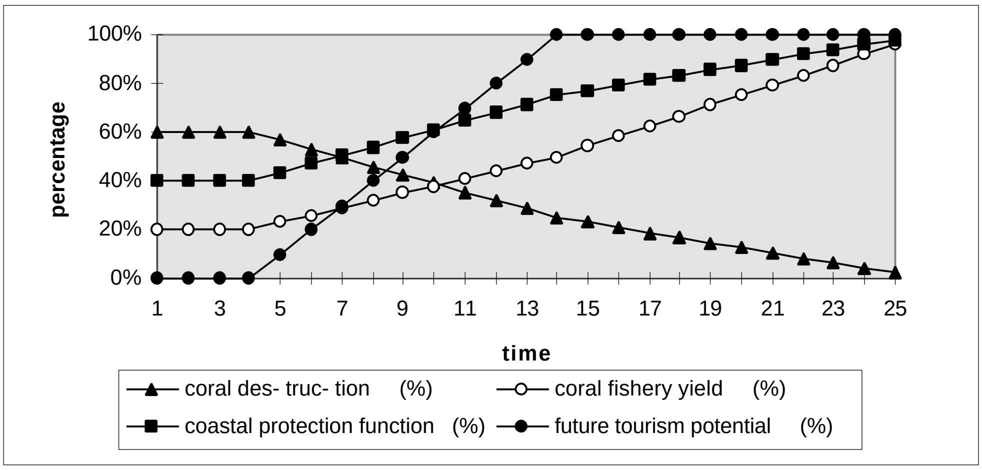
Though it was confirmed that blast fishing is extensively practised in TBR, the use of this gear as percentage of total catch is unclear. It is estimated that in Ujung Pandang, 10-40% of reef fish landings are from blast fishing (Lida Pet-Soede, pers. comm.). To be conservative, it is estimated here 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 luck 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 2/ 3 % 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, the 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, 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, 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.

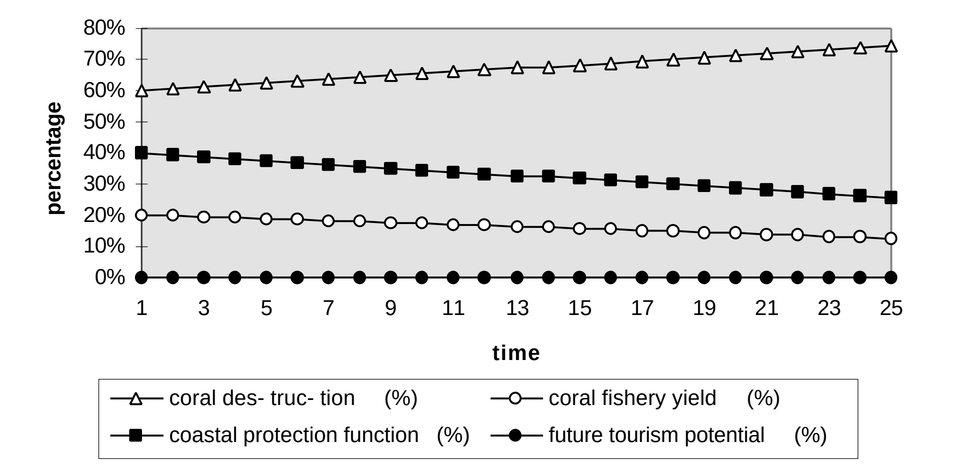
Trends for each of these key variables over 25 years are probably even harder to estimate than the current value of the variables (Figure 4-a and 4-b). It is assumed, over the three years of COREMAP I, that enforcement and surveillance will bring blast and poison fishing gradually to a near stand-still 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 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 than 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 scenario's are considered. The first scenario assumes that GEF will provide an amount of US$ 500 thousand over COREMAP II, consistent with current plans. IBRD would provide an additional US$ 350 thousand, which would keep the GEF-IBRD ratio for Taka Bone Rate the same as in COREMAP I. It is assumed that 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) *teras*i 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 draft Project Implementation Plan. Since the project will be demand driven, 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$35,000 by a group of 387 investors, the FRR is 39 percent, the benefit-cost is 1.17 and the NPV is US$ 21,600.

*Table 4: Financial Analysis of Representative AIGs*

| Microenterprise | Investment | FRR | NPV | B/C ratio | # of activities | Switching Values | |
|---|---|---|---|---|---|---|---|
| | *(US$)* | *(%)* | *(@12%; US$)* | | | **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%** |

*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 |
| **FIRR** | **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 $km^2$ 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, Indonesia[6]

### 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 $m^3$ 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.

### 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.

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

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 km$^2$ in Lombok (1 km$^2$ of reef is fully mined in a 10 year period)*

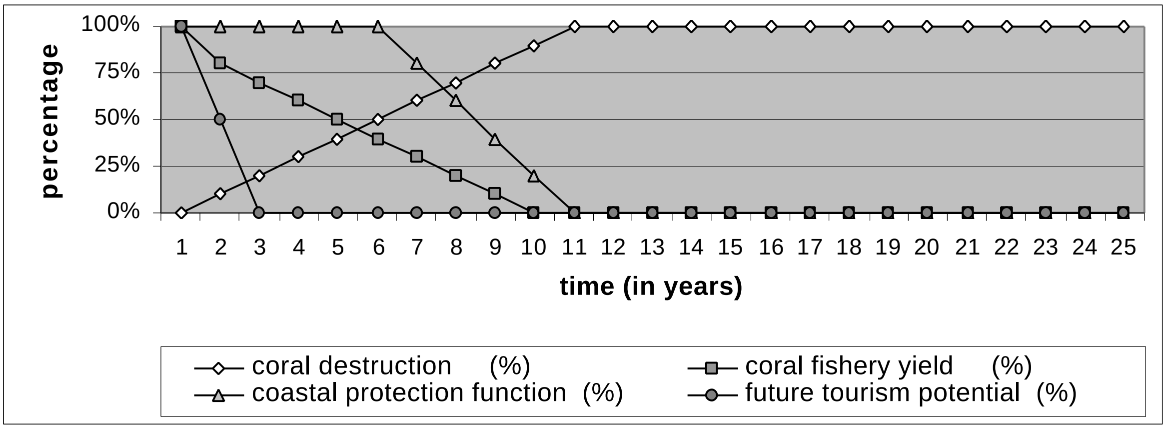
| Costs of Mining (thousand US$) | | Revenues of Mining (thousand US$) | |
|---|---|---|---|
| Fuel wood | 10.9 | Sale of Lime | 49.1 |
| Protection | 8.7 | | |
| Labour | 0 | | |
| Other costs | 2.2 | | |
| Total costs | 21.8 | Total Revenues | 49.1 |
| *Net profits per year: 27,300 US$* | | | |

### 5.2 Financial Economic Analysis: Societal Costs of Coral Mining

Extraction of corals for lime production affects many essential 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*

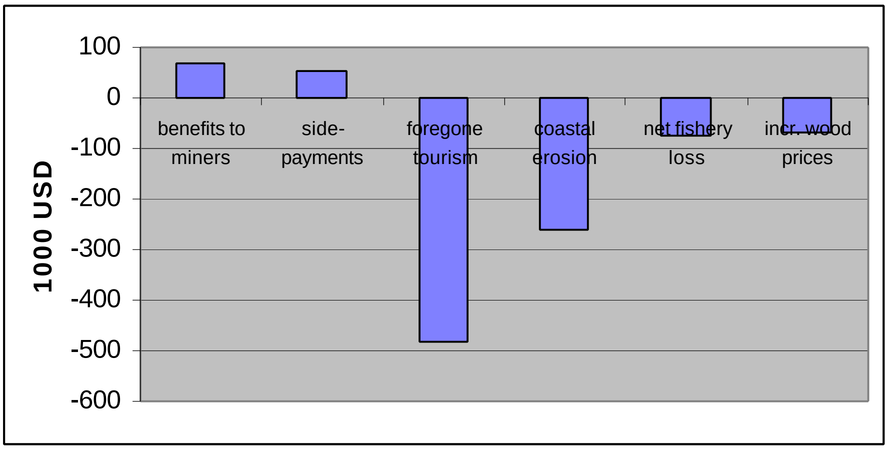



Fringing coral reefs act as natural wave breakers and protect against coastal erosion i.e. they have a coastal protection function. This has implications for the evaluation of reef degradation. In the Lombok study it was assumed that the coastal protection function would start breaking down gradually 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 km$^2$ 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 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 |

### 5.3 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”. Yet, 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 fact 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 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 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.

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