

Aus dem Institut für Agrarökonomie der Christian-Albrechts-Universität zu Kiel

**EXTENDED COST BENEFIT ANALYSIS OF PRESENT  
AND FUTURE USE OF INDONESIAN CORAL REEFS**  
**An Empirical Approach to Sustainable Management of Tropical Marine Resources**

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## Zusammenfassung

Korallen stellen einen wichtigen Faktor der indonesischen Wirtschaft dar. Im Vergleich zu anderen Ländern weisen die Korallenriffe Indonesiens die höchsten Schädigungen auf. Das zerstörende Fischen ist ein Hauptgrund für die Degradation der Korallenriffe in Indonesien, so dass das Gesamtsystem dieser Fangpraxis analysiert werden muss. Dazu wurden im Rahmen dieser Studie die Standortbedingungen der Korallen erfasst, die Hauptnutzungen mit ihren jeweiligen Auswirkungen und typischen Merkmale der Nutzungen bestimmt sowie die politische Haltung der gegenwärtigen Regierung gegenüber diesem Problemfeld untersucht. Die Feldarbeit wurde in der Zeit von März 2001 bis März 2002 an den Korallenstandorten Seribu Islands (Jakarta), Menjangan Island (Bali) und Gili Islands (Lombok) durchgeführt. Dort wurden zwecks Datengewinnung 225 Zyanidfischer, 90 Korallensammler, 19 Tourveranstalter und 100 Touristen interviewt. Die Auswirkungen der Hauptnutzungen auf die Korallen sowie deren bio-physikalische Indikatoren wurden direkt gemessen.

Die hohe Bevölkerungsdichte und das Fehlen alternativer Einkommensquellen führten zu einer verstärkten Nutzung der Korallenriffe durch die Küstenbewohner. Das Zyanidfischen und das Korallensammeln sind in ganz Indonesien verbreitet, obwohl das Zyanidfischen verboten ist. Messungen an verschiedenen Standorten ergaben, dass sich diese Nutzungsformen stark destruktiv auf die Korallenriffe auswirkten. Beispielsweise betragen die durch diese Aktivitäten verursachten Umweltkosten in Seribu Islands das Zehnfache des Nutzens in diesem Gebiet. Der Gesamtnutzen aus dem Zyanidfischen und dem Sammeln belief sich dort auf \$ 235.160,31 und \$ 163.430,00, wohingegen die Umweltkosten \$ 2.506.495,03 und \$ 1.382.552,88 betragen. Im Gegensatz dazu verursachte der Tourismus geringere Umweltkosten. Hier standen dem Nutzen in Höhe von \$ 1.265.257,30 Umweltkosten von lediglich \$ 39.542,23 (nur 3,12 % des Gesamtnutzens) gegenüber.

Eine um Umweltkosten erweiterte Kosten-Nutzen-Analyse wurde durchgeführt, um den Kapitalwert (NPV) der aktuellen Korallennutzung zu ermitteln. Die Analyseergebnisse zeigen, dass in Gebieten, wo das Zyanidfischen und Korallensammeln die höchste und der Tourismus die niedrigste Intensität aufweisen, der Kapitalwert negativ (-\$ 14,68 Mio.) ist. Demgegenüber wird in Gebieten mit intensivster touristischer Nutzung und moderatem Zyanidfischen und Korallensammeln der ermittelte Kapitalwert positiv (\$ 17,25 Mio.). In Gebieten, in denen das Fischen und Sammeln die niedrigste Intensität aufweist und die touristische Nutzung moderat ist, ist der Kapitalwert gleichfalls positiv (\$ 2,26 Mio.). Würde das Zyanidfischen gestoppt, ergäbe sich ein negativer Kapitalwert (-\$ 12,39 Mio.), während aus alleiniger touristischer Nutzung der höchste positive Kapitalwert resultierte (\$ 41,14 Mio.).

Die Ausdehnung des Zyanidfischens und Korallensammelns seit der letzten Wirtschaftskrise in Indonesien hat zu einer zunehmenden Schädigung der Korallenriffe geführt. Würde die destruktive Fangmethode in den nächsten 25 Jahren fortgesetzt, so wäre von einem negativen Kapitalwert auszugehen (-\$ 4,29 Mrd.). Unterstellt man technischen Fortschritt bei der Korallenriffnutzung, so bliebe der Kapitalwert dennoch negativ, da in 45,83 % der indonesischen Korallengebieten intensiv gefischt wird. Würde man eine geringe touristische Nutzung einführen und die Intensität des Netzfischfangs von hoch auf moderat reduzieren, so würde dies den Kapitalwert steigern. Verbesserungen in der Korallenriffnutzung sowie die Regulierung der Fangintensität einschließlich der dazu notwendigen Umsetzungskosten, würden einen positiven Kapitalwert ergeben (\$ 6,12 Mrd. ).

## Summary

Coral reefs have supported significant role to Indonesian economic. Unfortunately, Indonesian coral reefs have received highest anthropogenic threats among other countries. Destructive fishing is a major cause of coral reef degradation in Indonesia. Therefore, it was important to understand the whole system of destructive fishing practices. For that reasons, this study have measured coral condition and the effects of major actual coral reefs uses, and observed the characteristics of coral reefs uses and the related government policies. Field surveys were carried out over one year period, from March 2001 until March 2002 in three Indonesian corral reefs areas, such as Seribu Islands (Jakarta), Menjangan Island (Bali) and Gili Islands (Lombok). About 225 cyanide fishermen, 90 coral collectors, 19 tourism operators, and 100 tourists in those areas were interviewed to gain the data. The impacts from major actual coral reefs uses in study areas were directly measured together with bio-physic measurements.

The high density of inhabitants and the lack of alternative for income generating have pushed coastal communities to the activities related to the coral reefs. Cyanide fishing and coral collecting were the commonly used methods all over Indonesia, although cyanide fishing was illegal according to the government regulation. Both methods generated highly destructive effects to the coral reefs. The environmental costs caused by both activities were almost ten times their benefits. Annual benefit of cyanide fishing and coral collecting were \$235,160.31 and \$163,430.00 respectively, but annual environmental costs were \$2,506,495.03 and \$1,382,552.88 respectively. In contrast, tourism generated less environmental cost. Annual benefit of tourism was \$1,265,257.30, and only generated environmental cost as much as \$39,542.33 (3.12% of total benefit).

Extended cost benefit analysis, which internalised environmental costs to the economic analysis were used to calculate the expected net present value of actual coral reefs uses. The result of this analysis showed that on the area where cyanide fishing and coral collecting had the highest intensity and tourism had the lowest intensity, the expected NPV was negative (-\$14.68 million). In contrast, on the area where tourism had the highest intensity and cyanide fishing and coral collecting had the moderate intensity, the expected NPV was positive (\$17.25 million). Meanwhile, on the area where cyanide fishing and coral collecting had the lowest intensity and tourism had the moderate intensity, expected NPV was positive (\$2.26 million). If cyanide fishing was banned, expected NPV was still negative (-\$12.39 million). The expected NPV will be positive if tourism was the only activity allowed (\$41.14 million).

The extension of cyanide fishing and coral collecting practices since the last economic crisis in Indonesia has led to the increasing damaging impact to coral reefs. The result of economic analysis showed that if these destructive fishing methods were continued for the next 25 years, the expected NPV would be negative (-4.29 billion \$). Technical improvement of coral reefs uses still generated negative expected NPVs because of intensive fishing in 45.83% of Indonesian coral reefs areas. Introducing low tourism and reducing high intensity of barrier net fishing to moderate barrier net fishing would increase the expected NPVs. Coral reefs uses improvement and intensity regulation, which include implementation costs, would generate positive expected NPV (6.12 billion \$).

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## **List of Abbreviations**

AKKII	=	Assosiasi Kerang, Koral, dan Ikan hias Indonesia (see also ICSOFA)
BPN	=	Badan Pertanahan Nasional (national land council)
BPS	=	Badan Pusat Statistik (central bureau of statistic)
CITES	=	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRMP	=	Coastal Resource Management Project
CSO	=	Country Status Overview
DGF	=	Directorate General of Fisheries
ECBA	=	Extended Cost Benefit Analysis
EEZ	=	Economic Exclusive Zone
EIAs	=	Environmental Impact Assessments
GBRMPA	=	Great Barrier Reef Marine Protected Area
HK\$	=	Hongkong dollar
HP	=	Horse Power
HS	=	Harmonised System
ICRWG	=	Indonesian Coral Reef Working Group
ICSOFA	=	Indonesian Coral, Shell, and Ornamental Fish Association
IMA	=	International Marine Life Alliance
INCoM	=	Indonesian Network On Coastal Management
KSDA	=	Konservasi Sumber Daya Alam (natural resources conservation office)
LIPI	=	Lembaga Ilmu Pengetahuan Indonesia (Indonesian science agency)
LPPMHP	=	Laboratorium Pengembangan Produk dan Mutu Hasil Perikanan (laboratory of development and monitoring of fisheries product)
MAC	=	Marine Aquarium Council
MMAF	=	Ministry of Marine Affairs and Fisheries
MPR	=	Majelis Permusyawaratan Rakyat (peoples general assembly)
NEPA	=	National Environmental Policy Act
NGO	=	Non Government Organisation
NPV	=	Net Present Value
OLS	=	Ordinary Least Square
PD	=	Presidential Decree
PEB	=	Pemberitahuan Ekspor Barang (export declaration)
PKA	=	Pelestarian dan Konservasi Alam (nature protection and conservation)
Rp	=	Rupiah (Indonesian currency)
SCUBA	=	Self Contained Underwater Breathing Apparatus
SIAS	=	Surat Ijin Angkutan Satwa (permit for transporting wild plants and animals)
UNESCO	=	United Nations Educational, Scientific, and Cultural Organisation
WWF	=	World Wide Fund for nature

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## CHAPTER 1. INTRODUCTION

### 1.1. The Important Role of Coral Reefs

Coral reefs provide a variety of direct and indirect uses that benefit coastal communities. The most dominant and valuable uses are the abundant yield obtained from marine fisheries resources supported by the reef systems. The subsistence and commercial reef fisheries contribute significantly to the world economy. Coastal communities, especially those who live on small islands have utilised fisheries resources, seaweeds, and other biological resources for their subsistence for centuries (Burbridge *et al*, 1988). Rapidly growing human population and economic inequities are placing increasing demands on tropical marine fisheries. Coral fisheries constitute an important source of food and livelihood on a global scale (McManus, 1997).

Coral reef structures also protect islands and valuable beachfront properties from heavy waves, storms and other natural forces of the oceans. In addition, it has been reported that coral reef ecosystems play a major role in reducing global warming because they function as large carbon sink (Burbridge *et al*, 1988). From a biodiversity point of view, it can be stated that coral reefs are unquestionably complex ecosystems, which support an abundance of life forms. Coral reefs have been identified as having particularly high conservation values comparable to rainforests since they are biologically diverse, aesthetically pleasing, and serve as a major reservoir of genetic variability (Ruitenbeek *et al*, 1999).

In the last decade the natural beauty and uniqueness of coral reefs have attracted millions of both domestic and international tourists to visit coral reefs areas. The economic value of this marine-based tourism is very high, because it not only generates foreign exchange earnings but also many other multiplier effects, such as regional and local trades, transportation business, hotels and restaurants. Moreover, several archipelago countries in Pacific region are highly depended on this kind of tourism.

There is little doubt that tourism yields the greatest direct financial benefit of all reefs uses. Many small island nations depend heavily on reef-based tourism for economic development. All revenues directly generated from reef-related tourism are attributable to reefs, from diving and fishing to marine park entrance fees. In addition, indirect tourism revenues, such as accommodation, food and travel costs, are also attributable to reefs where their expenditure is directly related to reef activities (Spurgeon, 1992). It is estimated that the 27,000 km<sup>2</sup> of reef

in Mabini (Philippines) in their degraded condition still contribute at least US\$1.35 billion annually to the economy (White *et al*, 2000). The minimum economic value of coral reefs in Sri Lanka is estimated at US\$140,000 to US\$7,500,000/km<sup>2</sup> reef over a 20 years period (Berg *et al*, 1998).

## 1.2. Characteristics of Coral Reefs

Reef building corals are found throughout tropical and subtropical oceans such as the Indo-Pacific and Atlantic, normally between the Tropic of Capricorn and Tropic of Cancer (30°S, 30°N latitude). Reef development begins by settlement of reef forming organisms on a pre-existing hard foundation in shallow, warm well-illuminated water. The development of corals is influenced by such abiotic factors as light, substrate, wave forces, sediment, and temperature (Ginsburg, 2000). Southeast Asia contains one-quarter of the world's mapped reefs. Indonesia and the Philippines account for a major portion of these habitats. Reefs in both countries are noted for extraordinarily high levels of diversity, each containing at least 2,500 species of fish (World Resource Institute, 2000).

Coral reefs consist of many diverse species of corals. These corals in turn are made up of tiny organisms called polyps. The structure of the polyps and the skeleton of the coral is a rather simple combination. A polyp consists of two cell layers: the epidermis and the gastrodermis. The non-tissue layer between the gastrodermis and the epidermis is called the mesoglea. Corals belong to the phylum *Cnidaria*, which used to be known as *Coelenterata*. These are primitive animals that include hydroids, jellyfish, sea anemones and corals. The basic body plan shared by all is that of a simple sac with just one opening that functions as mouth, anus and genital opening (Queensland Fisheries Management Authority, 1999).

Corals grow in areas with sufficient light and appropriate temperatures; light is essential for the symbiotic relationship between corals and zooxanthellae and the intensity of light affects the growth and nutrition of the coral. Optimal coral growth occurs when water temperatures are between 25-29°C. Corals are often found along eastern shores of major land masses due to the presence of warm water flows. Abundance of corals decreases with increasing depth due to the extinction of visible light. They typically grow to depths less than 46 meters, although some species are found much deeper (Ginsburg, 2000).



The polyp contains mesentery filaments, which contain nematocysts used in food capture, a pharynx, endothecal dissepiments (horizontal layers of skeletal material) and the columella (the central axis of the corallite found below the mouth). The corallite is the part of the skeleton deposited by one polyp. The skeletal wall around each polyp is called the theca. Other structures include the calice (the upper opening of the corallite), the coenosarc (the coral tissue that stretches over the surface of the coral between the polyps), the coenosteum (the skeletal material around the corallites), and the corallum, which is the skeleton of the coral. The coral anatomy also includes calcareous plate-like structure known as septa. The septa radiate from the wall to the center of the corallite. There are two types of septa: insert septa that lie below the corallite wall and exsert septa that protrude above the corallite wall (Veron, 1986).

The foundation of coral reefs is laid by communities of hermatypic or reef building corals. Hermatypic corals are made up of tiny coral polyps that provide the calcium carbonate responsible for much of the structure of reefs. Corals belong to the phylum *Cnidaria*, best known for their possession of stinging organelles known as nematocysts. Distinguishing characteristics of cnidarians include radially symmetrical bodies, usually a crown of tentacles encircling the mouth, and a large hollow body cavity known as a coelenteron. Other cnidarians include sea anemones, jellyfish, hydroids, and sea fans. They exist as either free-swimming medusa or as sessile benthic polyps. Polyps have columnar bodies topped with a ring of tentacles, a centrally located mouth leading to a gastrovascular cavity, and nematocysts. When feeding, cnidarians capture food using their nematocysts that either inject prey, become entangled in prey, or adhere to prey. Reef-building (or hermatypic) corals are of the order *Scleractinia* in the class *Anthozoa*. There are 6,000 species of anthozoans, all of them marine, although most do not make reefs and many zooxanthellate scleractinians do not get large enough to contribute significantly to reef construction (Ginsburg, 2000).

Corals are of two types: perforate and imperforate. Perforate corals have porous skeletons with connections between the polyps through the skeleton. Imperforate corals have solid skeletons. Many corals have different growth forms. They can be plocoid as in *Tubastrea coccinea* (orange cup coral) and *Favia fragum* (golf ball coral). They can also be meandroid in which corallites form a series within the same walls, as in the species *Dendrogyra cylindrus* (pillar coral). Other growth forms include cocoid, spherical shaped and phalocoid, as in *Eusmilia fastigiata* (Queensland Fisheries Management Authority, 1999).

Corals exhibit sexual and asexual reproduction. The coral colony expands in size by budding. Budding may be intra-tentacular, in which the new bud forms from the oral discs of the old polyp, as in *Diploria*, or extra-tentacular in which the new polyp forms from the base of the old polyp, as in *Montastraea cavernosa*. A common type of asexual reproduction in corals is by fragmentation. Broken pieces of corals that land on a suitable substrate may begin growing and produce a new colony. This type of reproduction is common in branching corals like *Acropora cervicornis* in which a positive correlation was found between fragment size and survival (Queensland Fisheries Management Authority, 1999).

Many coral species have mass spawn. Within a 24 hours period, all the corals from one species and often within a genus release their eggs and sperm at the same time. This occurs in related species of *Montastraea*, and in other genera such as *Montipora*, *Platygra*, *Favia*, and *Favites*. In some *Montastraea* and *Acropora* species, the eggs and sperm are released in a sac. They float to the surface where they separate and fertilization takes place. Intra-species is common but mass spawning raises the possibility of hybridization by congeneric species. The zygote develops into larvae called planula which attaches itself to a suitable substrate and grows into a new colony. Some species of coral brood their larvae. The sperm fertilizes the egg before both are released from the coral. The larvae float to the top, settle, and become another colony. Species of *Acropora* release brooded larvae (Wallace and Willis, 1994).

Generally, long live corals grow slowest and have the least regular recruitment of sexually derived offspring. At the other end of spectrum, acropoids corals have linear extension rates 10 – 15 cm a year and dominate recruitment on bare surfaces. This comparison indicates a great variety in lifestyle of different corals. All species, however, face a difficult challenge in becoming established within suitable habitats (Queensland Fisheries Management Authority, 1999).

Corals have adapted to different environments through time by evolving unique morphological or physiological features. There are hundreds of coral species, many with different colors, growth forms, and colony sizes. With so many coral species, scientists have developed a classification system to distinguish among different species, often based on a such characters as a coral's morphology and/or individual corallite (skeleton) shape and size (Ginsburg, 2000).

There is a wide range of variation both in corallite shape and size. Many corals have round corallites, such as mountainous star coral, while other corals have more elliptically shaped corallites like the elliptical star coral (Suharsono, 1996). The size of corallites also varies with species; some corals have small corallites like the lettuce coral, while others have very large corallites. The internal diameter of a corallite is measured across the corallite center between the inner wall margins and is classified as small (less than 1.5 mm), medium (between 1.5 to 10 mm), large (between 10 to 20 mm), or huge (more than 20 mm) (Ginsburg, 2000).

In addition to using corallite structure to identify coral species, the morphology of the entire colony is also often used to distinguish one coral from another. Similar to other animals, corals have a variety of growth forms – some tall and thin, some short and robust (Suharsono, 1996). Generally, corals can be categorized in one of six general groups: *branching*, *mound*, *brain*, *plate*, *fleshy* and *flower*. Often a single species can have a variety of growth forms, especially at different depths; for example *Diploria strigosa* can form large round heads, small hemispherical mounds, or massive columnar plates. Branching or pillar corals have colonies composed of branches or elongated projections. Examples include elkhorn (*Acropora palmata*), staghorn (*Acropora cervicornis*), and pillar coral (*Dendrogyra cylindrus*). Acroporids often have the fastest growth rates (up to 10 cm/year) (Ginsburg, 2000).

Mound corals include mounding hemispherical, irregular-shaped or encrusting colonies whose lower surface is usually attached to the substratum. Examples include mountainous star coral (*Montastraea faveolata*), massive starlet coral (*Siderastrea siderea*), elliptical coral (*Dichocoenia stokesii*), and mustard hill coral (*Porites astreoides*). Large mound corals often have lower growth rates than branching corals. Brain corals often form hemispherical mounds, but are characterized by their unique distribution of polyps that grow in a winding pattern to give a brain-like appearance. Examples include grooved brain (*Diploria labyrinthiformis*), knobby brain (*Diploria clivosa*), and maze (*Meandrina meandrites*) (Ginsburg, 2000).

Plate corals include plate, leaf, and sheet coral and grow in a flattened plate, saucer-like, or thin sheet fashion. They usually have thin disc-shaped colonies with corallites growing only on one side. Examples include lettuce coral (*Agaricia agaricites*) and thin leaf lettuce coral

(*Agaricia tenuifolia*). Fleishy corals include plate and mound varieties but are distinguished by their large “fleshy” looking polyps. Examples include a variety of solitary disk corals and the spiny flower coral (*Mussa* spp.). Flower corals have solitary, encrusting or clumping growth forms and often have polyps on elongated stalks. Examples include smooth flower coral (*Eusmilia fastigiata*) and a variety of cup corals (Ginsburg, 2000).

### 1.3. Threats to Coral Reefs

Coral reef ecosystems in populated and industrialized areas have been under serious threats to an extent that endangers their sustainable growth and development. The threats can be grouped in three categories:

- (1) over-exploitation of reef resources,
- (2) pollution from both marine and land-based activities, and
- (3) physical degradation of coral reefs due to coral mining and destructive fishing practices.

Destructive fishing is a major cause of coral reef degradation and is often associated with Malthusian over-fishing, a condition related to poverty and coastal crowding. Studies based on the Gordon-Schaefer bio-economic model indicate that for many coral reef areas, a return to optimal resource use will require a reduction of fishing effort by 60% (McManus, 1997). Effects of destructive fishing with sodium cyanide and explosives (blast fishing) and anchor damage in live coral were investigated on a heavily exploited fringing reef. A simple balance-sheet model indicates that approximately 0.4%/year of the hermatypic coral cover may have been lost by cyanide and 0.03%/year by coral-grabbing anchors. The potential coral recovery rate reduced by about one third, from 3.8%/year in the absence of disturbances to 2.4%/year (McManus *et al*, 1997).

Cyanide fishing is a most effective method for capturing live fish because it does not kill the fish. It is used in the form of a 35 to 50 grams compressed tablet. One tablet can be placed in cracks and between rocks on the reef using the current to disperse the cyanide or more often dissolved in water in squirt gun, and squirted into cracks and crevices. The cyanide stuns the fish. Then a metal hook is used to lift up rocks and chase out the fish into a net. After the diver has left with his fish, cyanide residue remained on the coral reef destroying other resources, in particular, killing coral reef, juvenile fish species and larvae (Cu, 2001).

The damage done by the cyanide fishery for the much smaller sized ornamental fishes is probably much higher than that from the cyanide fishery for food fish, as the number of target fish per unit reef area is much higher. Also, mechanical reef destruction in the fishery for ornamental fishes may be more extensive as large areas of branching corals are broken apart to retrieve the numerous small target fish (Mous *et al*, 2002).

Laboratory experiments showed that exposure of *Zooxanthellae* hard coral to a range of cyanide doses likely to occur during cyanide fishing results in coral bleaching or death of the polyps. However, the toxicity of cyanide to corals under experimental conditions is, in itself, no proof for degradation on the scale of reef. This is because the rate of coral loss due to cyanide fishing may be lower than the rate of natural coral growth. Under natural conditions cyanide might be dissipated too rapidly by water currents to affect exposed corals (Jones and Steven, 1997).

Commercial coral collection suggests specific reductions of abundance and colony size range of harvested population. Commercial quantities of stony corals are currently collected from the shallow reefs areas, which include 28 species of 17 genera of stony corals with specific type, size, and form. The impact of coral collection is estimated based on logarithmic regressions of natural mortality and fishing mortality. Comparison of the measured coral community parameters suggests selective population changes and reduced abundance of exploited coral populations as a result of commercial collection (Ross, 1984).

The economic consequences of coral mining were investigated and economic costs (US\$110,000-7,360,000) were found to exceed net benefits (US\$750,000-1,670,000) by as much as US\$6,610,000/km<sup>2</sup> reef when analysed for a 20 years period in tourism areas. The highest costs were associated with decreased tourism (US\$2-3 million) and increased erosion (US\$1-4 million). However, in rural areas there is still a strong incentive for coral mining, because coral mining in the short-term perspective provides a more profitable business compared to fishing and agriculture (Berg *et al*, 1998).

Studies from World Resource Institute suggest that only 30 percent of Indonesian reefs is in good or excellent condition (as measured by live coral cover). The results, which include threats from over-fishing, indicate that 83 percent of the reefs are at risk. Because of the reef area it contain, coastal zone policy and management decisions made by this countries will have a major impact on the global heritage of coral reef diversity for future generations

(World Resource Institute, 2000). Indonesian reefs are being rapidly destroyed by poison fishing, blast fishing, coral mining, sedimentation, pollution and over-fishing. The economic valuation shows that the private benefits to individuals involved in these destructive practices are often considerable. However, the costs to society are much larger (Cesar, 2000).

Trade of Indonesian corals are limited by Appendix II from CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Export quota of live corals in year 2000 are 858,960 pieces (68 species), in year 2001 are 896,000 pieces (68 species), in year 2002 are 637,650 pieces (69 species), and in year 2003 are 813,950 pieces (71 species). The data of live corals export indicated that export from Indonesia in year 1997 were 787,045 pieces (World Resource Institute, 2000).

Indonesian reef fish stocks are declining as a result of over-fishing and destruction of habitat. The latter is caused by the dying of corals from cyanide and by the breaking of corals around holes where fish are hiding. In areas where cyanide fishing has been practised intensively, the reef is mostly dead, overgrown with algae, and has only very few animals still living on it. The target fish species in the cyanide fisheries are all species, which aggregate at specific sites to spawn (Pet-Soede and Erdmann 1999).

Although Indonesia has extensive areas of coral reefs, the collection of aquarium and ornamental pieces appears to be confined mostly to locations relatively close to Bali and Jakarta. These areas have the advantage of being close to transportation centres. Jakarta and Bali are served by international airports, which offer the primary means of export for coral pieces. Coral exporting companies based in Jakarta mostly buy corals from collectors operating in Seribu Islands, Belitung Island and the Lampung area. Coral exporting companies based in Bali obtain corals from around Madura, Lombok and Sumbawa islands. Although some coral collection may occur in more remote areas of the country, no evidence of this has been found and it is probably minor compared to the areas described. Although there is growing domestic demand for aquarium and ornamental pieces in the more affluent centres of Jakarta and Bali, this trade is minor compared to the quantity exported (Bentley, 1997).

The situation in Seribu Islands is almost post-apocalyptic in nature: *Serranids* appear so rare that no targeted fishery for them was observed. In its place, teams of 6-10 rag-clad skin-

divers were frequently observed methodically combing the reefs for ornamental fishes. These men were each outfitted with cyanide squirt bottles and hand nets, diving among the mostly dead coral heads in search of any flash or bright colour. Sadly, this form of cyanide fishing is the most destructive observed; with a wider range of target species, much larger volume of cyanide are used, often with daily-repeated exposures. Moreover, this small-scale, relatively high value fishery with little capital investment required, rendering it virtually impervious to economic over-fishing (Pet-Soede and Erdmann 1999).

Tourism pressures are creating concerns about how to reach a balance between use and resource protection in a marine environment. Terrestrial-based research has led to conceptual planning and management frameworks that address issues of human use and resource protection. Results indicate that snorkelers who travelled with larger tourism operators differed from those travelling with smaller operators on benefits received and in the way that specific conditions influenced their enjoyment (Shafer and Inglis, 2000).

Impacts of recreational diving and snorkelling on corals can be striking on popular areas. Broken coral litters the reef and many broken colonies appear bleached or overgrown with algae. Direct damage of corals is caused by tourist kicking, trampling or holding onto corals, which once and may be more damaged susceptible to disease and algal competitors. Additional, often serious damage occurs when misplaced boat anchors scour the reef (Hawkins and Roberts, 1994).

Coral reefs in a marine reserve at Sodwana Bay (South Africa) make it a premier dive resort. A linear regression indicated that 10% diver damage occurs at 9000 dives per site annually. Taking uncertainty into account, a precautionary limit of 7000 dives per site annually was recommended (Schleyer and Tomalin, 2000).

Coral reefs at Elliat, northern Red Sea, are among the most heavily used in the world for recreational diving, with more than 250,000 dives per year on only 12 km of coastline. Frequencies and types of recreational SCUBA dives varied widely between 12 coral reef sites, with more than 30,000 dives per year at most heavily-used sites. Diver behaviour caused about 10 incidents of reef contact per dive, mostly via raising of sediments onto the reef and direct breakage of corals. The proportion of damaged coral colonies varied significantly with the frequency of SCUBA diving, and did not depend upon site topography (Zakai and Chadwick-Furman, 2002).

Tourism and other development pressures in Bali have led to fragmentation and degradation of coastal ecosystems, modifications to coastal erosion, deposition and regeneration processes, and inequity regarding access to coastal resources, especially for local people relative to their traditional activities. An integrated approach is recommended to protect and rehabilitate linked coastal ecosystems within the context of cultural tourism policies (Knight *et al*, 1997).

Coral reef degradation will directly affect the abundance of reef fishes. Linear regression analysis of the effect of percentage live coral cover on the number of fish species and individuals showed that there was a highly significant positive relationship between live coral cover and total number of fish species and number of individuals. Species richness of most of coral fishes rose with increasing live coral cover (Bell and Galzin, 1984). Multiple linear regression analyses revealed that variation in potential living space accounted for over half of the variation in species richness and total abundance of fish on a coral. In contrast, species composition appeared to be influenced more by the physical setting within the lagoon. Relationship derived from the initial analyses predicted 65-78% of the variation in species richness among a different set of corals (Holbrook *et al*, 2002).

Coral reef management involving local fishing communities, local governments and other concerned organisations is a cost-effective way to alleviate the pressure on the numerous threatened coral reefs. In addition, economic valuation and cost-benefit analysis can provide essential information to support more investment in reef conservation (White *et al*, 2000). Alternative options to enhance a coral reef would generally include improved management of the reef, or off-site activities to reduce other potentially damaging impacts. All potential costs and benefits for each option should be weighed to ensure that the most economically efficient option is selected. Unless a thorough benefit-cost analysis is undertaken for a reef restoration scheme, it is difficult to say whether or not the overall benefits will outweigh the costs (Spurgeon, 2001).

Economic activities that benefit a group of individuals may impose costs on society as a whole, by reducing the ecosystem's provision of a flow of goods and services. The economic benefit or cost of a particular resource allocation, or economic activity affecting coral reefs, is the measurement of the resulting increase or decrease in human welfare. Certain uses of coral reefs impose burdens on society to attribute damage (Wielgus *et al*, 2002).



A review of the economic benefits derived from various coastal habitats reveals that many thousands US\$ per hectare could ultimately accrue from their rehabilitation. The benefit cost analysis framework can play an important role both in assessing the justification of coastal habitat rehabilitation initiatives, and by helping to improve the overall effectiveness of such initiatives (Spurgeon, 1999).

There has been too much focus on transplanting fast-growing branching corals, which in general naturally recruit well but tend to survive transplantation and relocation relatively poorly, to create short-term increases in live coral cover, at the expenses of slow-growing massive corals, which generally survive transplantation well but often recruit slowly. In those cases where transplantation is justified, it is advocated that a reserved stance, which focuses on early addition of slowly recruiting massive species to recovering community, rather than a short-term and sometimes short-lived increase in coral cover, may be more appropriate in many cases (Edwards and Clark, 1999).

#### **1.4. Coral Reefs Management Worldwide**

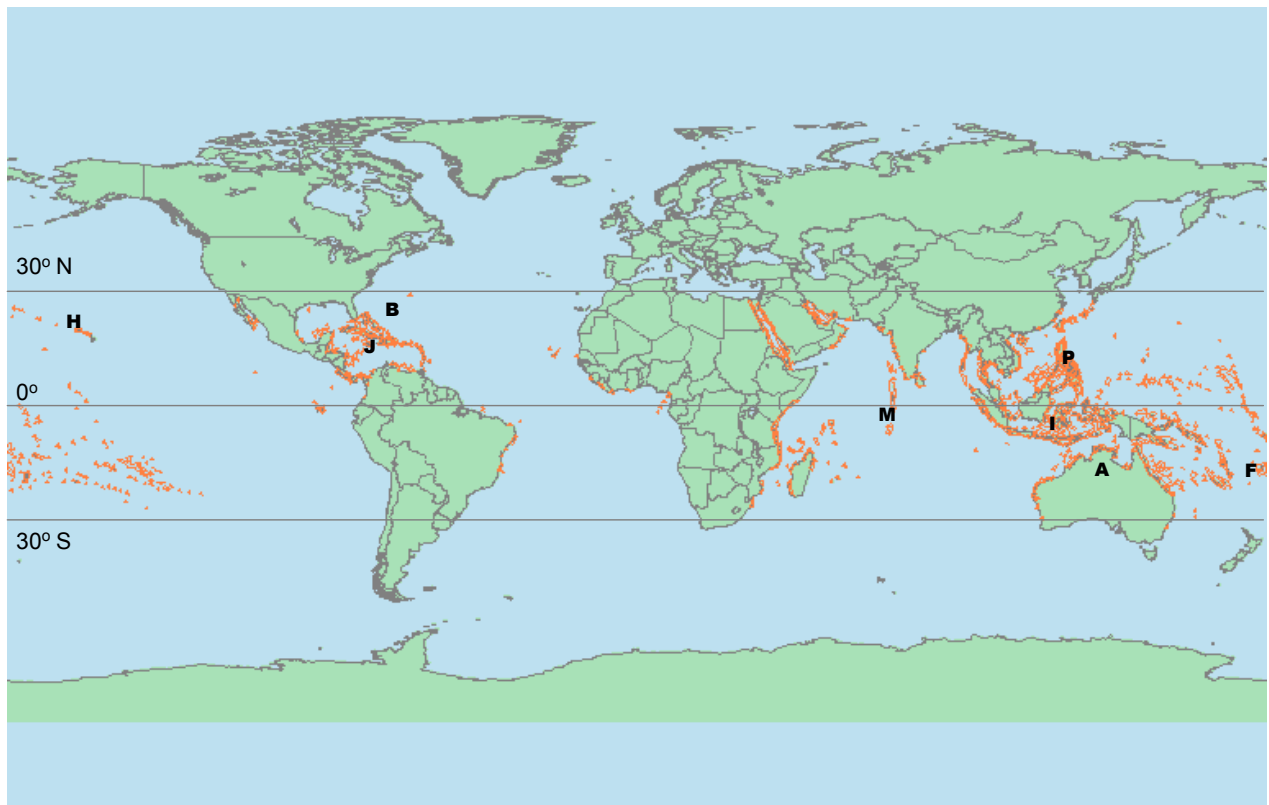
Coral reefs of the world received different pressures from human activities. Australian coral reefs have received low level of human pressure due to the low human population around their coral reefs. Australia has the largest area of coral reefs after Indonesia, but this coral reefs area formed great barrier reefs in one compacted area. In fact, Indonesian coral reefs are well distributed all over Indonesian marine waters, surrounding about 1800 islands separated. Compared to Philippine and Indonesia, there are no inhabitants in Australian coral reefs area. Although there are many remote coral reefs areas in Philippine and Indonesia, those areas are occupied by inhabitants, which generated stress to the area. Therefore, coral reefs are easier to manage in compacted areas rather than in large number of separated areas, and of course easier managed in areas with lower human densities.

There are many kinds of human pressures to coral reefs, ranging from the lowest indirect pollution from lowland agriculture to the highest direct impact from destructive fishing practice. The major sources of the threat to coral reefs are different in every country. Australian coral reefs receive low to moderate level of fishing pressures and the major source of threat is pollution from low land agriculture. There is overexploitation of certain reefs organisms, illegal fishing with toxic chemicals, and pressures from dredging, landfill, and sedimentation to the Bahamian coral reefs. Pollution from land-use changes, agriculture, and various industries are the main sources of threat to Fijian coral reefs. Jamaican coral reefs

received stresses from over-fishing, sediment, and sewage pollution. Coral reefs around heavily populated islands in Maldives received pressures from coral mining, dredging, pollution and coastal construction, while the use of concentrated chlorine to stun lobster and collection of invertebrates are the main problems in coral reefs management on Hawaii.

Coral reefs in Indonesia and Philippine have received almost all kinds of human pressure with high intensities. Over-fishing, destructive fishing practices, coral mining, and collection of reefs organisms are the common problems in reefs management. Uncontrolled pollutions and sediments from timber estate, agriculture, and various industries, including domestic sewages, are discharged directly to the coastal areas. These human pressures are spread over all coral reefs areas in the countries. Moreover, World Resource Institute (2000) identified that 83 percent of Indonesian reefs are at risk.

Figure 1. Coral reefs distribution worldwide



(A=Australia, B=Bahama, F=Fiji, H=Hawaii, I=Indonesia, M=Maldives, P=Philippine)  
Source: Reefbase (2003).

Different management strategies have been applied in different countries. Management of Australian coral reefs was under a single authority of GBRMPA in cooperation with Queensland State Government. This authority created planning and carried out control of coral reefs resource uses based on sustainable development approaches. The declaration of

Environment Protection and Biodiversity Conservation Act (EPBC Act 1999) has supported this authority to manage Australian coral reefs. Australian government has a success record in raising public awareness to reduce pollution from agriculture and sewage from tourism activity. Unlike Australia, responsibilities of coral reefs management in Bahama have been distributed among 3 main organisations, but government also supported NGO role under National Trust Act 1959. Fijian government has recognised the customary fishing right and incorporated it into the Fisheries Act 1942. Jamaican government has created integrated coastal management under the new council namely Council for Ocean and Coastal Zone Management where the members were the heads of all relevant agencies. Similar to Fijian government, Maldives government has also incorporated traditional management systems into Fisheries Law 1987, while coral reefs in Hawaii have been protected by a number of existing laws and regulations concerning uses and impacts on coral reefs. Philippine government has also established many relevant laws and regulations to protect corals and coral reefs. Detailed descriptions of coral reefs condition and management in each country are given in the next sub chapter.

#### **1.4.1. Australia**

After Indonesia, Australia has the largest area of coral reefs of any nation, nearly 50,000 square kilometres, or some 19 percent of the world's total area of reefs. Conditions for reef development vary considerably along the coastline. In the far west the climate is dry and there is little terrestrial runoff. Reef development is not continuous, though away from loose coastal sediments there are important areas, including Australia's best developed fringing reefs. The southward flowing Leeuwin Current is also important for this coastline, bringing warm waters to relatively high latitudes and enabling the development of some unique reef communities. Further north there are several reefs on the outer edges of the continental shelf. These include remnants of what may have been a substantial barrier reef structure drowned as a result of rising sea levels over geological time scales. The northern coastline is less known, however this is an area of high terrestrial runoff, and the waters are shallow and turbid, greatly restricting reef development. The eastern boundary of the Arafura Sea is marked by a narrow constriction, the Torres Strait. East of here, the world's largest coral reef complex commences, extending out to the margins on the continental shelf and continuing southwards as the Great Barrier Reef. The warm, southward flowing East Australia Current also supports the development of high latitude reefs along Australia's eastern shores to the south of the Great Barrier Reef. Other reefs are found in Australia's offshore waters. Most notable among

these are the extensive reef structures of the Coral Sea, east of the Great Barrier Reef (Spalding *et al*, 2001).

Human pressures are low on Australian reefs as the population density is low, the reefs are mostly remote from the coast, fishing pressures are moderate to slight and in some areas virtually non-existent. In particular, the offshore atoll reefs on both coasts are so remote from the mainland influences that they are only subject to occasional fishing, although the extent of illegal and international fishing is poorly known. Also many reefs are adjacent to areas with low rainfall and minimal runoff. Increased levels of nutrients and sediments entering the GBR system in river discharges are a potentially significant threat to the GBR, particularly the inner-shelf reefs, however these impacts on coral reefs have never been measured directly. The major sources of nutrient pollution (nitrate and phosphate) on the GBR are increased runoff from large areas cleared for cattle grazing, enriched runoff from sugar-cane and banana farming and domestic sewage. Education and extension programmes run by the Department of Primary Industry and reef managers have raised awareness and lead to improved practices in the rural sector. Monsoonal flood events are the major vectors of sediment and nutrient pollution, particularly from grazing lands laid bare after long periods of droughts. Sugar cane and banana farmers are regulating their use of fertiliser to minimise runoff loss. The practice of green tillage of crops and trash blanketing (leaving the trash on the ground as compost and not burning crops) is increasing, which reduces sediment and nutrient loss. All tourist resorts and cruise boats are required to either treat sewage or dispose of it so that there is no pollution (Maniwavie *et al*, 2000).

Management of the coral reefs are now regulated by substantial legislation, with the authority vested in a single authority for the GBR (GBRMPA) in cooperation with the Queensland State Government. This was reviewed in the 1998 report. Fisheries resource management is a complex mix of Commonwealth and State/Territory responsibility, with the States or Territories responsible out to 3 nautical miles and the Commonwealth managing fisheries beyond that to 200 nautical miles (Maniwavie *et al*, 2000).

Most commercial fisheries are managed mainly through input controls limiting the number of vessels, the time and place of fishing, and the type gear. Progressively, the management focus for the coral reef fisheries has moved from considering the fishing impacts on target species to consideration of non-target species and the environment, especially the effects of trawling on benthic habitats. The release of the Australian Ocean Policy in 1998 listed the principles,

and the planning and management approaches necessary to achieve the ecologically sustainable development of the ocean resources. In 1999, major changes were made to national environmental legislation via a new Act (the Environment Protection and Biodiversity Conservation Act 1999, EPBC Act) by replacing 5 existing Commonwealth Acts and introducing an assessment and approval process for activities likely to have significant impacts on: Commonwealth marine areas; nationally threatened species and ecological communities; the marine environment; and on internationally protected migratory species. This act is particularly relevant to fisheries within the GBR World Heritage Area (Maniwavie *et al*, 2000).

#### **1.4.2. Bahama**

The Bahamas, an archipelago of some 700 islands and numerous reefs, stretch out over 1,225 kilometres from north to south. Most of these islands are scattered over two shallow banks, the Little Bahama Bank and the Great Bahama Bank, with depths of 10 meters or less bounded by extremely deep water of up to 4,000 meters. The Bahamas are named after these banks: *baja mar* is Spanish for “shallow sea”. The other islands occur on smaller, more isolated, banks to the southeast (principally the Crooked, Mayaguana and Inagua Banks) and the west (Cay Sal Bank). To the south, Hogsty Reef is one of the few atoll-type structures in the Caribbean. All the Bahamian islands have low relief and are formed from carbonate material, laid down by corals and calcareous algae, or by physical deposition from saturated water. Successive ice ages exposed these carbonate platforms, and wind-blown sand dunes-created at much the same time-subsequently lithified, further raising the elevation in some areas (Spalding *et al*, 2001).

Reef development in much of the Bahamas is naturally limited by the exposure to hurricanes of the windward sites, by unusually cold winters in the northern islands and by turbid, high salinity waters on many leeward bank margins. However there are thousands of small patch reefs, dozens of narrow fringing reefs and some bank barrier reefs, such as the Andros Barrier Reef which is one of the longest reef systems in the Western Atlantic. Many Bahamian reefs are in fairly good condition, which is probably due to limited anthropogenic disturbance associated with their remoteness and the country’s low population density (Spalding *et al*, 2001).

Edible reef animals are still common on many Bahamian reefs, and fish stocks are generally abundant. There is a well developed commercial and export fishery, with total landings in 1999 close to 5,000 tons, valued at over US\$70 million. This figure includes over 2,700 tons of the very high value spiny lobster tails. There is local overexploitation of certain stocks, including whelk *Cittarum pica*, queen conch, spiny lobster and several species of grouper. Concern has been expressed that spawning aggregations of groupers have become the target for spearfishers. A number of illegal fishing activities occur which include the use of toxic chemicals, the harvesting of hawksbill turtles, the taking of undersized or juvenile queen conch, and the collection of spiny lobster out of season or with prohibited diving gear. Artificial shelters are often positioned close to reefs to attract spiny lobsters, although there is concern that these may simply aggregate existing spiny lobsters rather than enhancing natural stocks. There is a limited legal harvest of adult green turtles during an open season (April-July). Sand is still being mined from a few reef sites on a fairly small scale. Over half of the commercial dive sites have mooring buoys. Declines in coral cover have been recorded in some locations. On New Providence dredging, landfill, sedimentation and the construction of a cruisership port have led to the loss of 60 percent of the coral reef habitat (Spalding *et al*, 2001).

The Bahamas is a stable, developing nation with an economy heavily dependent on tourism and offshore banking. Tourism alone accounts for more than 60 percent of gross domestic product and directly or indirectly employs 40 percent of the archipelago's labor force. Moderate growth in tourism receipts and a boom in the construction of new hotels, resorts and residences has led to localized pressures on coral reefs, but the total area is so great that the majority of reefs are probably little affected. Overall prospects for the conservation of the marine environment in the Bahamas will depend heavily on the fortunes of the tourism sector and continued income growth in the USA, which accounts for the majority of tourist visitors (Spalding *et al*, 2001).

There are 3 main government and non-government bodies responsible for coral reef resource protection and conservation in the Bahamas (Woodley *et al*, 2000):

- a. The Bahamas Environment Science and Technology (BEST) Commission is responsible for the development of legislation to protect the environment and issue permits for development;
- b. The Department of Fisheries, within the Ministry of Commerce, Agriculture and Fisheries is aggressively taking responsibility not only for fisheries management, but

also for the establishment of marine fisheries reserves and coral reef monitoring programmes. It has a staff of 43, employing the greatest number of marine and fisheries scientists in the country, and participates in regional programmes;

- c. The Bahamas National Trust, a non-government organisation (NGO), was mandated, under the National Trust Act of 1959, with the responsibility and legal authority to manage the national parks of the country. The Government supports the park system through specific enforcement responsibilities carried out by the Bahamian Defence Force.

### 1.4.3. Fiji

Fiji is a vast archipelago centred on two relatively shallow geological features, the Fiji Platform and the Lau Ridge. Geologically, the area lies on the Indo-Pacific plate close to the boundary with the Pacific plate, in an area of relatively complex geology and fracturing. The two largest islands of Viti Levu and Vanua Levu, together with quite a number of smaller ones, lie on the relatively shallow Fiji Platform. Fringing reefs surround most of Viti Levu, with the largest continuous fringing reef running for 100 kilometres along the Coral Coast on its southern shore. Offshore from eastern Viti Levu the Suva Barrier Reef follows the shelf edge up to the island of Ovalau. The northern coast of Viti Levu is dominated by a very complex array of platform reef structures and intervening channels. Running northeast at some distance west of Viti Levu is a string of high islands known as the Yasawa Group, again with an associated complex of fringing and patch reefs. These islands lie close to the edge of the Fiji Platform, and part of this shelf-edge is capped by Ethel Reef, a 30 kilometres barrier reef. Immediately south of Viti Levu is the island of Beqa, enclosed to the south and west by the Beqa Barrier Reef. Further south, the large island of Kadavu is separated from the Fiji Platform by the Kadavu Passage. This island has fringing reefs along much of its coastline, but is further dominated by a 95 kilometres long barrier reef running along its southern and eastern coasts and extending into the Great Astrolabe and North Astrolabe Reefs (Spalding *et al*, 2001).

The line of the Yasawa Group in the west is continued eastwards towards Vanua Levu by Fiji's longest barrier reef structure, the Great Sea Reef which runs along the shelf edge in a near continuous chain for over 200 kilometres, gradually converging towards the coastline of Vanua Levu at its northeastern tip. The Vatu Ira Channel between the two high islands is a tongue of deeper water, also fringed by elongated barrier reef structures including the Vanua

Levu Barrier Reef along the eastern edge of this channel and up to the southern shore of Vanua Levu. Much of the southern shores of Vanua Levu are lined by fringing reefs, while the northern edge is marked by a similar complex of platform reefs to that along Viti Levu. Out to the east lies a complex of islands and reefs collectively termed the Ringgold Islands. These include several atolls, and also Budd Reef which is a near-atoll, with a group of high islets located in its lagoon. A group of reefs on the outer edge of the Ringgold Islands make up the Nukusemanu and Heemskercq Reefs, parts of which are submerged, but may be considered a nearatoll or barrier-type structure (Spalding *et al*, 2001).

The Lau Islands make up the eastern edge of the Fiji group and lie at the top of the Lau Ridge, separated from the Fiji Platform by the Nanuku Channel. Most of the northern islands are high and of volcanic origin, but further south carbonate islands predominate. There are a number of atolls and near-atolls throughout the chain. The Exploring Isles make up one of the largest structures in this group, including the high island of Vanua Balavu, as well as a long barrier reef running out to the east and enclosing a number of smaller islands. Towards the centre of the group the Bukatatanoa Reefs are another massive barrier reef complex. Lying considerably to the south of the main group of Lau Islands are the smaller islands of Vatoa (a high limestone island with a barrier reef) and the atoll of Vuata Vatoa. Further south again is a complex of four small reef systems including Ono-i-Lau, a small group of islands enclosed by a barrier reef (Spalding *et al*, 2001).

The Koro Sea is a relatively enclosed sea between the Lau Islands and Viti Levu. There are a few islands scattered in this area. The Lomaiviti Group east of Viti Levu is mostly volcanic and has well developed fringing and barrier structures. Further south, the Moala Group is made up of three high volcanic islands with predominantly fringing reefs around them (Spalding *et al*, 2001).

Far from the main islands of Fiji are three other reef areas. In the far northwest, the island of Rotuma is volcanic and has wide fringing reefs. A number of smaller islands nearby also have fringing reef structures. In the far southwest Conway Reef or Ceva-i-Ra is a small coral cay of some 200 by 50 meters on a platform reef. Finally, in the southeast, Fiji claims the Minerva Reefs, although these are also claimed by Tonga (Spalding *et al*, 2001).

As populations grow in Fiji, urbanisation and development expand and pressure on the coastal and the coral reef increases. There are additional demands for land and as a result mangrove



areas are reclaimed. There is also a high demand for coral sand for cement construction material. Potential sources of point source pollution in Fiji include: mining, shipyards and slipways, moorings, tourist developments, sugar mills, timber mills, a cement factory, litter refuse disposal sites, sewage, agricultural pesticides and herbicides, changing landuse, and various industries (Vuki *et al*, 2000).

Intensive agriculture has greatly contributed to the increased sediment loads deposited into Fiji's rivers and marine environment. The sediment load in the Waimanu River in southeast Viti Levu indicates that the average soil loss was about 53 tonnes/hectare/year. As a result of high sediment loads in Fiji's rivers, dredging of sediments from rivers in Viti Levu and Vanua Levu alone has cost Fiji government more than \$50 million to date. A significant proportion of the sediment is attributed to agricultural run-off. Recent studies have shown that fringing reefs in Kadavu with goats on them have serious problems with siltation. The goats on Yanuynu-i-loma on the Great Astrolabe Reef had cleared all vegetation on the island and had caused serious erosion on fringing reefs and lagoons. The removal of vegetation and grazing by goats has also been very serious in some of the uninhabited islands in the Lau Group (Vuki *et al*, 2000).

Coral reefs have provided indigenous Fijians with the bulk of their dietary protein for thousands of years. A range of traditional customs and practices has evolved to conserve resources on environmentally sensitive islands and coral reefs in Fiji. Customary marine tenure was the most important. The sea estates were integral part of the land-owning group or clan's estate. Prior to the Deed of Cession to the British in 1874, the Fijian system of ownership was based on communal lifestyle. This enabled Fijians to control the exploitation of fisheries resources. At present Fijians have the right to fish for their own consumption but the ownership of the seabed belongs to the State (Vuki *et al*, 2000).

These sea estates were guarded and defended by the owners. Overfished areas could be reserved (tabooed) from fishing. Large and vulnerable species prone to overfishing, for example, turtles were often reserved for chiefs. Clans had totems tabooed to the clans. The clans were also responsible for the conservation of their totems and these were often marine species (Vuki *et al*, 2000).

The control over the littoral zone, foreshore and submerged seafloor is held by the State (State Lands Act 1946). However, the Fiji government recognises the customary fishing rights of Indigenous Fijians and this was incorporated into the Fisheries Act of 1942. The Fisheries Act

of 1942 prohibits destructive fishing methods and imposes minimum sizes on a number of reef species. The use of chemicals, native fish poisons, explosives or dynamite is prohibited. The Fisheries Act of 1942 also recognises registered fishing right owners to fish for subsistence in registered customary fishing grounds without a licence. A licence is required for commercial purposes (Vuki *et al*, 2000).

The Fiji Sustainable Development Bill 1999 has several clauses detailing codes of environmental practice, national resource management plan, offences and penalties. It also proposes a National Council for Sustainable Development, Environment Trust Fund, Environment Registers, Environment Management Units and Committees and Environmental Impact Assessment. The Fiji Sustainable Development Bill 1999 is still under review by a parliamentary sub-committee and the submissions on the Bill from the public are currently being considered (Vuki *et al*, 2000).

#### **1.4.4. Jamaica**

Jamaica is the third largest island in the Greater Antilles and is located in the centre of the Caribbean Sea. Cuba, 150 kilometres north, moderates the effects of the northeast trade winds on the fringing reefs of the north coast, which grow on a narrow shelf. Patchy reef formations on the south coast, punctuated by rivers and sediment slopes, grow on a wider shelf extending up to 20 kilometres offshore. Reefs and corals also grow on nine offshore banks, notably at the Pedro Cays, 70 kilometres south, and the Morant Cays, 50 kilometres to the southeast. Coral cover on the mainland fringing reefs is low, although this was not always the case. Cretaceous basement rocks are covered by Tertiary limestone, and on the north coast by Pleistocene reef deposits. Past changes in sea level have created terraces above and below present sea level to form raised or drowned cliffs. There are two wet seasons, in October and May, and two dry seasons. The water temperature on the north coast ranges from 26 to 30°C. The weather, particularly on the north coast, is dominated by the northeast trade winds, occasionally interrupted by cold fronts from North America in winter. Two of the most severe hurricanes on record, Allen and Gilbert, hit Jamaica in the 1980s, with significant impacts on the coral reefs (Spalding *et al*, 2001).

Jamaica has a long history of exploiting its marine resources. Since early colonial days there was a substantial import of fish to feed the growing population, including turtle meat from the Cayman Islands, and dried fish from North America. Fishing the immediate offshore waters was also undertaken, but the maximum yield of some 11,000 tons of fish per year in the 1960s

was clearly unsustainable and fish stocks have now collapsed. Overfishing is particularly bad on the north coast, where the narrow coastal shelf concentrates fishing into a smaller area, while making the shallow reef communities more accessible. Many of the fish now caught have not yet attained reproductive maturity, and it has been suggested that reef fish stocks in Jamaica may be being supplemented by fish larvae from other parts of the Caribbean. The offshore banks are also heavily fished, and there is a large conch fishery on Pedro Bank (Spalding *et al*, 2001).

Jamaican reefs are further stressed by human impacts resulting from terrestrial activities, including sedimentation caused by soil erosion from agriculture, but more particularly from sewage nutrient pollution. Coastal development has been rapid in many parts of Jamaica, encouraged by massive tourism developments. In many areas sewage receives little or no treatment (Spalding *et al*, 2001).

The population of 2.8 million is increasing, unemployment is high and the cost of living rising, therefore more people seek food and income by fishing, especially on the very accessible northern shelf. Rivers carry considerable runoff of suspended sediment, resulting from hillside clearance, and sewage pollution. Excess nitrogen is also channelled to the sea underground in the widespread limestone formations. The rapid growth of facilities for coastal tourism (about 1.5 million visitors per year) has also contributed to terrestrial runoff. There are proposals to site new industrial developments, including a transshipment port, in coastal areas (Woodley *et al*, 2000).

Until recently, the major law available for coral reef management was the Beach Control Act (1960). This was one of more than 50 environmental laws, administered by a multiplicity of ministries and other agencies. The enactment of the Natural Resources Conservation Authority Act (1991) started a process of rationalisation and, since it binds the Crown, obliged public sector entities to comply. That process continued in 2000 with the formation of the National Environmental Planning Agency (NEPA) by merger of the NRCA with the Town Planning Department and the Land Development Commission. In 1998, recognising the need for inter-sector collaboration in management of the Exclusive Economic Zone and coastal areas, government agreed to creation of the Council for Ocean and Coastal Zone Management. Its members are the heads of all relevant agencies and it reports, through the Ministry of Foreign Affairs, directly to cabinet (Woodley *et al*, 2000).

#### 1.4.5. Maldives

The Maldives is a spectacular chain of 22 coral atolls which run for some 800 kilometres north to south in the Central Indian Ocean. These include the largest surface-level atolls in the world: the area of Thiladhunmathi and Miladhunmadulu Atolls (with two names, but a single atoll structure) is some 3,680 square kilometres, while Huvadhu Atoll in the south is over 3 200 square kilometres. (The Great Chagos Bank to the south occupies an even greater area, but is now largely submerged). More than any other nation outside the Western Pacific, the Maldives is highly depended on coral reefs for the maintenance of their land area, food, export earnings and foreign currency from tourism revenues (Spalding *et al*, 2001).

The Maldivian people have been estimated to have among the highest levels of per-capita fish consumption of any nation, at 125 kilos per person per year. The majority of this consumption is of tuna and other pelagic species, while the majority of export fisheries are also centred on tuna. Some reef fish are taken for local consumption, but the most important reef fishery is the capture of live bait for the offshore tuna fishery. Fish exports for the live fish markets of East and Southeast Asia have also been significant through the late 1990s, and this is having an impact on grouper stocks (Spalding *et al*, 2001).

Most of the reefs here are better protected than other reefs in South Asia; mainly because most are isolated from human activity. The main damage to reefs occurs around those islands that are heavily populated and where there is a high level of development. Impacts on the reefs include coral mining, pollution, dredging of channels for boats, coastal construction, increased reef fisheries and the crown-of-thorns starfish. Coral mining has lowered the reef flat around the capital of Male, such that concrete walls have been constructed to prevent shoreline erosion. Construction of wharves and breakwaters have resulted in increased erosion around some tourist resorts. However, the total reef area damaged by human activities is relatively small compared to the extensive reefs present in the Maldives (Rajasuriya *et al*, 2000).

There are two main pieces of legislation directly related to coral reef management and conservation: 'The Fisheries Law of the Maldives 1987' and 'The Environmental Protection and Preservation Act 1993'. Traditional management systems are still practiced in some atolls and these practices have been incorporated into fisheries law. Specific regulations associated with coral mining were introduced in 1992 and are currently under revision to be made

applicable to the whole country. Many sectors of government are involved in managing coral reefs and reef resources, these include (Rajasuriya *et al*, 2000):

- a. Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources;
- b. The Environment Section of the Ministry of Home Affairs, Housing and Environment;
- c. Ministry of Construction and Public Works;
- d. Maldives Water and Sanitation Authority; and
- e. Ministry of Tourism.

#### **1.4.6. Philippine**

The Philippines are a large and complex mass of over 7,000 islands making up the north of insular Southeast Asia. Together with Indonesia to the south, the Philippines lie in the centre of global coral reef biodiversity and have a vast area of reefs. In the far north the archipelago commences with the Batanes and Babuyan Islands in the Luzon Strait, just south of Taiwan. The northern third of Luzon itself is highly mountainous and parts remain heavily forested, while the central parts are predominantly agricultural with large areas of low-lying land. Relatively close to Luzon are the islands of Mindoro and Marinduque, the former mountainous and still largely under forest. South of Luzon lies a complex mass of islands known as the Visayas, including Panay, Negros, Cebu, Bohol, Leyte and Samar, centred around the Visayan Sea which, despite the tight configuration of islands, reaches a depth of more than 200 meters in some places. The southernmost major island is Mindanao, which lies separated from the Visayas by the Bohol Sea. This is another mountainous island, with a narrow shelf on all sides. The Philippines Trench to the east of Mindanao and Samar reaches depths of more than 10,000 meters at a distance of less than 80 kilometres from shore. Stretching to the southwest from Mindanao is a chain of islands known as the Sulu Archipelago, coming close to the coastline of Sabah in Malaysia and separating the Sulawesi (Celebes) Sea in the south from the Sulu Sea to the north. There are several remote islands and atolls in the central Sulu Sea, while its northern edge is marked by the long mountainous island of Palawan as well as various smaller ones (Spalding, *et al*, 2001).

The use of fish poisons (especially cyanide) to catch aquarium and food fishes is a rapidly growing problem in many Pacific and Indian Ocean nations, but is most serious in the Philippines and Indonesia. About 85% of the aquarium fish traded have been caught using cyanide, with 379 species involved in the marine aquarium trade. These were composed

mainly of members of the fish families Labridae (wrasses), Pomacentridae (damselfishes), Chaetodontidae (butterflyfishes), Pomacanthidae (angelfishes), and Scaridae (parrotfishes). Various invertebrates and plants, as well as methods used to harvest these, have also been included (Licuanan and Gomez, 2000).

Trade in Philippine marine live food fish increased in 1995 to 3,500 tons while marine aquarium fish exports declined. Live fish trade declined to 1,500 tons in 1999. As with aquarium fish, the live food fish trade depended mostly on cyanide to stun the fish and make them easier to catch. Groupers, especially *Plectropomus leopardus*, are the main targets and their particular mix of life-history attributes make them susceptible to overexploitation. A specific concern is the targeting of the spawning aggregations. Landings for aquarium fish and live food fish are highest in Cebu and Tacloban respectively, although problems in consistent monitoring remain. Whether this has any relation to the large changes in reef condition in the Visayas remains subject to speculation (Licuanan and Gomez, 2000).

Information on the long-term effects of cyanide on corals and other reef residents is largely limited to anecdotal accounts. Over 150,000 kg of dissolved cyanide is estimated to be squirted onto about 33 million coral heads every year in the Philippines. The immediate impact of the toxin on the photosynthetic machinery of the coral's symbiont algae, and on the colony, range from almost imperceptible loss of zooxanthellae, to death within 24 hours. A 1980 Philippines report describes all corals in two quadrants dying three months after two cyanide exposures, four months apart. Cultures of the seaweed *Plectropomus leopardus* and pearl oysters are also affected. The effects apparently persist long after the toxins are used, hence seaweed farmers avoid former cyanide fishing grounds since yields from these areas are reported to be lower. The effects on coral-associated organisms and their recovery rates have not been documented. The consequences of repeated exposures are much less known. No reliable method exists for determination of ambient concentrations of cyanide in seawater. Cyanide effects cannot even be distinguished in the field from those of increased seawater temperatures, siltationer diseases. This lack of basic quantitative information on cyanide and the environmental effects of cyanide fishing is a problem. It prevents a proper evaluation of cyanide impacts in relation to resource management and biodiversity concerns. International Marine-Life Alliance's cyanide testing program results suggest a small proportion of the recent catch test positive for cyanide and that there is some decline of these cases. Despite these findings, increased vigilance remains necessary (Licuanan and Gomez, 2000).

While many laws and regulations have been established relevant to the protection of corals and coral reefs, the landmark legislation directly associated with the protection of corals and coral reefs was *Presidential Decree No. 1219 (1977)*, followed a few years later by *P.D. 1698 (1980)*. These decrees essentially prohibit the gathering, possession, and exportation of scleractinian corals. *Fisheries Administrative Order No. 184 (1992)* provided guidelines on the experimental collection of precious and semi-precious corals. The provisions of the two decrees have been embodied in the *1998 Republic Act 8550*, otherwise known as the *Fisheries Code*. This law is important because it encourages the establishment of reserves, refuges and sanctuaries, and also requires all coastal municipalities to set aside about 15% of their coastal areas, where applicable, as fish sanctuaries. More and more local municipalities have passed legislation for the protection of the coastal zone, including the establishment of marine reserves and sanctuaries, but this has led to the creation of more ‘paper’ parks. *Section 91* of the code bans coral exploitation and exportation (Licuanan and Gomez, 2000).

All Scleractinian corals in the Philippines have been listed in Appendix 2 of the *Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES)*, no doubt contributed to by the plight of Philippine coral reefs. In the subsequent national legislation, there is a provision making it unlawful to fish or take rare, threatened or endangered species as listed in the CITES and as determined by the Department of Agriculture. This provision has been interpreted by the government to mean that all Scleractinian corals are threatened or endangered, an obvious fallacy. With this overkill provision, the government prohibits legitimate attempts to culture corals for the aquarium trade, a position that appears counter-productive. The provision nonetheless simplifies enforcement since different coral taxa need not be distinguished, as all are covered (Licuanan and Gomez, 2000).

#### **1.4.7. Hawaii**

Dynamite and cyanide fishing are not problems in the Hawaii, but recent cases involving the use of concentrated chlorine to stun or kill lobster or nocturnal food fish located deep in the recesses of coral reef holes and caverns has raised concern about the impact of this rarely reported criminal activity. During the Spring and Summer of 2000 unconfirmed reports of ‘juicing’ were received from the islands of Maui, O‘ahu and Kaua‘i. Unless apprehended in the act, “juicing” is difficult to prove or document. However, since it destroys habitat for all, most fishers in Hawai‘i find such action deplorable (Gulko *et al*, 2000).

Collection of sessile benthic invertebrates for the marine ornamental trade has raised concerns about destruction of coral reef habitat from the removal of habitat-forming organisms such as anthozoans, sponges, bryozoans and seaweeds. Extraction of cryptic or infaunal organisms (especially the feather-duster worm, *Sabellastarte sanctijosephi*) often leads to destruction of habitat through the collection process (Gulko *et al*, 2000).

The extensive use of long gill nets throughout most of the Hawaii is thought to have caused localized depletion of reef fish through its effectiveness and non-selectivity. Bycatch of endangered species (sea turtles, Hawaiian monk seals) and breakage of high-relief coral colonies caused by untended nets persists despite State laws requiring that nets be checked at least every 2 hours and removed after 4 hours (Gulko *et al*, 2000).

The State of Hawai'i has a number of existing laws and regulations concerning uses and impacts on corals and coral reefs. Sand, rubble, live rock and coral are protected from harvest or destruction in State waters. Many Hawaiian stony corals are also prohibited from being sold. Certain Administrative Rules provide for protection of marine water quality, and creation of MPAs. The State Constitution can specifically be applied to protection of coral reef habitats. Portions of Section 1 state that "the State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, air, mineral and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State." Section 9 of the same document states that "each person has the right to a clean and healthful environment, as defined by laws relating to environmental quality, including control of pollution and conservation, protection and enhancement of natural resources. Any person may enforce this right against any party, public or private, through appropriate legal proceedings, subject to reasonable limitations and regulations as provided by law" (Gulko *et al*, 2000).

In spring of 2000, the Hawaii State Legislature passed a law banning the harvest of shark fins from State waters or landing of shark fins in the State regardless of the waters in which the sharks were caught. The result is a lessening of the fishing pressure on sharks, including species that play a role in reef ecosystems in Hawaii. The Coastal Zone Management Act (CZMA) provides for controlled management and development of shoreline areas through cooperation between federal and state agencies (Gulko *et al*, 2000).



## CHAPTER 2. CORAL REEFS MANAGEMENT IN INDONESIA

### 2.1. The Role of Coral Reefs in Indonesia

Indonesia consists of 2,915,000 km<sup>2</sup> marine waters, 1,847,700 km<sup>2</sup> shelf area, and 1,826,440 km<sup>2</sup> land area. Indonesia is the world's largest archipelago nation, with over 85,000 km<sup>2</sup> of reefs, extending nearly 5,000 km from east to west, and harbouring over 18,000 islands (including rocks and sandbanks). It touches on the Indian and Pacific Oceans as well as many seas, including the Andaman, Java, South China, Sulawesi, Banda and Arafura Seas. This country has a vast array of coral reefs, many poorly described or completely unknown, while it completely straddles the region with the greatest reef biodiversity in the world.

Despite the vast area of the Indonesian Archipelago and the lack of detailed information about its reef communities, the major part of its coastal area is already heavily utilized, particularly in the west, and considerable areas are under increasing stress from human activities. About 6,000 of Indonesia's islands are inhabited, and marine and coastal resources and activities generate 25 percent of the country's gross domestic product.

Fisheries are a major activity, and it has been estimated that 60 percent of protein consumptions is derived from fisheries. About 90 percent of all fisheries are traditional, with products for local consumption or for sale in local markets. Unfortunately over-fishing is widespread and is almost continuous in all regions. In addition a number of destructive fishing practices, blast and cyanide fishing amongst them, are employed in all areas, including many remote reefs and atolls. Blast fishing, in particular, is having an extremely detrimental effect across the country. Although illegal since 1985, only a few places have escaped it, even in protected areas.

Collection of fish and corals for export in the ornamental and aquarium trade is considerable. Indonesia is the world's largest exporter of corals, reaching well over 1,000 tons of coral per year in the early 1990s and now exporting around 500 tons per year. Indonesia has provided approximately 41 percent of all coral exports worldwide since 1985. These exports are relatively low on a unit-area basis because of the very large coral reef area in the country, but that may have localised impacts (Spalding *et al*, 2001). The data from Ministry of Industry and Trade showed that marine ornamental fish and marine live food fish export value increased from \$5,606,433.00 in year 1999 to \$8,924,161.00 in year 2000. While the data

from World Resource International showed that coral export as much as 787,045 pieces or equal to about US\$2,361,135.00.

Indonesia, which is one of the greatest sources of reef fish and coral reefs, only enjoys a little value of a long-term benefit from the trading activities on regional as well as on global scale. Furthermore, pressures upon productive habitats, such as coral reefs, as the result of its utilisation, is not paid by the traders or the parties who receive the most benefit from the dynamics of the trading of reef fish and live corals. The local community and Indonesia have to deal with the changes caused by the utilisation activities mentioned above.

Besides many kinds of human pressures to Indonesian coral reefs, there are several un-clear regulations and confusions among regulations in Indonesia. Traditional marine and coastal resource management, which involves various monitoring mechanisms, is not acknowledged by government regulations. Although Indonesia has a Ministry of Marine Affairs and Fisheries since 1999, the responsibilities of coral reefs management are still dispersed over different government organisations without coordination mechanism. Government regulations did not seriously acknowledge the role of NGO, though many NGOs have taken responsibilities of coral reefs management in Indonesia.

## **2.2. Coral Reefs Management in Indonesia**

### **2.2.1. Community Management**

Community or traditional marine and coastal resource management mechanisms are still applied in several areas of Indonesia, both in the form of fishing ground management and catching season management. An example would be *sasi* system in several areas in eastern Indonesia, which has been proven through generations as being able to maintain the natural resources, which are the lifelines for the community.

In several cases, this mechanisms face obstructions from outsiders who do not accept local systems. An even bigger problem is the fact that in Indonesia, traditional law is not acknowledged by the state, although it is acknowledged internationally. Instead, the Indonesian government has adopted an intervention on natural resource management in the form of conservation areas.

Traditional fishing ground management usually comes in the form of local zoning and tenure, types of fishing gears, and profit sharing mechanisms. Tenure patterns are usually passed down from generation to generation. Zoning in conservation areas actually implements the

concept of utilisation zones, buffer zones and saving zones. The most complete zoning exists in national parks, which contain sanctuary zone, protection zone, intensive utilisation zone, traditional utilisation zone, and buffer zone. Activities that can be conducted at sanctuary zones are only research, education, and science development. Limited tourism activities can be carried on in protection zones, besides the three mentioned above. These two zones act as saving zones in traditional fishing area management. Any natural resources extraction are prohibited in these zones.

The difference between intensive utilisation zones and traditional utilisation zones only based on the users: outsiders or the local community. A buffer zone is an area outside the park, which supports the life of biota and the ecosystems in the area. Intervention on fishing ground management in conservation areas is not effective due to the inconsistency in operation, such as insufficient regulation and resource problems. Moreover, government resources are not sufficient to expand this intervention out of the conservation area.

Several communities are also familiar with catching season management, such as of the open-shut system. This system allows the ecosystem to rehabilitate. Like the fishing ground management, the open-shut system needs close monitoring and public admittance.

### **2.2.2. Government Management**

There is no clear vision in government institutions on the management of reef fishery resources. This can be seen from, among others, the comprehension on fisheries management in government institutions, where there often are ambiguities of definition and terminology. Besides that, there are several confusions as can be seen below:

- a. Confusion between fishery management and fishery business management. Fishery management consists of three aspects: the quality of life of the people, the quality of habitat, and economic aspects (exploitation and trading). In contrast fishery business management is generally profit-oriented. For example, Presidential decree No. 15/1984 on Fishery Management in EEZ area in Indonesia, which only concern financial profit.
- b. Confusion between monitoring and managing fishery activities. All monitoring activities by Directorate General of Fisheries on fishery activities are often considered as fishery management, while monitoring is only one component of the management process.

Acts that regulate the management of marine and coastal resources in Indonesia are centralistic, product-oriented, and unsystematic. Policies are dominantly issued as decrees from the Minister of Agriculture, while some are issued by the Ministry of Forestry, the State Ministry of Environment and the Ministry of Tourism, besides a small number which are distributed among the Ministry of Mining, the Ministry of Industry and Trade, the Ministry of Transportation, and others. This happened since there was no shelter for maritime sectors in the previous cabinets. The incomplete set of acts at the level of government regulation (above the ministerial decree) can become a problem in the future since the issuance of the decree by the Peoples General Assembly (II/MPR/2000). This decree (No. II/MPR/2000) on Sources of Law and Rules of Law eradicate ministerial decree as a source of the law. There will be a legal gap, since complete rules of law on the management of marine and coastal resource is on the ministerial decree level.

There are at least two important factors, which are yet accommodated within the acts that regulate the marine resources, and they are:

- a. Community tenure-ship and management (authority for land in Acts of PA/60 only regulates land area),
- b. Regulation of fishermen rights on economic, environment, social and culture (which includes the acknowledgement of traditional fishermen rights by the state), which is based on basic principles found in Acts No. 39/1999 about human rights.

Another form of government policy intervention is monitoring mechanism on reef fishery exploitation and trade. One of the mechanisms triggered by the demand from the importing countries (marine product certification), which has started to get the governments attention. Several experts believe that the road to establishing certification in developing countries with geographical and cultural condition as in Indonesia is still long (Erdmann and Pet, 1999; Pet-Soede and Pet, 1999; Cesar, 2000; Mous *et al*, 2002). Although the certification purpose is to protect the habitat and the marine products, it is also required to guarantee the quality of life of the local community, as well as profitable for exploitation and trade. In other words, it must be planed step by step on preparation and socialising to every stakeholder involved in exploitation and trade chain. In Indonesia, the problem mapping, including stakeholders mapping, is not clear yet.

For reef fishery commodities listed on CITES, a special monitoring mechanism exists, that is a quota regulation. The problem in Indonesia is that the quota regulation is not followed by

the implementation of its monitoring mechanism, in export as well as in exploitation level. Moreover, the supporting mechanism, which is the rehabilitation mechanism, is not clearly regulated in Indonesia.

In fact local communities acknowledge various monitoring mechanisms, which can help the government in optimising the fishery resources management in Indonesia. However, there is no regulation, nor acknowledgement from the government until now.

Based on Government Regulation No. 8/1999, The Directorate General of Nature Protection and conservation (PKA) is appointed as the management authority of plants and wild animals conservation, which includes marine and coastal resources. With the establishment of the Ministry of Marine Affairs and Fisheries, there is a confusion of authority, since the PKA is under the Ministry of Forestry.

Furthermore, the function of management authority under a technical ministry, such as the Ministry of Forestry or the Ministry of Marine Affairs and Fisheries, is not appropriate. In general, the vision of a technical ministry is aimed at exploitation of natural resources to give maximum financial profit. This is the opposite to the aim of natural resource conservation, which is to limit the exploitation of natural resources for the sake of sustainability.

Ideally, management authority should be under the governance of an institution with cross-sectoral authority, and in close coordination with local governments. According to the above government regulation, management authority should be parallel to scientific authority, which is given to LIPI (Indonesian Institute of Science). In case of quota, for example, LIPI calculates and recommends the quota, while the PKA will do the monitoring. It is not clear as to who is responsible and accountable for the rehabilitation.

Several chapters in Act No. 22/1999 on Local Autonomy that is related to coral reefs management are:

- a. Chapter 2(1): The Republic of Indonesia is divided into provinces, regencies (*kabupaten*) and towns, each with its own autonomy.
- b. Chapter 3: A provincial area consists of land area and sea area as far as 12 nautical miles measured from the beach line to the sea, and/or to the island waters.
- c. Chapter 10: local autonomy on sea area includes; 1) exploration, exploitation, conservation and marine resource management within the area, 2) administrative regulation, 3) spatial planning, 4) law enforcement towards the regulations issued by

local authority or which are delegated by the state; and 5) upholding the security and the state sovereignty.

- d. Chapter 10 (3): Local autonomy of regencies and cities in sea area is one-third of the sea area of the province.

The implementation of local autonomy is with high risks on the marine and coastal resources management, when related to the incomplete state regulation on marine and coastal resources management, as described in the Rules of Law Section. Government Regulation on local autonomy in sea area is trying to list the authority of the provinces or regencies, though there are parts that remain unclear (issuance of permit to manage small islands is still under the National Land Council or BPN). Government regulation is the legal base for local regulation by each province, regency, or town.

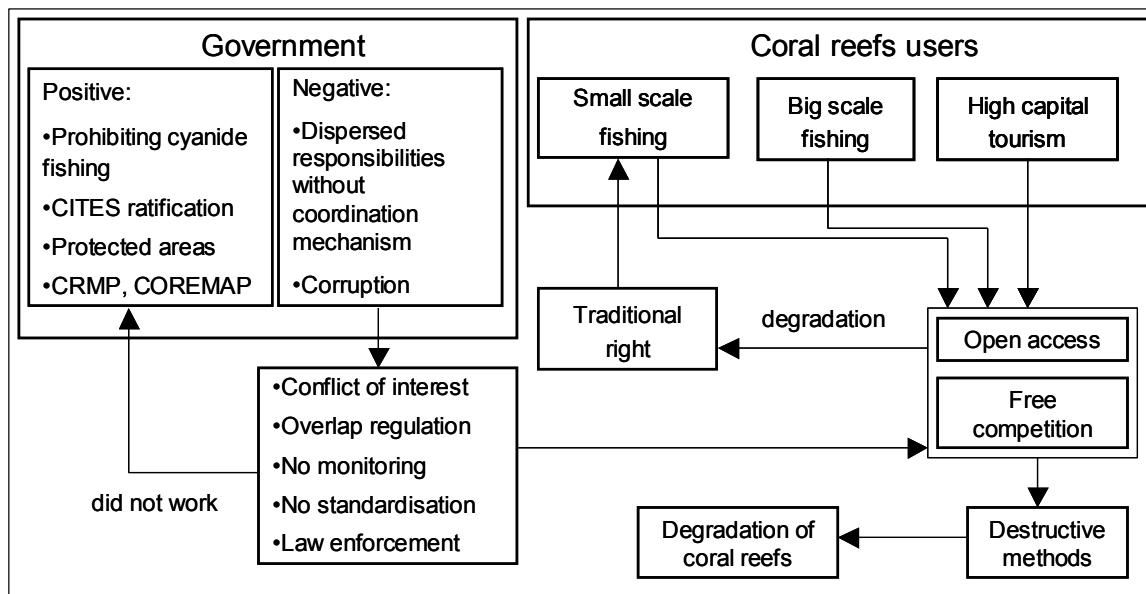
### **2.3. Problems of Indonesian Coral Reefs Management**

Big scale fishing communities in Indonesia seem to support the open-access nature of reef fisheries there, and show little interest in efforts to restrict this access. Again, this is likely to be related to their ultra-mobile fishing style; these big scale fishermen rarely share the perception that over-fishing is a problem, and may even view reef ownership as an unwanted infringement, which would restrict their current mobility.

The well-known *sasi* system of traditional marine tenure in the eastern Indonesia has generally ceased as the social structure of the fishing communities has been eroded by unemployment, emigration and short-term profit aims. On the other hand, new village-based reef ownership schemes have generated other problems in many parts of Indonesia. Fishermen from the neighbour villages who did not know the boundary of their reefs area would be attacked by other fishermen who claim that they were fishing in the wrong fishing ground. Sometimes, this situation created conflict among villagers, as can be seen in recent time in the North Coast of Java and East Coast of Sumatra.

Reef fishery resources in Indonesia are mostly to meet the export market. However, up to now, there is no reliable export volume data, not to say exploitation data for each species of food fish, ornamental fish or live corals. This is mainly caused by the incomplete policy on exploitation and trading of reef fisheries.

Figure 2. The diagram of problems of Indonesian coral reefs management



Several problems of government policies were identified as follows:

- a. There is no mechanism or export standard for live reef fish that regulates the quota and quality, except for two types of commodity, which are hump-head or napoleon wrasse and live corals. Capturing napoleon wrasse was once prohibited by a joint decree issued by the Minister of Agriculture and the Minister of Trade, based on the suggestion from the State Minister for the Environment, since the large size of napoleon requires a dose of cyanide, which is destructive. But then the Directorate General of Fisheries (then under the Ministry of Agriculture, now a part of the Ministry of Marine Affairs and Fisheries) issued a decree, which allows the capture of napoleon, though the size is limited. In fact, the size limitation was made based on marketable size. In all, there is not any mechanism, which requires an exporter to report the export volume to the Directorate General of Fisheries. Meanwhile, the export of corals is regulated through CITES ratification by the Directorate General of Protection and Natural Conservation, Ministry of Forestry (as the management authority) and LIPI (scientific authority), and the implementation is conducted by AKKII (Indonesian Corals, Shellfish, and Ornamental Fish Association).
- b. All live fish export business can be done easily without any monitoring mechanism, nor incentives for the exporter to report their activities. There are no requirements for the fish exporters to interact with the Ministry of Marine Affairs and Fisheries (MMAF) as a sector ministry. Exporters are only required to have Trading Permit (Surat Ijin Usaha Perdagangan) from the Department of Industry and Trade and an obligation to report to the customs through PEB (export declaration). Even this is only

done if the export is carried out through sea/airports where there is customs. Live reef fish export is often done in the middle of the sea (transport vessel pick up the commodity from small islands or from the floating cage, then directly sail to destination countries). The Ministry of Marine Affairs and Fisheries only issued a permit for fish capture. Meanwhile, field facts show a lot of exporters do not have a specific basis for capturing the fish, and therefore the fish can come from anywhere. There is no regulation that covered coordination mechanisms among sectoral ministries in natural resources commodity export. The customs only report the export volume based on export declaration to the Ministry of Treasury, Ministry of Industry and Trade, and filed in the BPS (Central Bureau of Statistics). Meanwhile, MMAF as a sectoral ministry who is supposed to be the main regulator can only ask BPS to send a copy. And this is often six month overdue. Therefore, MMAF does not have any monitoring tool.

- c. Report mechanism from regency - provincial - central level is not clear. Fishery Agency in the province is not obliged to report the fishery/marine products and their trading (including export) to Central (The Directorate General of Fisheries, MMAF), since the Agency is a part of local government, and not under the related department. There is a reluctance to report to related departments in Central, due to the former system where the Central extracts local income. Fishery agencies in regency level are also not obliged to report to the provincial level since the execution of local autonomy.
- d. Data collecting methods are not representative. Aside from the fish auction centres, data is only gathered randomly from fishermen and middlemen in accessible landing spots. The data comprises all kind of marine products, not focused on reef fish.
- e. With the implementation of the Act on Local Autonomy, Local Offices for Forestry are eradicated. There is no government agency with the authority to issue fishing permits. Meanwhile, in the state regulation No. 25/2000 about the implementation of Act No. 22/1999, it is stated that the management of the utilisation and trading of flora and fauna regulated by CITES are still under the authority of the central government.

Moreover, Indonesia is facing a major problem in law regulation enforcement. For example, there is a ministry decree, which regulates the capture of napoleon wrasse and live corals, and that is Minister of Forestry Decree No. 62/kpts-II/1998 on the business of trading of wild plants and animals. The decree stated that trading wild plants and animals between provinces needs a SIAS (permit for transporting wild plants and animals). SIAS is issued by the local/regional office or unit of KSDA (Natural Resources Conservation Office) on the



provincial level, or sub-section of KSDA on the regency level if necessary. The request for SIAS has to be accompanied with a capture permit, which is issued by local offices, and a recommendation from the local government. This permit mechanism cannot function properly to monitor the trade, because in reality SIAS is not conducted properly.

Another example: it has become a public secret that violators of fishing regulations do not always undergo the process of investigation and judicial court. It is suspected that a lot of law reinforcement officials involved have economic interest in exploitation and trade of marine and coastal resources.

Mechanism of the reef fisheries exploitation and trade monitoring is so loose, that data compiled from various sources differ greatly. For example, for the same region, e.g. South Sulawesi, Hasanuddin Fish Quarantine shows that the export volume of live reef fish in year 2000 is 115,200 tons, while the volume reported by LPPMHP (Laboratory of Development and Monitoring of Fisheries Product Quality) Makasar is 33,404 tons. If there were no mistakes in data collecting, it means more than 70% of export through quarantine was not reported to LPPMHP, as was obliged.

Marine resource condition and recent status of resource uses are not well recorded due to several problems:

- a. Incomplete Data Reference System. Harmonised System (HS) Code is classifying the system for export commodities. HS code is uniform worldwide, so it can be a useful tool in reef fisheries export monitoring. This system has been adopted by Indonesian Fisheries Statistic, for example: trout fry is coded as 030191100, live trout is coded as 030191900, while reef ornamental fish is coded as 030110910. However, since the categorising of types of commodity by Central Bureau of Statistics (BPS) is too simple, this system has become ineffective.
- b. Data manipulation. Export data does not show the real export volume, since it relies only on the reporting exporters. In the year 2000 there were only 8 exporters reported Napoleon wrasse export to the Directorate General of Fisheries (DGF), and 3 reports on grouper. Moreover, the reported figures may not be valid, since there are chances of data manipulations to minimise export tax.
- c. No export commodity standardising. Data of reef food fishery in DGF only comprises napoleon wrasse and grouper. The Central Bureau of Statistics (BPS) does not even employ reef fish categorisation. Instead, export categories of live food fish are eels,

carps, trout, and other. There is no wild trout (family *Salmonidae*) in Indonesia. This category was adopted from the coral trout (*Plectropomus leopardus*), another name for leopard cod, known as *kerapu sunu* or *kerapu tungsin* in Indonesia. The commodity categorized by BPS as trout and other comes from places where there is live reef fish trade, and mostly exported to Hongkong, which is the biggest importer of this commodity. But, assuming trout and other are reef fishes, then the export volume data is not even similar to the export volume data of napoleon and grouper from DGF.

#### **2.4. The Role of NGOs in Indonesian Coral Reefs Management**

Several non government organisations (NGOs) have been working to help Indonesian government to manage coral reefs. Some of them are international organisations such as International Marine Life Alliance (IMA), The Nature Conservancy (TNC), and World Wide Fund for Nature (WWF). These international NGOs have been collaborating with several local NGOs to carry out their programs, because local NGOs can easier monitor and evaluate the long-term programs. Their programs are ranging from increasing public awareness to facilitating institutional creation to manage coral reefs all over Indonesia.

WWF has been working in Indonesia since 1960s especially for forest management, and since the last decade also created programs for marine resource management including coral reefs. In the first stage, WWF has carried out monitoring of coral reefs, then tried to increase public awareness and proposed coral reefs management strategies to the Indonesian government (central and local government). Their successful programs in year 2001-2002 are:

- a. monitoring of coral reefs condition in Ujung Kulon National Park (West Java) and Bali Barat National Park (West Bali),
- b. first stage research on certification of marine products in Bali,
- c. campaigning of sustainable marine resource use in Riung Nature Reserve (Flores)
- d. launching new special programs on coral reefs conservation in March 2003, namely *Friends of The Reefs*, which was carried out around Bali Barat National Park (West Bali) and Bunaken National Park (North Sulawesi) and collaborated with local NGOs, park authorities and tourism operators.

The International Marine Life Alliance (IMA) established its first Indonesian program in North Sulawesi during 1997, a village level pilot project which showed that Philippine methods for training cyanide fishermen in cyanide free capture techniques were also viable in Indonesia. In 2000, IMA established its Indonesian national program to promote a new

paradigm of marine conservation that focuses on improving the quality of life of local fishermen, conserving marine and coastal habitats, and ensuring the sustainability of industry and trade activities that utilise marine resources (its initial focus is on the live reef fish trade). In the field, IMA is working with a network of local NGOs and selected local communities to develop direct community programs to combat destructive fishing and reform the trade in live reef fish and other reef species. IMA is also developing a marine education and awareness program and promoting Indonesian participation in the annual International Coastal Cleanup.

The Nature Conservancy is working with the Indonesian government and local communities to implement a marine conservation program and reduce destructive fishing in Komodo National Park. Mooring buoys have been installed to prevent dive boats from dragging their anchors near fragile coral reefs. At the Conservancy's request, the government also recently banned the use of hookah compressors, breathing devices used by cyanide fishermen. Conservancy staffs have also helped local fishermen and international scientists to make an inventory of the diverse marine life form and to develop ways to help local communities protect these resources. The Nature Conservancy's *Rescue the Reef* program is raising funds to help preserve the rich coral reef diversity and marine life in Indonesia's Komodo National Park because it is one of the world's most biologically diverse marine environments, which encompasses 701 square miles of marine waters, three major islands, and features coral reefs, mangroves, seagrass beds and semi-enclosed bays. Komodo National Park is also one of the last refuges for fish targeted by the live reef fish trade, an international business that supplies live fish to food and aquarium markets worldwide. Cyanide fishing is often used to capture these fish, which has resulted in significant damage to the coral reefs, other fish species and marine life in the area. Other threats to the Park include uncontrolled tourism growth, pollution and discharge from passing ships.

Terangi (*Terumbu karang Indonesia*) or The Indonesian Coral Reef Foundation is a non profit organisation. Terangi was established in 1999 and is the first non-government organisation in Indonesia to focus exclusively on coral reef conservation issues. Terangi as a coral reef conservation organisation tries to give people information as complete as possible. In order to provide appropriate information on particular topics, Terangi works closely with *Coastal Resource Management Project* (CRMP) in producing some fact sheets on coral reefs and coral bleaching, posters and comic books of coral reefs. On April 2001, Terangi is sub-contracted by UNESCO for co-ordinating the collection and analysis of secondary data on marine ecosystems of the Banda Islands. An ecotourism survey is carried out to describe the

present status of marine tourism industries in Indonesia and to gain information on marine tourism industry.

Terangi together with *The Marine Aquarium Council* (MAC) and Telapak foundation assessed the skills and techniques of fish collectors and the ability of middlemen to implement a basic management plan in collecting areas. This was carried out as a first activity within a wider cooperation framework with the objective of “Marine Ornamental Certification Capacity Building” in Indonesia. This step was continued to build the capacity of fishermen and middlemen in order to enable them to meet MAC standards. The initial capacity building process was planned to carry out in Seribu Islands (Jakarta), and continued gradually to involve fishermen in other areas. The socialisation of marine product certification reaches to various stakeholders at Sumatra (Padang, Batam, and Belitung), Java (Banyuwangi), Bali, and Sulawesi (Makassar).

Telapak foundation established its *Marine Monitoring Program* in 1997 which was focused in combating destructive fishing practices in Indonesian coral reefs. Field works are collaborated with local NGOs, such as Leuser Lestari foundation in Medan (for North Sumatra region), Palung foundation (for Jakarta region), Lakpesdam foundation in Makassar (for South Sulawesi region), Cinta Alam foundation in Kendari (for Southeast Sulawesi region and around Wakatobi National Park), Hivlak foundation in Tual (for Southeast Maluku region), Yali foundation in Jayapura (for Papua region), Bahtera Nusantara foundation in Denpasar (for Bali region), and Primasari Desa foundation (for Nusa Tenggara region and around Komodo National Park). It is planned in 2004 to continue this activity, and also for helping destructive fishing practicers in changing their methods and supporting fish traders to give price incentives for fishermen. This activity will be carried out in Les village (Bali), Mantigola village (around Wakatobi National Park), Sembilan Islands (South Sulawesi), Kukusan village (around Komodo National Park), and Raja Ampat Islands (West Papua).

Besides their own programs, NGOs also established collaborative programs such as Indonesia Network On Coastal Management (INCoM) and Indonesia Coral Reef Working Group (ICRWG). INCoM programs are carried out to give training on integrated coastal management to government officer and coastal communities. The objective of this activity is to support government officers and local communities with knowledge and skills to do marine resources monitoring and conservation. The ICRWG, which was established in 2001, consists of coral scientists, individuals who work with government agencies, NGOs and

businessmen. The Group members share the same concerns about coral reefs issues. In the year 2002, the ICRWG has concentrated on reviewing the 1998 coral utilisation guidelines document, which was then renamed "Patterns of Coral Utilisation in the Live Coral Trade". The ICRWG's last discussion was held in workshop on August 2002 with output revised Patterns and some Protocols. The various protocols require field-testing. The field testing in the form of training for collectors, suppliers and exporters is considered very important to make sure that they are capable of correctly recording the data. Also training is especially necessary to encourage them to work on the inventory forms for each of the collection areas, and to complete their logbooks, as part of the dependent monitoring data collection process. Lampung (Southern part of Sumatra) as one of the major collection areas for hard corals are chosen as a pilot site.

Prior description showed that coral reefs have supported significant role to Indonesian economic besides their biophysical functions. Unfortunately, Indonesian coral reefs have received the highest anthropogenic threats among other countries, ranging from indirect pollution from lowland agriculture to the direct impact from destructive fishing practice. Several authors have published their researches about destructive fishing practices in Indonesia, but these fishing practices still continued till today. Although Indonesian government have created a Ministry for Marine Affairs and Fisheries since 1999, there were no considerable policy changes in coral reefs management. Moreover, the latest policy on local autonomy has created confusions among other policies.

Since early 1990s, several international and national NGOs have helped Indonesia to manage coral reefs, but no significant decreasing of destructive fishing practices. Therefore it was important to understand the whole system of destructive fishing practices, such as the basic reason, effects to the coral reefs, and estimation of their economic value overtime, as the aims of this study. For that reasons, this study have measured coral condition and the effects of major actual coral reefs uses, and observed the characteristics of coral reefs uses in selected sites and the related government policies.

## CHAPTER 3. RESEARCH METHODOLOGY

### 3.1. Hypotheses and Objectives

The previous chapter showed that research on management of Indonesian coral reefs is urgently needed. The expected results of this research will provide ecological economic modelling of coral reefs management, which can be used for more proper planning of and decision-making on the development of coral reefs uses. It is also expected that the results of this research can contribute to the knowledge base necessary to manage the unique tropical coral reefs ecosystems of the world. Ruitenbeek *et al* (1999) emphasize that a key conceptual problem facing policy makers is a lack of quantitative models and procedures designed to facilitate a comprehensive economic and ecological analysis, including identification, measurement and prediction of the effects of economic activity on coastal marine ecosystems. In particular, the degradation of coral reefs has not been extensively analysed in a framework amenable to economic policy analysis.

The research questions under investigation in this project are:

- a. What are the environmental costs of cyanide fishing, live coral collecting, and tourism?
- b. Are the environmental costs of cyanide fishing, coral collecting and tourism greater than their benefits?
- c. Can the environmental costs of cyanide fishing, coral collecting and tourism be reduced by coral reef uses improvement?
- d. Can the coral reef uses improvement be implemented in Indonesian coral reefs management?

Several hypotheses can be derived from those questions:

- a. Cyanide fishing, live coral collecting, and tourism generate greater environmental costs than their benefits.
- b. The environmental costs of cyanide fishing, live coral collecting, and tourism can be reduced by coral reef uses improvement.
- c. Coral reef uses improvement can be implemented in Indonesian coral reefs management.

General objective of this research is to develop an economic model for and to conduct an economic analysis of coral reef management. More specific objectives are:

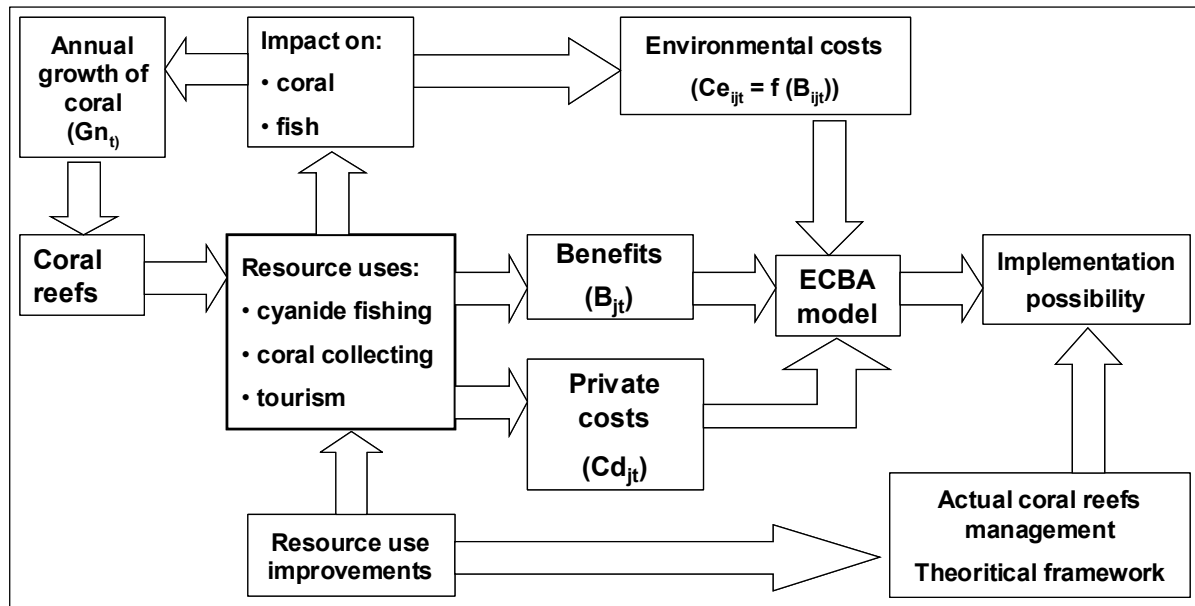
- a. To analyse the linkages between fish and live coral conditions with major actual activities in coral reefs ecosystems,
- b. To identify and quantify benefits and costs of major actual activities related to coral reefs ecosystems,
- c. To evaluate economic linkages between coral reefs ecosystems and major actual activities related to coral reefs ecosystems,
- d. To integrate those linkages in a model that can be used for coral reefs management overtime,
- e. To evaluate economic effects of improvement of coral reef uses,
- f. To analyse the possibility of implementation of improved coral reef uses.

### 3.2. Scope of The Study

Extended Cost Benefit Analysis (ECBA) based on the effect on production (EOP) was used in this research. Change in environmental quality lead to the change in productivity and production costs. The quality of environment is viewed as a factor of production. Therefore it assesses direct and indirect relationship between the loss of an environmental resource and associated changes in economic output (Hufschmidt *et al*, 1983; Barton, 1994; Spurgeon, 1999). The approach relies heavily on quantitative ecological analysis of the bio-geophysical impacts of coral reefs uses. The analysis of changes in the output of natural systems was based on the assumptions that the resource uses improvement, environmental impacts, and changes in output were so small that market prices would not be affected (Barton, 1994). In general, the approaches can be summed up as follows (see also Figure 3):

- a. Identifying inputs, outputs and environmental impacts from coral reef uses,
- b. Quantifying inputs, outputs and environmental impacts from coral reef uses,
- c. Valuing inputs, outputs and environmental impacts from coral reef uses overtime in terms of economic costs and benefits,
- d. Distinguishing environmental impacts from internalised costs and benefits in estimating of results,
- e. Improving coral reefs uses to reduce environmental impacts,
- f. Revaluing inputs, outputs and environmental impacts from coral reef uses overtime in terms of economic costs and benefits,
- g. Internalising implementation costs to estimate the application possibility of coral reefs uses improvement.

Figure 3. Research approach in economic analysis of coral reefs



The selection of coral reef uses on coral ecosystems based on major actual coral reef uses, which were cyanide fishing, live coral collecting, and tourism (diving and snorkelling). Certainly, each coral reef use has different inputs, outputs and environmental impacts. The first step in the ECBA is to identify inputs, outputs, and environmental impacts from coral reefs uses, as can be seen in Table 1.

Table 1. Inputs, outputs, and environmental impacts of coral reefs uses

No.	Activity	Input	Output	Impact
1.	Cyanide fishing	Boat and engine Gear Fisherman	Fish harvest	Live coral damage Fish stock damage
2.	Coral collecting	Boat and engine Gear Collector	Coral harvest	Live coral damage Fish stock damage
3.	Tourism	Tourism equipment Tourism facility Tourism operator	Tourist number	Live coral damage Fish stock damage

The inputs of cyanide fishing are fishing boat, fishing gear, and fisherman. The output of cyanide fishing is fish harvest (species harvested and harvest quantity). The environmental impacts are estimated by quantifying the linkages between fish harvest and coral reefs damage, and fish harvest and fish stock damage.

The inputs of live coral collecting are collecting boats, collecting gears, and collector, while the output of live coral collecting is coral harvest (species harvested and harvest quantity).



The environmental impacts are estimated by quantifying the linkages between coral harvest and coral reefs damage, and coral harvest and fish stock damage.

The inputs of reef tourism are tourism facility, tourism equipment, and tourism operator. The output of reef tourism is tourist number. Environmental impacts are estimated by quantifying the linkages between tourist number and coral reefs damage, and tourist number and fish stock damage.

The second step in the ECBA is to quantify the inputs, outputs and environmental impacts in the coral reef uses. All linkages from the first step are estimated by appropriate equations to calculate environmental impacts. The third step is to value inputs, outputs and environmental impacts from coral reef uses overtime in terms of economic damages, costs, and benefits. Thereafter, current coral reef uses are improved by more sustainable resource uses. The effects of resource use improvements are measured by revaluing all the inputs, outputs and environmental impacts in terms of money. These values are calculated based on market prices. Afterwards, implementation costs are internalised to estimate the application possibility of coral reefs uses improvement.

The last step is to compare costs and benefits from current coral reefs uses to the costs and benefits from coral reefs uses improvements. One criteria can be used to determine which coral reefs use alternative is chosen once net benefits are compared overtime. This criteria is net present value (NPV) as can be seen below:

$$NPV = \sum_{t=1}^n \frac{(B_t - Cd_t - Ce_t)}{(1+r)^t} \quad (1)$$

where NPV = net present value of resource use,  $B_t$  = direct benefits at time t,  $Cd_t$  = direct costs at time t,  $Ce_t$  = external or environmental costs at time t. When comparing alternatives the resource use with the highest NPV is the preferred one, where  $NPV_1 > NPV_2$ . This is provided that the scale and scope of the alternatives under consideration are the same. The NPV is the most usual criterion in resource use analysis. The net present value of a flow of net benefits overtime from a natural resource is also called *asset value*.

### 3.3. A Review of Cost Benefit Analysis

Cost Benefit Analysis is built on assumptions of neoclassical economics, which can be used to find the most efficient allocation among alternative uses of scarce resources, using market prices as a guide. There are however, many other dimensions related to whether to go ahead with development of natural systems or not.

The basic assumptions related to neoclassical economics, and upon which CBA is built, are summed up below (Barton 1994):

1. Social welfare is the sum of individual welfare. Aggregating individual welfare is not straightforward and certain strong assumptions must be made.
2. Individual welfare can be measured. A practical and common yardstick of measurement is the monetary unit. Market prices as a measure cannot be used directly in a CBA, but must first be corrected.
3. Individuals maximise their welfare by choosing that combination of goods, services and savings that yields the largest possible sum of total utility given their income constraints.

The total social welfare from consumption of good or service is equivalent to the sum of individual willingness to pay (WTP) to do so. This sum includes the expenditure needed to obtain the good or service, and the consumer surplus. The marginal utility or benefit obtained from consuming each successive unit of the good or service is assumed to be decreasing. The WTP for each successive unit is therefore also declining.

Two things are important to note concerning valuing goods and services. Using the market prices multiplied by the consumption provides a minimum estimate of the utility derived from a use of goods and services. The consumer surplus needs to be included as well to capture its full value to the individual. Consumer surplus is in this sense a value concept net of expenditure. One can see that free or un-priced goods and services entail a large consumer surplus. When they are destroyed the loss of utility is correspondingly large (Hufschmidt *et al* 1983).

Assuming markets that are free from distortions and a distribution of income in society that is deemed politically acceptable, individual demand curves can be aggregated to a market demand curve. This market demand curve will in turn reflect total willingness to pay for goods or services in question. These two assumptions are strong. In a CBA they can be partially corrected for through the use of coefficients for weighting of these efficiency and social effects.

Deriving benefits from the use of goods or services will also entail a social cost. For goods and services that are traded in undistorted markets, the market prices will represent the true cost to society of not employing goods or services in its best alternative use. The net benefits that can be derived from this next best alternative are called (social) opportunity cost. For the producer, marginal costs rise with output, because of technological factors and because the inputs that go into production become increasingly scarce. Market supply of the good is represented by the marginal cost curve, which climbs for increasing levels of production. Producer surplus is the difference between the revenue obtained for the goods and the total costs of production, or opportunity cost in a perfect market. The producer surplus is also commonly called economic rent.

Total social welfare is the sum of producer surplus and consumer surplus. Both producer surplus and consumer surplus are at a maximum when marginal social benefits are exactly equal to marginal social costs. Total net social benefits will accordingly be largest at this level of supply and demand.

Different policies will entail different combinations of supply and demand, depending on the multiple uses of the scarce resources. If they were traded in markets, the goods and services provided by one alternative set of compatible uses could be represented by a number of these partial equilibria. The social welfare (producer surplus plus consumer surplus), for each good or service could then be added up to provide an estimate of the total social welfare of compatible uses overtime.

For free or public goods and services demand curves are not made explicitly visible through market prices. Supply curves for the ecosystem goods and services have been considered fixed for conventional CBA purposes. Ecosystem productivity and the supply of natural amenities vary according to natural processes and human intervention, which was included very limited in conventional CBA. Estimating more complex supply curves for ecosystems goods and services has often not been attempted in conventional CBA, because supply has been seen to be so large that it is not a restraint on the economic system, and for lack of knowledge of natural processes.

### **3.3.1. Extended Cost Benefit Analysis**

In the case of environmental goods and services that are not traded in any market, the social cost is the opportunity cost of user benefits foregone. For example, corals removed freely for

building materials may also serve as a recreational attraction and have aesthetic value (as well as supporting fisheries production). These uses are foregone when coral is extracted, which entails an opportunity cost at least equal to the consumer surplus derived from recreational and aesthetic uses. In a social benefit analysis there is thus asymmetry between costs and benefits. A benefit foregone is a cost and a cost avoided is a benefit.

Valuation techniques are available for estimating the demand curves for non-marketed environmental goods and services and thereby determine total consumer WTP. Assuming that this is done, a social cost-benefit analysis will compare changes in supply and demand curves for all the different ecosystem uses, as well as changes to non-use values, entailed by a policy option. In theory then, a policy option might be represented by a number of partial markets. Dynamic equilibrium and interaction between ecological and economic systems have to be modelled quantitatively. Furthermore, a number of environmental benefits are considered tangible with today's valuation methods and will be included in the ECBA.

From the above discussion we understand that the economic analysis of society's benefits and costs is based on welfare effects being measured by willingness to pay, and costs by opportunity costs of resource uses foregone. The focus is on the normally un-priced environmental or other effects of a policy or resource uses on society as a whole. These are not captured by accounting only direct benefits and costs of resource use. An economic analysis should include external and environmental improvement benefits and damage costs, as well as the costs to society of environmental protection measures. This has been summed up in the simple formula:

$$NPV = B_d + B_e - C_d - C_e \quad (2)$$

where NPV = net present value of resource use alternative,  $B_d$  = direct benefits,  $B_e$  = external or environmental benefits,  $C_d$  = direct costs, and  $C_e$  = external or environmental costs (Pearce and Turner, 1990).

It is important to make clear that many direct uses of coastal resources and systems are not traded in a market and so fall outside  $B_d$  and  $C_d$  in the ordinary analysis. These un-priced direct uses should be considered part of  $B_e$  and  $C_e$  (in the case of a use benefit foregone). Those effects are also included by external costs and benefits, which are produced externally to the coastal management area being studied, and which work through the ecological linkages of coastal systems. Such benefits and costs can be internalised in the ECBA by expanding the geographical and the temporal scope of the analysis to include indirect and

delayed linkage effects. In this sense delayed environmental impacts that occur within the studied area, but after its economic lifetime can also be considered external in ECBA context. This approach to externalities in economic analysis has also been summed up in table below, where external effects in a coral reefs area are split into on-site, off-site, marketed and non-marketed.

Table 2. Externalities in economic analysis of coral reefs

	on-site	off-site
Marketed	fisheries, coral mining, aquarium trade, tourism	fish or other marine product in adjacent waters
Non-Marketed	spawning, nursery and feeding ground for fish and other marine biota	physical protection to coastline and other coastal ecosystems

The next step of the ECBA is to compare the costs and benefits overtime. The glue is used to bind and to compare benefits and costs over different period of time is the discount rate. Costs and benefits today are given more weight than those in the future. Economists argue about the choice of discount rate and the relative weighting of net benefits overtime. The choice of discount rate is normally justified by and based on the opportunity cost of capital, the cost of borrowing money, and the social rate of time preference.

Having presented some of the basic concepts of cost benefit analysis, we now move on to the practical, methodological and ethical questions relating to its use. Several further limitations and important issues of cost benefit analysis are:

#### 1. Financial and economic impact

Financial and economic impact rather than economic efficiency may be what matters most to the local society who are affected by a development of resource. Policy-makers, and especially local stakeholders, will be more concerned with impact measures such as sales, income, employment, tax revenues, and balance of payments, than with the economic efficiency measures used in ECBA. In most cases, connections can be established between the financial impact of various activities on the one hand and alternative resource allocations and economic efficiency on the other. However, they are not always likely to move in the same direction. Furthermore, non-use values do not have a financial impact, but inform economic value. Management may find that the trade-off considered between development and preservation actually becomes a political by determined choice of financial impact versus economic efficiency.

## 2. Aggregation and incrementalism

CBA has been criticised among others for its excessive level of aggregating information of importance to the decision-maker. One danger of this monetary reductionism is related to incrementalism in resource use evaluation (Dixon and Hodgson, 1988). By focusing on aggregated measures of resource use performance, important information may be lost as to how individual resource use fits into development of the larger natural system. While one resource use may not entail environmental costs that are of significance, a large number of individual developments of a particular ecosystem may lead to its collapse. One example is that of the incremental destruction of parts of a coral reef caused by fishing, tourism and mining use, each of which are evaluated separately (Ruitenbeek *et al*, 1999).

Another related criticism refers to the one dimensional welfare test of conventional CBA and its closed and undemocratic nature. The conventional cost-benefit analysis can be justified so long as there is a consensus in society about the evaluation rules inherent in cost-benefit analysis (Mishan, 1979). This is in reference to the neoclassical assumptions. A high level of aggregation can mean that the decision-making criteria of an ECBA are difficult to explain to the local resource user. The critique is also of a collective nature in that ECBA is laid on a neoclassical foundation of individual preferences while the preferences of society as a whole are ignored. A prime example of this is the apparent difference in the personal and social rate of time preference.

## 3. Poor data

One criticism to ECBA is that it must often be based on poor and incomplete national statistics. Some have doubted the gains from the use of such method in comparison with the costs of data collection and the training of competent personal. It is therefore recommended that the analyst starts with the most obvious, most easily valued environmental impacts (Dixon and Hodgson, 1988). The increasing number of ECBA studies being undertaken that include environmental effects is also an indication that the gains have been seen to outweigh the research costs, also in developing countries. Even with very limited data, using ECBA can reduce the amount of personal speculation involved in a decision that may have to be made before additional research was available. Once again it must be underlined that ECBA is only one of the tools in the kit of coastal zone manager.

#### 4. Monetisation and unmeasurable items

The basic problems of measurement exist where; (a) actual markets are far from perfect, (b) the consequences of environmental disruption are heterogeneous and cannot be measured quantitatively, and (c) the benefits obtainable from the environmental control are heterogeneous and can neither be compared quantitatively with one another nor with the outlays for control. Concerning the doubts as to measurement and comparison of different environmental effects this critique addresses the neoclassical assumptions of individual preferences being measurable by the concept of willingness to pay. This is a fundamental questioning of today's mainstream economics which is noted, but the developments in valuation technique and ecological sciences in recent years could overcome at least some of those questions. For example, ecological studies conducted by Bell and Galzin (1984), Schleyer and Tomalin (2000), and Zakai and Chadwick-Furman (2002) can be used to quantify environmental impacts.

CBA also faced the problems of data and measurement. Un-quantified impacts of important value to the society affected have been left out of the last cost-benefit analysis for obvious reasons. However, problems arise when these important societal values are not flagged for the decision-maker as subjective information that nevertheless should weigh heavily in the final development versus preservation alternative. The results of ECBA which are complemented by other valuation technique and ecological analysis, could reduce some of these problems.

The argument continues that not everything should, nor indeed can, be measured in terms of money. In fact, the comparison of costs and benefits can be undertaken by any common yardstick, or unit of measurement provided they represent calculable values. In most situations, the decision-maker implicitly weights the advantages and disadvantages of a policy. ECBA has the advantage of using common evaluation criteria between policies and limiting the amount of subjective evaluation required by the decision-maker (Barton, 1994).

Nonetheless, it is recognised that even careful application of these valuation methods will leave many aspects of the value of the ecosystems un-quantified. The limitations also stem from the natural science field and their limited ability to understand the functions performed by natural systems and how these are altered by human use. Many of these unknowns have been found at least partial clarification in recent years.

With some exceptions, these values currently cannot be quantified with any accuracy. Some cultural, historical, and aesthetic values can to some extent be measured in money terms by the direct method of contingent valuation. Much of importance will be left out. Some examples of intangibles are, the value of much of biodiversity, of obscure rare species. Other problems are encountered where people's willingness to pay to protect a site of cultural importance is in fact infinite. A contingent valuation approach may uncover values that are limited by the respondents levels of income, but in reality no amount will be sufficient to compensate them for the loss of the site (Dixon and Hodgson, 1988). Furthermore, policy decisions that entail the saving or loss of human life cannot be valued in any sense of the word so far used, as these ethical questions transcend economic analysis (nevertheless attempts have been made through for example the loss of earnings method).

Valuation methods have come a long way during the last twenty years in providing at least rough estimates of what was earlier considered to be un-quantifiable. An important task of ECBA will, however, be to make explicit all assumptions and limitations of the analysis to the decision-maker.

#### 5. Lacking alternatives for evaluation

Another criticism concerns the use of ECBA to rank multiple alternative policies. In certain regions of developing countries one might be fortunate to find even one well-defined resource use alternative. However, taking the country as a whole there usually exists a number of alternatives for which there is a shortage of capital. Problems of defining resource use alternatives are in most cases a short term result of institutional limitations in the country in question. Even if one is confronted with but one resource use alternative or policy of action, a comparison still needs to be made with the status quo. Economic analysis is always conducted based on *with and without use* framework (Dixon and Hodgson, 1988). Should the one alternative set of uses for a coastal area confer less net benefits to society than the present state of use, the policy should not be implemented (even if it is the only alternative, and even if it does have a net present value to society greater than zero).

#### 6. Market distortions and social distribution of costs and benefits

As we have seen, financial analysis employs domestic market prices that directly affect the individual decision-maker's expenses and income. However, from society's point of view



these markets are subject to a number of distortions, and the market prices of scarce resources will not represent their true social opportunity cost. Distortion may be due to monopolies, intervention in market processes through taxes and subsidies, as well as external economies and diseconomies stemming from environmental impacts that are not taken into account in private market transactions. In order to determine the most efficient allocation of resources from an economic point of view, shadow prices need to be calculated that correct for this distortion. These shadow prices also called efficiency prices. The use of efficiency prices presumes that the current distribution of income in society is perfect (Barton, 1994).

Aggregating individual demand curves to apply for all the people affected by a resource use is based on the assumption of perfect (or equitable) income distribution. It is assumed that individual marginal utility of income is identical for all individuals, and furthermore that income elasticity of demand is the same for all individuals (i.e. that each individual's demand will increase by the same amount for an equal incremental increase in income). However it is obvious that the distribution of income from a resource use or policy falls differently on rich and poor groups of society and that their marginal utilities of income are different.

If society views the present distribution of income as unjust, one technique employed in ECBA is to weight the changes in income for different groups to reflect society's collective values concerning their distribution of wealth. In other words, society may wish to value one dollar's worth of extra income to the poorest group at three times that of an equivalent increase for the highest income group. This correction of efficiency prices using weights produces estimates of so called social prices (Munasinghe and Lutz, 1992).

#### 7. Time horizon, future generations and the choice of discount rate

The social rate of time preference may for evaluation purposes be determined through the political process and will vary from country to country. It will depend on a number of factors, such as the opportunity cost of capital, the cost of money to government, today's saving and investments in relation to concerns for future generations, and ultimately also the decision-makers own time horizon in the electoral process.

As was indicated the choice of discount rate is a highly political question as it will determine what type of policies are adopted and will affect the welfare of the nation. A principle criticism concerns the valuation of costs and benefits that occur far into the

future, and may affect future generations. Discounting costs and benefits overtime can reduce them to insignificance in a matter of decades with the rates commonly used for example by development agencies. For example, 100 dollars will be worth just 0.85 dollars after 50 years at a 10 % discount rate and next to nothing after one hundred years. In this way, the higher the discount rate the more activities with short payback periods will be favoured. On the other hand, the lower the rate the more activities with long-term net benefit streams will be favoured.

Economists do not generally advocate manipulating the discount rate for different types of resource uses in a country. One reason is that the same criteria should be used for society as a whole when choosing between alternative allocations of its scarce resources. Some environmentalists argue that the discount rate should be lowered (or zero) to take into account future generations. The net effects of such a policy on the environment would however be unclear. Rather than manipulate the discount rate, that future generations can be better taken into account in ECBA by trying to incorporate all important environmental effects and values into the analysis (Barton, 1994).

The degree to which environmental benefits, including for future generations, can be incorporated into the analysis also determines the legitimacy of ECBA as a decision-making tool for policies with important environmental consequences. Without having covered the whole range of issues in discounting, it is safe to say that much of this legitimacy also rests on how the choice of discount rate is made, and whether this choice is made explicit to the decision-maker and the public at large (Dixon and Hodgson, 1988; Pearce and Turner, 1990).

#### 8. Irreversibility, uncertainty and risk

Certain resource uses and policy options will lead to irreversible damage to the environment through the destruction of certain species and their habitat. Irreversible decisions and risk pose problems in ECBA, but a number of approaches have been developed to deal with them. The concepts of option value capture the value people place on reducing risk and uncertainty, and avoiding irreversible decisions and can be the target for contingent valuation methods. Another way of incorporating irreversible options into analysis is to measure the costs of not proceeding with them. The opportunity cost is the benefit foregone from not going ahead (Pearce and Turner, 1990).

### 3.3.2. A Review of ECBA Studies

Several studies that are reviewed here use CBA for economic analysis of coral reefs. Although they do not implicitly state *extended*, by *Pearce and Turner's* definition (1990) can be classified as ECBA studies.

1. Dixon and Hodgson, 1988

This ECBA study evaluates management options with or without logging ban in Bacuit Bay drainage basin, Philippines. The results of this study show that present value gross revenue of fisheries activities without logging ban is US\$9,108 and with logging ban is US\$17,248. This calculation based on assumption of constant return to scale of natural systems and on regression analysis of sediment loading, coral cover and species, and fish biomass relationship. Present value of gross revenue of tourism activities without logging ban is US\$6,280 and with logging ban is US\$13,334. This calculation based on average hotel capacity, occupancy and daily rates, and also assumed 10% annual decline in tourism revenue due to degradation of seawater quality from sedimentation.

2. Sawyer, 1992

This CBA study evaluates management options with establishment of marine-park and regulated fishing or no management action in Taka Bone Rate atoll, Indonesia. The present value of gross revenue of fisheries activities without management varied from -Rp2 billion to Rp103 billion and with management varied from Rp47 billion to Rp777 billion. This calculation based on fishing activity surveys and sensitivity analysis where fish catch declines vary 0% to 15% and discount rates vary 5% to 15%.

3. Cesar, 1996

This study uses ECBA to compare the private and social net benefits of sustainably managed reef fishery in Indonesia, with those of a fishery subjected to detrimental fishing practices, coral mining or sedimentation. Net present value (NPV) of fisheries loss per square kilometre is US\$40,000 of reef because of poison fishing practice, US\$86,000 because of blast fishing, US\$94,000 because of coral mining, US\$81 because of sedimentation, and US\$109 because of over-fishing. NPV of tourism loss per square kilometre vary from US\$3000 to US\$436,000 because of poison fishing practice, US\$3,000 to US\$482,000 because of blast fishing or coral mining and US\$192,000 because of sedimentation. This calculation based on assumptions of

linear rate of reef degradation associated with each practice. NPV of coastal protection loss per square kilometre vary from US\$9,000 to US\$193,000 because of blast fishing practice and US\$12,000 to US\$260,000 because of coral mining. This calculation based on replacement costs, linear rate of reef destruction from each activity and linear rate of decline in reef's ability to protect coastal land.

#### 4. Pet-Soede, Cesar and Pet, 1999

This study is almost equal with the study conducted by Cesar (1996), but it was calculated the potential of tourism and coastal infrastructure to the low and high value separately, and split benefits calculation from blast fishing in large, medium and small scale operator. This tourism and coastal protection value also extracted from Cesar (1996). Based on this study, the net loss after 20 years of blast fishing is US\$306,800/km<sup>2</sup> of coral reef where there is a high potential value of tourism and coastal protection, and US\$ 33,900/km<sup>2</sup> of coral reef where there is a low potential value.

These studies tried to link reef quality to fishery productivity. Reef quality is viewed as a factor of production. The change of reefs quality leads to the change in reef productivity, and productivity change is measured in terms of output levels. Three types of weakness are often evident in these types of valuations. First, fishery values are usually assumed to be its gross revenue, thus ignoring the opportunity cost of capital and labour in fishing-effort. Second, the dynamics of the coral reef and surrounding natural systems are often simplified. Third, a less obvious weakness of many approaches is that they usually base harvest rates on some level of extraction effort, which are implicitly assumed to be value maximising. Some analysts (Sawyer, 1992; Cesar, 1996) are more careful about this aspect of extraction, and base their assessments on maximum sustainable yield (MSY) to introduce some form of sustainability constraint. Even in such cases, however, it is important to note that MSY does not necessarily coincide with an economic optimum. In cases where current harvest rates are used, it is likely that the methods over-estimate the value, while estimates based on MSY will probably underestimate economic value.

The change in productivity approach was used to valuing coral reefs by Cesar (1996) for Indonesia, and Hodgson and Dixon (1988) for Bacuit Bay, Philippines, but all take the gross revenue approach. From a utility perspective, these values ignore the consumer surplus generated by the recreation experience and as a result underestimate this value. From a

production perspective, gross tourism revenue ignores the labour and capital costs of supplying the services, as well as the costs associated with the environmental impacts of tourism.

### 3.4. Model Specification and Estimation

Previous studies showed that: (1) there was a highly significant positive linear relationship between live coral cover and total number of fish species and number of fish individuals (Bell and Galzin, 1984), (2) there was a linear corals growth (Queensland Fisheries Management Authority, 1999), and (3) there was a linear impact of diving activity to coral cover (Schleyer and Tomalin, 2000). Based on previous studies and major activities in selected coral reefs areas in Indonesia, a linear model was built to calculate environmental costs. These linear equations estimated linear impacts of coral reefs uses directly to live corals and indirectly to reef fishes.

Certain variables were used to estimate the impact of cyanide fishing, such as  $Cef$  = total environmental cost of cyanide fishing (\$),  $Cef_c$  = cyanide fishing impact to live coral (\$),  $Cef_f$  = cyanide fishing impact to the reef fish (\$),  $Bf$  = benefit of cyanide fishing (\$), and  $Ef$  = coral cover damage affected by cyanide fishing ( $\text{cm}^2$ ). For coral collecting, let say  $Bc$  = benefit of coral collecting (\$),  $Cec$  = total environmental cost of coral collecting (\$),  $Cec_c$  = coral collecting impact to the coral (\$),  $Cec_f$  = coral collecting impact to the reef fish (\$), and  $Ec$  = coral cover damage affected by coral collecting ( $\text{cm}^2$ ). For tourism, let say  $Bd$  = benefit of tourism (\$),  $Ced$  = total environmental cost of tourism (\$),  $Ced_c$  = tourism impact to the coral (\$),  $Ced_f$  = tourism impact to the reef fish (\$),  $Ed$  = coral cover damage affected by tourism ( $\text{cm}^2$ ). Therefore, linear equations can be specified as below:

- for cyanide fishing

$$Cef = Cef_c + Cef_f \quad (3)$$

$$Cef_c = a_1 + b_1 Bf \quad (4)$$

$$Cef_f = a_2 + b_2 Ef \quad (5)$$

$$Ef = a_3 + b_3 Bf \quad (6)$$

- for coral collecting

$$Cec = Cec_c + Cec_f \quad (7)$$

$$Cec_c = a_4 + b_4Bc \quad (8)$$

$$Cec_f = a_5 + b_5Ec \quad (9)$$

$$Ec = a_6 + b_6Bc \quad (10)$$

- for tourism

$$Ced = Ced_c + Ced_f \quad (11)$$

$$Ced_c = a_7 + b_7Bd \quad (12)$$

$$Ced_f = a_8 + b_8Ed \quad (13)$$

$$Ed = a_9 + b_9Bd \quad (14)$$

Indirect impacts to reef fish from each activity in equations 5, 9, and 13, were estimated through the linkage between reef fish value ( $Ce_{jf}$ ) and live coral cover ( $E_j$ ) as can be seen in the equation below:

$$Ce_{jf} = a_j + b_jE_j \quad (15)$$

Therefore, equations 3, 7, and 11, can be written as follows:

$$Cef = a_1 + b_1Bf + a_2 + a_3b_2 + b_2b_3Bf,$$

$$Cec = a_4 + b_4Bc + a_5 + a_6b_5 + b_5b_6Bc,$$

$$Ced = a_7 + b_7Bd + a_8 + a_9b_8 + b_8b_9Bd.$$

At time = t, then:

$$Cef_t = a_1 + a_2 + a_3b_2 + (b_1 + b_2b_3)Bf_t,$$

$$Cec_t = a_4 + a_5 + a_6b_5 + (b_4 + b_5b_6)Bc_t,$$

$$Ced_t = a_7 + a_8 + a_9b_8 + (b_7 + b_8b_9)Bd_t.$$

Overtime with t = 1 to n, then:

$$\Sigma Cef_t = \Sigma \{a_1 + a_2 + a_3b_2 + (b_1 + b_2b_3)Bf_t\},$$

$$\Sigma Cec_t = \Sigma \{a_4 + a_5 + a_6b_5 + (b_4 + b_5b_6)Bc_t\},$$

$$\Sigma Ced_t = \Sigma \{a_7 + a_8 + a_9b_8 + (b_7 + b_8b_9)Bd_t\}.$$

And with discount rate = i, then:

$$\Sigma \{Cef_t / (1 + i)^t\} = \Sigma \{[a_1 + a_2 + a_3b_2 + (b_1 + b_2b_3)Bf_t] / (1 + i)^t\}$$

$$\Sigma \{Cec_t / (1 + i)^t\} = \Sigma \{[a_4 + a_5 + a_6b_5 + (b_4 + b_5b_6)Bc_t] / (1 + i)^t\}$$

$$\Sigma \{Ced_t / (1 + i)^t\} = \Sigma \{[a_7 + a_8 + a_9b_8 + (b_7 + b_8b_9)Bd_t] / (1 + i)^t\}$$

To calculate total NPV, then:

$$\Sigma Bt_t = \Sigma \{ (Bf_t + Bc_t + Bd_t) / (1 + i)^t \} \quad (16)$$

$$\Sigma Ct_t = \Sigma \{ (Cdf_t + Cdc_t + Cdd_t + Cef_t + Cde_t + Ced_t) / (1 + i)^t \} \quad (17)$$

$$NPV_t = \Sigma Bt_t - \Sigma Ct_t \quad (18)$$

where  $Cdf$  = private costs of cyanide fishing (\$),  $Cdc$  = private costs of coral collecting (\$),  $Cdd$  = private costs of tourism (\$),  $Bt$  = total benefits of all activities (\$) and  $Ct$  = total costs of all activities (\$).

Naturally, benefits and costs of all activities are changed overtime due to the change of live coral cover. In other words, net annual growth of coral will affect benefits and costs of activities. Let say  $Gn_t$  = net coral growth at year t (%),  $Ng_t$  = natural coral growth at year t (%),  $Df_t$  = destructive impact of cyanide fishing to live coral cover at year t (%),  $Dc_t$  = destructive impact of coral collecting at year t (%),  $Dd_t$  = destructive impact of tourism at year t (%),  $Yf_j$  = yield of cyanide fishing (individual/species),  $Yc_j$  = yield of coral collecting (piece/species),  $Yd_j$  = tourist number (person),  $Pf_j$  = price of fish (\$/individual/species),  $Pc_j$  = price of coral (\$/piece/species), and  $Pd_j$  = tourist expense (\$/person), then:

$$Gn_t = Ng_t - Df_t - Dc_t - Dd_t \quad (19)$$

where

$$Df_t = a_{10} + b_{10} Yf_t \quad (20)$$

$$Dc_t = a_{11} + b_{11} Yc_t \quad (21)$$

$$Dd_t = a_{12} + b_{12} Yd_t \quad (22)$$

Because of  $Bf_t = Pf_j \cdot Yf_j$ ,  $Bc_t = Pc_j \cdot Yc_j$ , and  $Bd_t = Pd_j \cdot Yd_j$ , then:

$$Bf_{12} = Bf_{11} (1 + Gn_{11}), Bf_{13} = Bf_{12} (1 + Gn_{12}), \dots, Bf_{1n} = Bf_{1(n-1)} (1 + Gn_{1(n-1)}),$$

$$\Sigma Bf_t = \Sigma \{ Bf_t (1 + Gn)^{t-1} \},$$

$$\Sigma Bc_t = \Sigma \{ Bc_t (1 + Gn)^{t-1} \},$$

$$\Sigma Bd_t = \Sigma \{ Bd_t (1 + Gn)^{t-1} \}.$$

If the change of costs are assumed equal to the change of benefits, then:

$$\Sigma Cdf_t = \Sigma \{ Cdf_t (1 + Gn)^{t-1} \},$$

$$\Sigma Cdc_t = \Sigma \{ Cdc_t (1 + Gn)^{t-1} \},$$

$$\Sigma Cdd_t = \Sigma \{ Cdd_t (1 + Gn)^{t-1} \},$$

$$\Sigma Cef_t = \Sigma \{ Cef_t (1 + Gn)^{t-1} \},$$

$$\Sigma Cec_t = \Sigma \{Cec_t (1 + Gn)^{t-1}\},$$

$$\Sigma Ced_t = \Sigma \{Ced_t (1 + Gn)^{t-1}\},$$

or

$$\Sigma Bt_t = \Sigma \{(Bf_t + Bc_t + Bd_t) (1 + Gn)^{t-1}/(1 + i)^t\}, \quad (23)$$

$$\Sigma Ct_t = \Sigma \{(Cdf_t + Cdc_t + Cdd_t + Cef_t + Cde_t + Ced_t) (1 + Gn)^{t-1}/(1 + i)^t\} \quad (24)$$

The model can be expanded to arrange the intensities of all activities to keep constant coral conditions overtime. Percentage of live coral overtime will be similar if net annual growth of coral equals to zero ( $Gn_t = 0$ ), therefore total destructive impact of all activities ( $Df_t + Dc_t + Dd_t$ ) should be kept equal to natural growth of coral ( $Ng_t$ ). The effects of coral reef uses improvement can also be estimated by the change of parameter values ( $a_1$  to  $a_{13}$  and  $b_1$  to  $b_{13}$ ) in the equations of this model.

Parameter estimations of the model are done by using Ordinary Least Square (OLS) to all linear equations. Parameter values and the result of their *t-test* can be easily calculated by using the statistical package of any professional calculation tool. The OLS model determines the straight line that minimises the sum of the square of errors for a set of observations (Vose, 2000). It can be shown that this occurs when:

$$b = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^n (X_i - \bar{X})^2} \quad (25)$$

$$a = \bar{Y} - b\bar{X} \quad (26)$$

where  $\bar{X}, \bar{Y}$  are the mean of the observed  $X$  and  $Y$  data and  $n$  is the number of data pairs ( $X_i, Y_i$ ). For least squares regression, the fraction of the total variation in the dependent variable that is explained by the independent variable is known as the *coefficient of determination*  $R^2$ , which is calculated as:

$$R^2 = \frac{\sum_{i=1}^n (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^n (Y_i - \bar{Y}_i)^2} \quad (27)$$

where  $\hat{Y}_i$  are the predicted  $Y$ -values at each  $X_i$ :

$$\hat{Y}_i = a + bX_i.$$



Correlation coefficient  $r$  (the Pearson's correlation coefficient) provides a quantitative measures of the linear relationship between  $X$  and  $Y$ . It can be calculated as:

$$r = \frac{(\sum_{i=1}^n (X_i - \bar{X}))(\sum_{i=1}^n (Y_i - \bar{Y}))}{\sqrt{(\sum_{i=1}^n (X_i - \bar{X})^2)(\sum_{i=1}^n (Y_i - \bar{Y})^2)}} \quad (28)$$

where it ranges from  $-1$  to  $+1$ : a value of  $r = -1$  or  $+1$  indicates a perfect linear fit, and  $r = 0$  indicates no linear relationship exists at all. As  $\sum_{i=1}^n (Y_i - \hat{Y}_i)^2$ , the sum of squared errors between the observed and predicted  $Y$ -values, tends to zero, and therefore  $r$  tends to  $-1$  to  $+1$ , its sign depending on whether  $b$  is negative or positive respectively (Vose, 2000).

The predictions of environmental costs also included an analysis of variances, which were calculated by the equation below (Koutsoyiannis, 1978; Vose, 2000):

$$Var(\hat{Y}_F) = \hat{\sigma}_\mu^2 \left\{ 1 + 1/n + \frac{(X_F - \bar{X})^2}{\sum_{i=1}^n (X_i - \bar{X})^2} \right\} \quad (29)$$

where  $Var(\hat{Y}_F)$  = variance of predicted variables (i.e.  $Cef$ ,  $Cec$ ,  $Ced$ ,  $Df$ ,  $Dc$ , and  $Dd$ ),  $\hat{\sigma}_\mu^2$  = estimate of the variance of  $\mu$ ,  $X_F$  = value of predicted variables,  $n$  = size of the sample,  $\bar{X}$  = mean value of sample. Estimate of population variance ( $\hat{\sigma}_\mu^2$ ) can be written as:

$$\hat{\sigma}_\mu^2 = \frac{\sum_{i=1}^n (Y_i - \hat{Y}_i)^2}{n-2} \quad (30)$$

where the uncertainty distribution for  $\sigma$  is independent of the uncertainty distribution for  $(a+bX)$  since the model assumes that the random variations about the regression line are constant, i.e. that they are independent of the values of  $X$  and  $Y$  (Vose, 2000).

The rules to calculate total variance are:

- The variance of a variable  $X$  multiplied by a constant  $k$  is equal to the square of the constant times the variance of the variable (Koutsoyiannis, 1977; Vose, 2000).

$$\text{var}(kX) = k^2 \text{var}(X) \quad (31)$$

- The variance of the sum of two dependent variables is equal to the sum of the individual variances plus twice their covariance (Koutsoyiannis, 1977; Vose, 2000).

$$\text{var}(X+Y) = \text{var}(X) + \text{var}(Y) + 2 \text{cov}(XY) \quad (32)$$

- The variance of the sum of two independent variables is equal to the sum of the individual variances (Koutsoyiannis, 1977; Vose, 2000).

$$\text{var}(X+Y) = \text{var}(X) + \text{var}(Y) \quad (33)$$

- The variance of the sum of  $n$  independent variables is equal to the sum of the individual variances (Vose, 2000).

$$\text{var}\left(\sum_{i=1}^n X_i\right) = \sum_{i=1}^n \text{var}(X_i) \quad (34)$$

- If  $X$  is a random variable and  $a$  and  $b$  are constants (Koutsoyiannis, 1977), then

$$\text{var}(aX+b) = a^2 \text{var}(X) \quad (35)$$

- Relative variances add on multiplication or division (Vose, 2000) is:

$$\frac{\text{var}(XY)}{(XY)^2} = \frac{\text{var}(X)}{X^2} + \frac{\text{var}(Y)}{Y^2}, \text{ therefore variance of a variable } X \text{ multiplied by variable } Y$$

can be calculated as:

$$\text{var}(XY) = (XY)^2 \left\{ \frac{\text{var}(X)}{X^2} + \frac{\text{var}(Y)}{Y^2} \right\} \quad (36)$$

### 3.5. Survey and Measurement

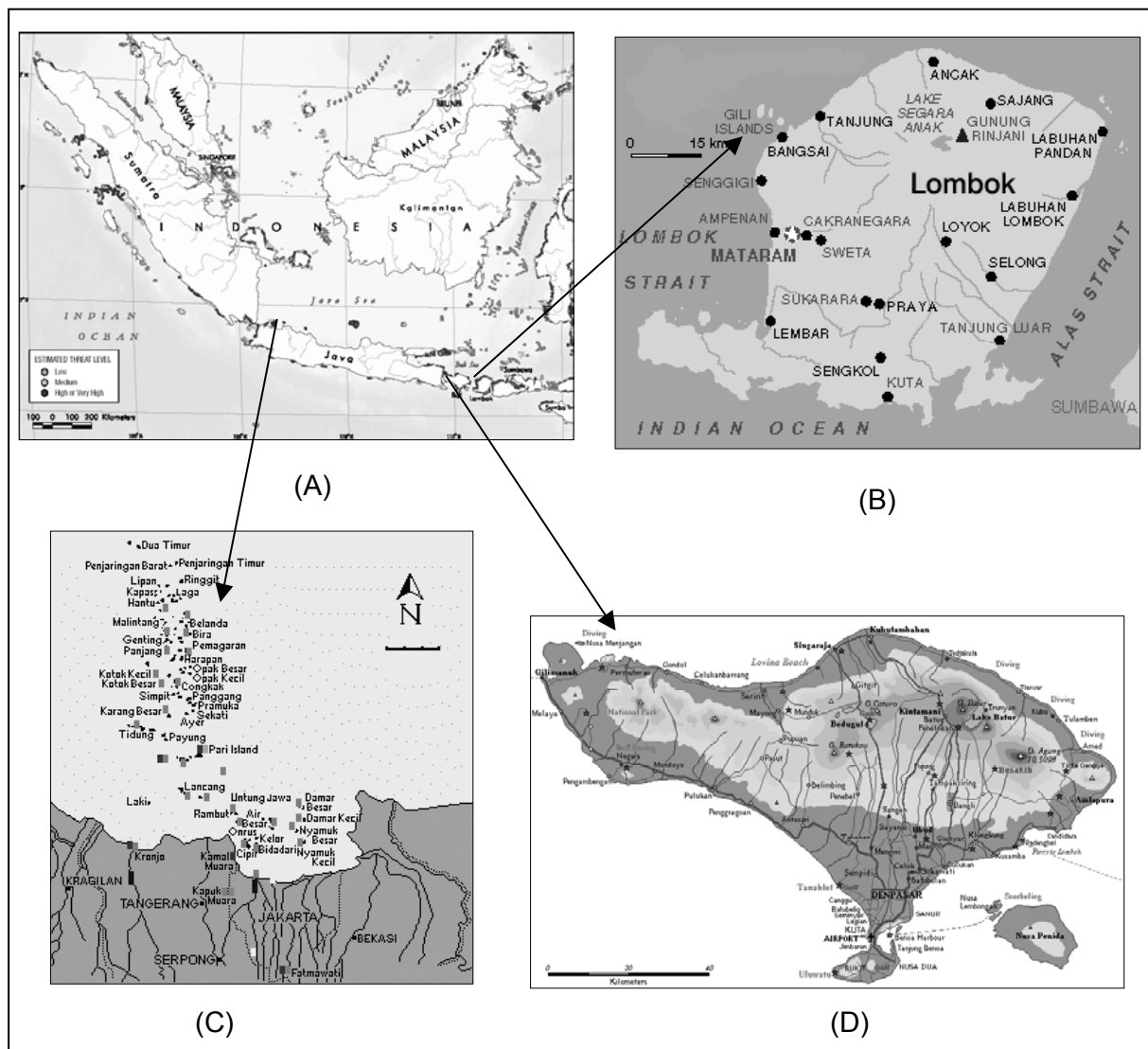
Field surveys were done on Seribu Islands (Jakarta), Menjangan Island (Bali), and Gili Islands (Lombok). The main reason of selecting these three locations was to obtain a representation of different levels of major actual coral reefs uses in Indonesia. Coral reefs in Seribu Islands received high level of cyanide fishing (Erdmann, 1999) and live coral collecting activities (Bentley, 1997), Menjangan Island has moderate level of those activities, while Gili Islands received the smallest pressure from cyanide and live coral collecting (see Figure 4). Jakarta and Bali were also the main outlets for coral fishes and live corals exports (Bentley, 1997; ICSOFA, 2001; and CSO, 2001).

The measurement campaigns were conducted over a one-year period, from March 2001 until March 2002, as described below:

- First field measurement in Seribu islands (Jakarta) was done on 12<sup>th</sup> to 16<sup>th</sup> March at Pandan Island, Opak Island, Bira Island, Puti Island, Melinjo Island, Genteng Island, Kotok Island, Layar Island, Panggang Island, and Sekati Island. Measurement in Menjangan Island (Bali) was done on 9<sup>th</sup> to 20<sup>th</sup> April at Garden Eel, Wreck, and Posdua. Measurement in Gili Islands (Lombok) on 22<sup>nd</sup> April to 3<sup>rd</sup> May at Gili Meno Island, Gili Air Island, and Gili Trawangan Island.

- b. Second field measurement was done on 6<sup>th</sup> to 14<sup>th</sup> June in Seribu Islands, on 18<sup>th</sup> to 23<sup>rd</sup> June in Menjangan Island, and on 25<sup>th</sup> to 29<sup>th</sup> June in Gili Islands.
- c. Third field measurement was done on 17<sup>th</sup> to 21<sup>st</sup> September in Seribu Islands, on 25<sup>th</sup> to 29<sup>th</sup> September in Menjangan Island and on 1<sup>st</sup> to 5<sup>th</sup> October in Gili Islands.
- d. Fourth field measurement was done on 19<sup>th</sup> to 23<sup>rd</sup> February 2002 in Seribu Islands, on 7<sup>th</sup> to 11<sup>th</sup> March 2002 in Menjangan Island, and on 12<sup>th</sup> to 16<sup>th</sup> March 2002 in Gili Islands.

Figure 4. Map of western part of Indonesian (A), Gili Islands, Lombok (B), Seribu Islands, Jakarta (C), and Menjangan Island, Bali (D)



Source: Burke *et al*, 2002 (see also Appendix 48-50).

### 3.5.1. Socio-economic Data

Socio-economic data were gathered from cyanide fishermen, coral collectors, and tourists. All cyanide fishermen in the study area (76 owners and 149 labours) were interviewed to gain

the data of fishing catch, fish price, and fishing cost. The same procedure was also carried out to gain the data of coral collecting, which interviewed 90 coral collectors (30 owners and 60 labours). As much as 100 tourists were interviewed to gain the data, which were used to estimate benefit of tourism. About 19 tourism operators, which provided service for diving and snorkelling, were interviewed to gain data of tourism cost.

Table 3. The number of respondent in each location

No.	Location	Fisherman		Coral collector		Tourist sample	Tourism operator
		Owner	Labour	Owner	Labour		
1.	Seribu Islands	39	87	18	42	37	6
2.	Menjangan Island	26	44	7	13	41	7
3.	Gili Islands	11	18	5	5	22	6
Total		76	149	30	60	100	19

The data of cyanide fishing and coral collecting include fishing catch, coral harvest, fish price, coral price, fishing cost, and coral collecting cost. Fishing catch, coral harvest, fish price, and coral price were collected from daily fishing catch and coral harvest record for each species, which were used to calculate benefits of cyanide fishing and coral collecting, and to estimate the total resource utilisation of both activities. Fish price and coral price were also collected from two exporters in Jakarta and one exporter in Bali. Fishing cost and coral collecting cost were collected to calculate private costs of cyanide fishing and coral collecting. Fishing costs and coral collecting cost include investment and maintenance costs for boat and engine, and operational costs for fishing gear, coral collecting gear, and logistic (fuel, food and beverages).

Table 4. The method and material for gathering socio-economic data

No.	Data	Unit	Methods	Materials	Source
1.	Fishing catch	Individual/boat/day	Interview	Questionnaire	Fishermen
2.	Fish price	US\$/individual	Interview	Questionnaire	Fishermen
3.	Fishing cost	US\$/boat/day	Interview	Questionnaire	Fishermen
4.	Coral harvest	Pieces/boat/day	Interview	Questionnaire	Coral collector
5.	Coral price	US\$/individual	Interview	Questionnaire	Coral collector
6.	Coral collecting cost	US\$/boat/day	Interview	Questionnaire	Coral collector
7.	Tourist expenditure	US\$/tourist	Interview	Questionnaire	Tourist
8.	Tourist number	Tourist/year	Interview	Questionnaire	Dive operator
8.	Tourism facilities	Unit/location	Interview	Questionnaire	Dive operator
9.	Tourism cost	US\$/year	Interview	Questionnaire	Dive operator

Data of tourism include tourist expenditure, tourism facilities, tourist number and tourism cost. Data of tourist expenditure include transportation and accommodation expenses (the costs for rent boat, diving and snorkelling equipment were included). Data of tourism

facilities and tourism cost were included the facilities for tourist (transportation and accommodation facilities, diving and snorkelling equipment), and the costs of all facilities (investment, maintenance and operational costs) in each location. Data of tourist number in year 2001 were collected from local authorities, and data of diving and snorkelling were collected from dive operators in each location. This study used US\$ as currency to valuing benefits and costs because US\$ was used as international payments in Indonesia, and during the study period the rate was around Rp10,000.00/US\$.

### 3.5.2 Biological and Physical Data

The measurements of physical parameters were important to ensure that the physical environment of coral reefs was in normal condition. In other words, there were no extreme physical factors, which affected coral reefs. The physical parameters in this study were temperature (°C), salinity (‰), acidity (pH), and Visibility (%). All surveys of living resources of coral reefs should include environmental parameters, which characterise the conditions at the site when the data were collected. The parameters to be included with the survey methods are important to the 'health' of the reef. The environmental parameters that should be measured are: temperature, salinity, and visibility (English *et al*, 1994).

The measurements of biological parameters were important to estimate fish and coral abundance and were used to calculate the economic value of coral and coral fish. The biological parameters in this study were coral abundance (cm<sup>2</sup>/genus) and fish abundance (individual/species). Both parameters were measured by direct observations and measurements (visual census) using quadrant transect method. The advantages of quadrant transect method are; 1) sampling is non destructive, 2) detailed and careful observation, photography, and mapping of such a fixed area provides a good record of what takes place in the area, and 3) can be a good source of information on population estimates. While the disadvantages are; 1) the method is slow, 2) the equipment is somewhat cumbersome, especially in strong current, 3) the photography requires a relatively flat area, and 4) the method only examines a small area (English *et al*, 1994).

Underwater observations were also done to measure the impact of activities directly to live coral. The impact of cyanide fishing was calculated based on measurement of destructed coral due to cyanide solutions and fishing boat anchors. Impact of coral collecting was calculated based on measurement of broken coral due to coral collectors and boat anchors. The same procedure was also done to measure the impact of tourism. Broken coral due to

tourists and boat anchors were measured to calculate its impact. A good approach was needed to measure the impact of cyanide fishing and coral collecting because these activities were illegal according to the Fisheries Act No. 9/1985.

Table 5. The method and material for gathering biological and physical data

No.	Variables	Unit of Measurements	Methods	Materials	Sites
1.	Coral genera	Genus number	Quadrant transect	Diving equipment	Coral reefs
2.	Live coral cover	cm <sup>2</sup> /genus	Quadrant transect	Diving equipment	Coral reefs
3.	Fish species	Species number	Quadrant transect	Diving equipment	Coral reefs
4.	Fish number	Individual/species	Quadrant transect	Diving equipment	Coral reefs
5.	Surface current	m/second	Manual	Current meter	Coral water
6.	Visibility	%	Manual	Secchi disk	Coral water
7.	Surface temperature	°C	Manual	Thermometer	Coral water
8.	Surface salinity	‰	Manual	Refractometer	Coral water
9.	Surface pH	-	Manual	Digital pH meter	Coral water
10.	Fishing impact	cm <sup>2</sup> /activity	Observation	Diving equipment	Fishing ground
11.	Collecting impact	cm <sup>2</sup> /activity	Observation	Diving equipment	Collecting ground
12.	Tourism impact	cm <sup>2</sup> /activity	Observation	Diving equipment	Tourism area

Station numbers were different in each sampling area due to the different coral structure and area covered by coral. Sampling procedure was based on coral visual census survey manual (English *et al*, 1994). A general survey of the reef was conducted to select suitable sites on the reef slope and reef flat, which was representative for that reef. Snorkelling was a technique to select sampling sites.

Table 6. Number of sampling stations in each location

No.	Location	Sampling site	Number of station
1.	Seribu Islands	Pandan Island	3
		Opak Island	1
		Bira Island	1
		Putri Island	1
		Melinjo Island	1
		Genteng Island	1
		Kotok Island	2
		Panggung Island	2
		Layar Island	2
		Sekati Island	2
2.	Menjangan Island	Garden eels	2
		Wreck	2
		Posdua	2
3.	Gili Islands	Gili Air Island	2
		Gili Trawangan Island	2
		Gili Meno Island	2
Total			28

The shallow transect was located on the reef slope when there was typical reef flat, crest, and slope, approximately 3 meters below the crest. The deeper transects were located approximately 9-10 meters below the crest. The transect depth was approximated to the depth below mean low water if the site was on a reef without a well-defined crest. The transect was laid at 6-8 meters depth if there was little or no coral at 10 meters. The number of sampling sites and sampling stations in each location can be seen in Table 6.

Secondary data were collected in sampling locations at the same time with field measurements, such as general condition of area being studied (general climate and human population), and monthly number of tourist in year 2001. The others were collected at the time when there were no field measurement activities, which were collected in Jakarta and Denpasar (Bali). The data of fish species based on scientific name and common (trade) name were important to identify fishing catch species because fishermen usually use local name. The data of coral and other invertebrate species or genus based on scientific name and common (trade) name were also important to identify coral and other invertebrate species that collected by coral collectors due to different local names.

### **3.6. General Description of The Study Area**

#### **3.6.1. Seribu Islands**

Seribu Islands are located in North of Jakarta (the capital city of Indonesia) or in Java Sea ( $5^{\circ}24'$  -  $5^{\circ}45'$  South and  $106^{\circ}25'$  -  $106^{\circ}40'$  East), which consist of 110 islands. Inhabitants only lived in 11 islands and the other islands are used for recreation sites and nature reserves. Total area about 1,080.00 km<sup>2</sup>, but land area only 7.74 km<sup>2</sup> (0.72%). These islands are remote areas where the distance of the nature reserve zone from Jakarta is approximately 37 nautical miles and the nearest island (Bidadari Island) is only 9 nautical miles away (Seribu Islands Marine Nature Reserve Authority, 2002).

The climate in this area is affected by monsoon wind, which can be separated into west monsoon from December until March and east monsoon from June to September. Wind speed on west monsoon from 7 to 20 knots per hour (especially on December to February), and on east monsoon is lower than 7 knots per hour. Wet season is from November to April with monthly rainy day around 10 to 20 days. The high rainfall on January could reach 1,700 mm. Dry season is from May to October with only 4 to 10 rainy days per month. Average daily air temperature is about 26.5 to 28.5 °C with 75% to 99% humidity and 1,009 to 1,011 mbar air pressure.

Table 7. Physical factors condition in Seribu Islands (February 2002)

No.	Island	Salinity (‰)	Acidity (pH)	Temperature (°C)	Visibility (%)
1.	Pandan Island	30.50	8.10	29.70	100.00
2.	Opak Island	30.40	8.11	29.30	100.00
3.	Bira Island	31.20	8.08	29.70	100.00
4.	Putri Island	31.10	8.07	29.60	100.00
5.	Melinjo Island	31.40	8.08	29.60	100.00
6.	Genteng Island	30.90	8.11	30.20	100.00
7.	Kotok Island	32.00	7.50	29.00	87.50
8.	Panggang Island	32.00	7.50	30.00	83.33
9.	Layar Island	31.80	7.50	30.00	88.89
10.	Sekati Island	31.50	7.50	29.00	85.71

Tidal type in this area can be classified as a single daily tidal with highest surface level is 0.6 m and the lowest is 0.5 m. The current speed of surface water is 0.5 m/second on west monsoon. The highest wave (1.75 m) is on west monsoon and the lowest (1.0 m) is on east monsoon. Temperature of surface water is between 28.5 to 30.0° C on west monsoon and is between 28.5 to 31.0° C on east monsoon, while surface salinity is between 30 to 34‰. The measurement on March 2001 in 10 islands shows that pH is about 7.50 to 8.11, salinity is between 30.40 to 31.40‰, temperature is between 29.00 to 30.20°C and visibility is around 83.33% to 100% (see table above).

### 3.6.2. Menjangan Island

Menjangan Island is a small island (about 1.75 km<sup>2</sup>) near the western edge of Bali Island. This island is a part of 190.23 km<sup>2</sup> West Bali Nature Reserve area (114°26'-114°35' East and 8°5'-8°13' South), which conserves animal and vegetation of low land rain forest. There is no village in Menjangan Island except 2 small buildings for watching officers and 2 buildings for Hinduism prayers.

Table 8. Physical factors condition in Menjangan Island (March 2002)

No.	Station	Salinity (‰)	Acidity (pH)	Temperature (°C)	Visibility (%)
1.	Gardeneel	33.00	8.57	26.33	100.00
2.	Wreck	31.00	7.83	27.33	100.00
3.	Posdua	32.33	8.03	27.33	100.00

Wet season is from April to September and dry season is from November to March. Average rainfall is around 1,365 mm/year and average humidity is about 85.29%. Highest rainfall is on February, which is affected by the hilly area in western part of Bali Island (between 310 to



803 meters high). Temperature of surface water is around 26 to 27° C and current speed is between 0.1 to 0.4 m/second. Water salinity is around 31 to 33‰, pH is about 7 to 8 and visibility can reach 100% in 25 m depth (Table 8).

### 3.6.3. Gili Islands

Gili Islands are located between 8°20' – 8°23' South and 116°00' – 116°08' East or between Java Sea and Lombok Strait and Sire Bay. These islands have been managed as marine natural tourism area by Marine Recreation Park Authority of Gili Indah and administratively under the government of Gili Indah village, district of Pemenang, West Lombok Regency. Total area including marine water is around 29.54 km<sup>2</sup>, which consists of three islands such as, Gili Air Island (around 1.75 km<sup>2</sup>), Gili Meno Island (around 1.50 km<sup>2</sup>) and Gili Trawangan Island (around 3.40 km<sup>2</sup>).

Most of the lands of Gili Islands are flat and only small parts of Gili Trawangan Island reach about 20 metres high from the sea level. The beaches of these islands are surrounded by white sand and shallow marine water with depth ranges from 1 to 3 metres from shoreline until around 20 metres to the sea. The deeper marine water with depth more than 20 metres can be found about 40 metres from the shoreline. The tidal range recorded from this area is around 3 metres (Marine Recreation Park Authority of Gili Indah, 2001).

According to the data from Bangsal Port in Pemenang (small port to Gili Islands), during west monsoon (December to February) wind speed can reach the peak of 3.5 knots per hour on January or February and will decrease to 1.5 knots per hour during east monsoon from July to September. During the wet season the rainfall can reach 459 mm on January and will decrease below 10 mm/month during dry season (July to August).

Daily temperature is between 20 to 32° C, which the highest temperature is recorded on June and the lowest on November. Relative humidity is about 74% to 85%, and humidity on November to May is relatively higher. Temperature of surface water is between 26 to 28° C, and current speed is around 10 to 30 cm/second. Water salinity is between 30 to 31‰ and pH is around 7 to 8. Water visibility is about 76% to 100% (Table 9).

Table 9. Physical factors condition in Gili Islands (March 2002)

No.	Station	Salinity (‰)	Acidity (pH)	Temperature (°C)	Visibility (%)
1.	Gili Air	30.67	8.07	28.17	100.00
2.	Gili Trawangan	31.33	7.00	26.50	100.00
3.	Gili Meno	31.33	6.83	26.67	76.20

The results from physical factor measurements in all sampling locations (Tables 7, 8, and 9) showed suitable conditions for coral reefs. As Wilkinson and Buddemeier (1994) said the growth and functioning of coral reefs is best under the following general conditions, such as:

- 1) water temperatures in the optimum range of about 23-30°C;
- 2) clear seas in tropical latitudes;
- 3) low level of sedimentation; and
- 4) salinity in the range of 25 to 40‰.

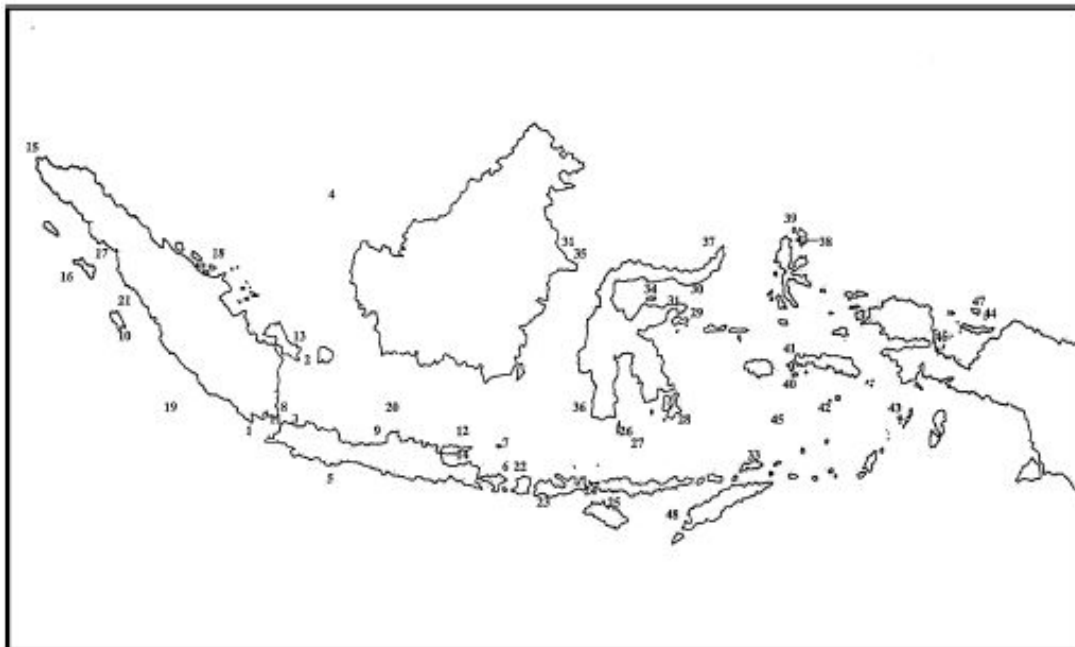
Thus, there were no natural extreme conditions in study area that affected coral reefs during study period.

## CHAPTER 4. CORAL REEFS CONDITIONS AND USES

### 4.1. Coral Reefs Conditions in Indonesia

The total area of coral reefs in Indonesia is about 85,707 km<sup>2</sup>, which consist of 14,542 km<sup>2</sup> fringing reefs, 50,223 km<sup>2</sup> barrier reefs, 1,402 km<sup>2</sup> oceanic platform reefs, and 19,540 km<sup>2</sup> atolls. A total of 421 stations from 48 different locations of reefs throughout Indonesia have been surveyed (see Figure 5). The results showed that 6.10% of the reefs were in excellent condition, 22.70% in good condition, 31.50% in fair condition, and 39.70% in poor condition (Hopley and Suharsono, 2000), as can be seen in Table 10.

Figure 5. Sampling stations in Indonesian coral reefs



Source: Hopley and Suharsono, 2000.

The latest data from National Aviation and Space Agency (LAPAN) showed that 18,108 islands are belonging to Indonesia (Kompas daily, 2003). According to this agency, the Indonesian coastal line is 108,920 km with total coral reefs area is 20,731 km<sup>2</sup>. This coral reefs area is smaller than previous calculation due to limitation of satellite. Coral reefs area in more than 30 m depth and in highly slope could not be covered by Indonesian satellite.

*Acropora* is the most diverse hermatypic coral genus with 114 species recognised worldwide and 91 species being identified for the Indonesian archipelago overall. Structural species such as *Acropora* are a vital ecosystem component, and variations in their abundance are critical to

the dynamic of entire reef communities. *Acropora* plays a dominant role in the species composition and abundance of many modern day Indonesian reefs (Wallace *et al.*, 2001).

Table 10. Coral reefs conditions in Indonesia

No.	Condition	West Indonesia	Central Indonesia	East Indonesia	Whole Indonesia
1.	Excellent (%)	3.00	6.70	10.00	6.10
2.	Good (%)	14.50	25.40	31.80	22.70
3.	Fair (%)	28.90	38.80	26.40	31.50
4.	Poor (%)	53.60	29.10	31.80	39.70
Total (%)		100.00	100.00	100.00	100.00

Source: Hopley and Suharsono (2000)

The clear water of the central and eastern part of Indonesian seas permits corals to develop to a depth of more than 30 m. In Western Indonesia, in contrast, coral growth is limited to an average depth of no more than 20 m. In shallow waters, coral reefs in Indonesia are dominated by *Acropora sp.*, *Montipora sp.*, and *Porites sp.*. In greater depth, coral growths are dominated by *Echinopora sp.*, *Mycedium sp.*, *Oxypora sp.*, and *Turbinaria sp.*. In total, approximately 400 species of Scleractinian corals belonging to 74 genera have been recorded from various localities of the Indonesian waters. The high diversity of Indonesian coral fauna is enhanced by the high level of endemism. Coral reefs in Indonesia vary greatly from one area to another. The variability of coral composition reaches its maximum in areas where high differences but stable abiotic factors influence coral growth and most of the habitats are considered to be real reefs. Even in the same area it appears that large differences in species composition may happen (Suharsono, 2001).

The data from 48 different locations of reefs throughout Indonesia showed that 64.58% of reefs area is dominated by *Acropora*. The other reefs areas are dominated by *Sinularia* (10.42%), *Porites* (12.50%), *Montipora* (6.25%), and *Lobophylla*, *Heliopora*, *Goniopora* (2.08% respectively) (Hopley and Suharsono, 2000). The result of calculation of live coral cover and coral growth rate of Indonesian coral reefs is presented in Table 11.

Table 11. Live cover and growth rate of Indonesian coral reefs

No.	Items	Live cover (%)	Growth rate (%)	Area (km <sup>2</sup> )
1.	Maximum	77.94	22.21	6902.58
2.	Minimum	12.00	4.71	287.61
3.	Average	37.92	13.45	1785.56
4.	Standard deviation	17.57	5.54	1649.47

Source: Hopley and Suharsono (2000)

The distribution of coral species in Indonesia is relative similar, which 96.84% of species or 91.55% of genera are found in all over Indonesian marine waters. About 5 coral species are only found in Eastern Indonesian, 7 species are found in Bali to Eastern Indonesian, 2 species are found in Lombok to Eastern Indonesian, and 1 species is found in Sulawesi to Eastern Indonesian (Table 12).

Table 12. Distribution of coral species in Indonesia

No.	Family	Number of genus	Number of species	Distribution
1	Astrocoeniidae	1	2	all over Indonesia
2	Pocilloporidae	5	6	1 species only in east Indonesia
3	Acroporidae	4	152	4 species only in east Indonesia
4	Fungiidae	12	35	7 species only in Bali to east Ind., 2 species only in Lombok to east Ind., 1 species only in Sulawesi to east Ind.
5	Agariciidae	5	30	all over Indonesia
6	Siderastreidae	3	17	all over Indonesia
7	Porotidae	3	61	all over Indonesia
8	Faviidae	14	87	all over Indonesia
9	Trachyphylliidae	2	2	all over Indonesia
10	Oculinidae	2	3	all over Indonesia
11	Merulinidae	3	8	all over Indonesia
12	Mussidae	6	22	all over Indonesia
13	Pectiniidae	4	16	all over Indonesia
14	Caryophylliidae	4	8	all over Indonesia
15	Dendrophylliidae	3	25	all over Indonesia
Total		71	474	

Source: Suharsono, 1996; Wallace *et al*, 2001.

There are 228,437,870 inhabitants living on about 6,000 Indonesian islands with 95.90% living in coastal areas. Human population density is about 125 inhabitants/km<sup>2</sup> with gross domestic product (GDP) per capita is about US\$2900. The economic crisis in Indonesia has bottomed out, and signs of recovery are appearing after nearly two years of financial and economic turmoil. GDP recorded a 0.20% growth rate in 1999 against the 13.20% contraction in 1998. Sound macroeconomic policies and the structural reform program have helped to stabilize the economy and initiate the recovery. Economic indicators show a rise in activity in several sectors, although the recovery was initially sparked by a rebound in agriculture. Government consumption and non-manufactured exports have provided the demand stimulus for growth.

Prices have increased marginally since October 1999 after declining successively for the previous seven months. Falling food prices contributed the most to the drop in inflation. The

appreciation of Indonesian currency, which was trading at Rp7,200.00 to the US\$ toward the end of 1999, as compared with Rp9,000.00/US\$ at the beginning of 1999, also eased inflationary pressures. Tight monetary policy likewise kept prices in check. Average inflation declined from 58.40% in 1998 to 20.50% in 1999.

The current account continued to show a sizable surplus and reached 3.50% of GDP in 1999, which was mainly because of low imports and near doubling of world oil prices. While natural resource-based exports increased significantly in the first half of 1999, seasonally adjusted manufactured exports remained sluggish. Export performance will depend on continued recovery in Japan and further improvement in the region's economies. Meanwhile, private capital inflows have risen, helping gross foreign reserves to reach an estimated US\$27 billion at the end of the year, equivalent to more than six months of imports.

Devaluation of Indonesian currency has resulted in lower prices within Indonesia but higher returns for exporters. Many new fishers have entered the export oriented fisheries and exporters have commenced more aggressive campaigns to source products from local fishers. Targeting spawning aggregations has become more common as enforcement of regulation has decreased because of a lack of funding in the enforcement agencies. Blast fishing may be down but this seems to be because of lack of profit in the locally sold products. In contrast industries, which are export oriented such as the live fish trade (both aquarium and food), which are largely dependent on cyanide techniques, have intensified. The Asian financial crisis has illustrated the extremely dynamic nature of fishing practices, especially destructive fishing practices in Indonesia. Far from being set in their ways, Indonesian fisherman respond quickly to changing market forces and can rapidly adopt new fishing techniques as they become profitable (Erdmann and Pet, 1999).

Most reefs of the outer region in Seribu Islands exhibited declines in coral cover since 1985, particularly in corals of the genus *Acropora* on the reef slopes (3 m depth). In 1985, the outer region supported the highest cover of hard corals (approximately 30 %), and there was an overall improvement in reef condition with increasing distance offshore from Jakarta. However, blast fishing was occurring at the time of the 1985 surveys. There was no evidence of blast fishing in 1995, although poison fishing with cyanide was reportedly occurring in the region (DeVantier *et al*, 1998).

Tourism is now important in many areas, and is itself responsible for a range of problems, particularly associated with the developments on small coral cays. A large number of the

islands in Seribu Islands have been modified in this way. At the same time, tourism provides as alternative income source and may lead to the reduction of fishing pressures in some locations. Several islands (in the centre part) have been declared and protected as conservation zones. Although there are many protected areas in Indonesia, they do not provide a good network for the vast area of reefs, nor do they yet reach the 300,000 km<sup>2</sup> goal set by the government for year 2000. Most of the existing sites are lacking comprehensive management and, in many, their conservation value is reported to be rapidly deteriorating (Spalding *et al*, 2001).

#### **4.2. Characteristics of Coral Reefs Uses in Indonesia**

Most of the reef fisheries exploitation in Indonesia uses cyanide, since they are considered to be effective, quick and relatively cheap, and furthermore it is easy to handle the capture. Since it has been used for more than one generation, a lot of fishermen do not know other fishing methods. Cyanide causes low tenacity on the captured fish. Around 80% of ornamental fish and 50% of food fish died in retainer and during transportation from the fishing areas to the buyers. The effort to eradicate cyanide by using fresh water or by giving antibiotics, such as tetra, does not help much. As a result, the players of the trading of live reef fish try to get more fish to fulfil the market demand. Cyanide does not only stun the target fish but also kill small fish and other marine biota in surrounding areas, including the coral reefs which are their nesting ground. This means less profit, but it ends up in more captures to satisfy the market demand.

The basic problems of coral reefs uses in Indonesia are twofold. First, because of both the intense effort put in by fishermen and because of the techniques used, many individual reef sites or even regions are over-fished as the result of taking unsustainable yields over many years. Second, many if not most of the methods used are destructive especially to the coral reef habitat. Very few, if any reef species are not targeted for one use or another. For example a scientific assessment of the coral reef fishes in Maluku identified 547 species from 47 families, 52% of which were identified as having exploitable value as ornamental fish, 38% as food fish and 10% as both ornamental and food value. Moreover, the utilisation of reef resources also extends to non fish products such as *trochus*, the sessile habits of which, combined with a large reef flat distribution make them easy targets. Even where fisheries may be very target specific (napolean wrasse, lobsters) the methods used may result in a high by catch (Hopley and Suharsono, 2000).

Capturing fish without the use of cyanide, though difficult, will result in having fish that stay alive longer, thus a lower mortality rate, and at the end, more profit is gained. Some consumers also prefer fish that are cyanide free. The ornamental fish, which are free of cyanide, have longer tenacity, and food fish free of cyanide are of no risks to the people who consume it. Consumers in several developed countries have started to look for fish that are cyanide-free. As the consequences, there is a tendency for an issuance of a certificate for reef fisheries. Indonesia will then have a better bargaining position in facing the free-trade era, if it can fulfil the criteria above.

Cyanide is an industrial chemical substance, which is generally used in gold mining, electroplating and steel refinery. There is a regulation issued by the Indonesian government, which limits the import quota for cyanide, which is 33 tons/year. In reality, however, the import volume can reach up to more than 7,000 tons. Cyanide is traded freely in the market (no permit needed) with the price of Rp40,000.00/kg (about US\$4.00/kg).

The other factor that supports cyanide fishing practices is the lack of marine tenure system. If there is no guarantee to protect certain coral reefs areas, the fishermen around coral reefs areas will harvest coral reefs resource as much and as quick as they can. Otherwise, fishermen from far away area will come and take their resources. It is a common situation for open access resources. Most of fishermen around coral reefs area are willing to protect their resources, but central government often release permits to other commercial corporations to harvest those resources. Marine tenure systems require a strong, socially structured community of fishermen, a condition that is uncommon in Indonesian.

Ornamental fish capturing and live coral harvesting mostly occur in areas around Jakarta and Bali. Seribu Islands, located in the greater Jakarta area, is one of the coral harvesting locations (especially for branching coral - *Acropora sp.*), and has undergone a decrease in intensity in the last decade. The rare, red *Goniopora* can easily be harvested in Kendari, Makassar and Lampung. Various species of ornamental fish and other corals are found in Flores, Medan, Madura, Belitung, Lombok, Sumbawa, Timor, Sulawesi, Maluku and West Papua.

The most exploited reef organisms in Indonesia are ornamental fish and live corals. There are more than 280 species of ornamental fish and more than 70 species of corals that are traded. The next popular commodity is live reef food fish. The main species are groupers (*Serranidae*), wrasse (*Cheilinus undulates*), and lobsters. Popular groupers are included tiger grouper (*Epinephelus fuscogatus*), barramundi cod (*Comileptus altivelis*), and coral trout



(*Plectropanus maculatum*). Although the volume is still unknown, sea horses (for aquariums as well as medicinal purposes), sea cucumber, abalone, and seaweed are also exploited.

According to fishermen and collectors, recently it becomes more difficult to find abundant fishing ground for ornamental fish and corals. Several species have become extinct or at least difficult to find, such as Indo-Pacific blue tang (*Acanthurus hepatus*), powder blue tang (*Acanthurus leuconestron*), blue-girdled angelfish (*Euxiphipops navarchus*), and emperor angelfish (*Pomacanthus imperator*).

Live reef food fishing mainly occur in the eastern waters of Indonesia, such as around the islands of Selayar, Spermonde, Taka Bonerate, as well as Bone Bay, Sinjai, Bulukumba, Takalar, and Mamuju (South Sulawesi); Banggai and Togean Islands (Central Sulawesi); Sangir Talaud Islands, Minahasa, Gorontalo (North Sulawesi); Aru and Kei Islands (Southeast Maluku), Halmahera (North Maluku); Seram and Banda Islands (Central Maluku); Biak, Padaido Islands and Cendrawasih Bay (West Papua), Sumbawa (West Nusa Tenggara); and Flores, Komodo, Sumba and Timor (East Nusa Tenggara). In smaller volume and intensity, fishing grounds are also found in several waters in the western part of Indonesia, such as the islands of Riau, Natuna and Anambas, Mentawai, Nias, as well as Bengkulu and Lampung (Sumatra); several places in Kalimantan; Karimun Jawa (Central Java); and Sapudi and Kangean Islands (East Java). Several waters have suffered a decrease in fish capture intensity in the last decade, as occurred in the Seribu Islands.

The trade of reef fish has increased in the last 14 years. The export of reef fish increased steeply from 300 tons in 1989 to 3,800 tons in 1995. Indonesia is now one of the leading source countries of live reef food fish in Asia, with Hongkong as the main market. There are several reef food fish export gates, such as Jakarta, Makasar, Denpasar, Medan, and Batam, mostly by transport vessels, besides airborne from Sukarno-Hatta (Jakarta) and Ngurah Rai (Bali) airports, though in smaller volume.

Ornamental fish and corals trading are centred in Jakarta and Bali, mainly for export. This is especially because of the availability of direct flights to destination countries in North America and Europe. Ornamental fish are more exported through Ngurah Rai airport (Bali), while corals are exported through the Soekarno-Hatta airport (Jakarta), since CITES permit is issued by the Directorate General of Protection and Natural Conservation in Jakarta. Permit is regulated by the branch office of the exporter in Jakarta for exports going through Bali. Besides the two cities mentioned above, there are only 3 other export gates with smaller

export volume, such as Solo, Medan and Makasar. The exports from Solo and Medan are sent with transit in Singapore, while the export from Makasar is carried through Bali.

The biggest trading centre for local marketing of ornamental fish and corals is situated in Jalan Sumenep, Central Jakarta. Other centres do not trade as many marine ornamental fish. There are also petshops selling marine ornamental fish in main shopping centres in Jakarta. The local market is mainly oriented towards the supply for aquariums in starred-hotels, shopping centres, office buildings and private collections of the upper class. The lower class is less interested in this type of fish due to the difficulties in maintenance and regular supply of seawater. Several traders from Jalan Sumenep admitted that the types of ornamental fish and corals sold to the local market are of lower quality compared to those for export. Powder blue-tang and emperor angelfish receive the least interest due to their high price.

Local markets for reef food fish can be found in various cities, such as Jakarta, Denpasar, Semarang, Medan, and Pontianak. In the last few years, the domestic demand for reef food fish has increased. Restaurants, which cater seafood and offer live reef fish have increased in a number of cities such as Jakarta, Semarang, Surabaya, Makasar, and Medan. Semarang has about 12 restaurants, which serve live reef fish in their menu. Complete information on local market is not available yet. Some information indicate that some of the reef food fish sold in local markets are fish that fall below export standard, due to, for example, cyanide or not being alive. However, there is always the possibility that there is a segment in the market, which can afford to buy prime quality fish.

Fishermen delivered ornamental fishes and corals to the middlemen or traders, who then deliver them to the exporters. Sometimes there are several agents between the traders and the exporters. This is possibly due to the distance between the fishing area and the exporters, which causes the high cost of delivery. It can also be due to the capital flow, especially between the fishermen and the traders who are usually the owners. The fishermen then would pay the loan by selling their captures to the owners. It is suspected that the fishermen obtained the cyanide through this mechanism. Besides providing capital for operational cost such as gasoline and food, traders also provide cyanide as a part of fishing material cost.

Similar as ornamental fish and corals, reef food fish is delivered to the traders, who usually are the owners who provide loans to the fishermen for operational cost, including gasoline and food. The fishermen then return the loan by delivering their capture to the traders. The

flow continues until the fish arrive at the exporters. Field surveys showed that within the capital provided, traders also included potassium or cyanide as fishing materials.

There are several systems for purchasing fish and corals used by exporters. First, wholesale systems in which exporters purchase all types of fish and corals captured, regardless of their species and conditions. Second, order systems, in which exporters have placed their order on specific species of fish or corals. A first type system would sometimes cause the exporters to try to sell all goods quickly, to avoid them being in retainers for a long period, that could cause fish or coral to die. There are also fish or corals that are not sold well in the local market.

In the reef fish and coral trading, each businessman is responsible for the costs of manpower, handling and transportation, profit, tax and levies, and the risk of having dead fish. There are 2 types of taxes, formal and informal. The formal tax is an export tax plus arranging of export documents such as for quarantine and for CITES certificates. The informal tax is varied and usually depends on the origin, the destination and the transportation system that is used. Included in informal tax is security and bribery. There is information that in each export of reef fish, the exporters have to allocate up to US\$ 8.00 for each fish sold depend on the kind of fish.

Besides the possibility of great profit margins for exporters, the situations mentioned above cause a significant difference between the prices paid to the fishermen and those paid to exporters for ornamental fish, corals and reef food fish. As an example, emperor angelfish (*Pomacanthus imperator*) which is sold for Rp25,000/fish (about US\$2.50/fish) by the fishermen to the traders, can be exported for US\$25.00/fish. Even in the local trader level, the difference of price can reach up to 300%. For food fish, coral trout (*Plectropomus leopardus*) which can be purchased from the fishermen for Rp35,000.00/kg (about US\$3.50/kg), is sold by the exporters to Hong Kong for HK\$350/fish (around Rp400,000.00). This type is usually sold in restaurants in Hong Kong for HK\$500 (Cesar, 1996) or around Rp600,000.00 per plate (consisting of around 1,5 kg). While in a seafood restaurant in Jakarta it is sold for Rp175,000.00/fish.

The opportunity to gain great profit is in the hand of the exporters, while the risks upon the players due to the decrease in the quality of the habitat are directly experienced by the fishermen. If coral reefs disappeared, the fishermen will have difficulties to find fish. In contrast, traders would easily be able to find other fishermen who would look for farther

fishing areas. And for the businessmen, it would be easy to move their business to other areas or even to change it altogether.

### 4.3. Coral Reefs Conditions in Selected Areas

#### 4.3.1. Seribu Islands

Seribu Islands are surrounded by patch reefs around 0.5 to 5.0 m depth, which consist of hard coral (massive coral, table coral, gorgonian, leaf coral and mushroom coral) and soft coral. This marine environment naturally could support more than a hundred kinds of marine fishes and invertebrates. Based on the record from two fish exporter firms around Jakarta, about 163 species of reef fishes, 101 species of corals and 26 species of other invertebrates, were sold in the year 2000. This study found about 91 species of ornamental fishes, 51 species of corals, and 8 species of other invertebrates, which were sold by fishermen from Seribu Islands to those exporter firms.

Coral condition in Seribu Islands can be categorized as bad to good condition according to the LIPI (Indonesian Science Agency) classification (Suharsono 2001). The best live coral cover (62.86%) was found in Layar Island (station 2), the worst (10.09%) was found in Putri Island, and average coral cover was 32.50% ( $\pm 16.04\%$ ).

Table 13. Coral distribution in Seribu Islands

No.	Island and station	Coral Cover (%)	Number of genus	Value (\$)
1.	Pandan (station 1)	45.87	8	18466.94
2.	Pandan (station 2)	30.42	7	26589.40
3.	Pandan (station 3)	38.73	6	16081.52
4.	Opak	13.49	7	8103.52
5.	Bira	10.36	6	6553.96
6.	Putri	10.09	7	1106.19
7.	Melinjo	22.65	6	1068.70
8.	Genteng	14.46	6	784.45
9.	Kotok (station 1)	38.42	9	4369.30
10.	Kotok (station 2)	34.72	12	6767.01
11.	Layar (station 1)	46.68	6	6234.52
12.	Layar (station 2)	62.86	8	6313.64
13.	Panggang (station 1)	34.12	6	3158.70
14.	Panggang (station 2)	43.64	2	3607.87
15.	Sekati (station 1)	20.32	8	5192.93
16.	Sekati (station 2)	53.12	18	9359.73

Coral genus was dominated by *Acropora*, which was almost found in every station. The highest percentage covers (47.64%) was *Heliopora*, which was found in Layar Island (station

2). The highest number of genus (18 genera) was found in Sekati Island (station 2) and the lowest (2 genera) in Panggang Island (station 2). Coral value can be calculated based on the measurement of coral cover (cm<sup>2</sup>) and coral price. The highest coral value (\$26,589.40) was found in Pandan Island (station 2), the lowest (\$784.45) was in Genteng Island, and average coral value was \$7,734.90 ( $\pm$ \$7,034.03). The best live coral cover was found in Layar Island (station 2), but the highest coral value was found in Pandan Island (station 2). This situation shows that there is more valuable coral genus in Pandan Island (station 2) compared to coral genus in Layar Island (station 2). *Acropora*, which is dominant in Pandan Island (station 2), has a higher price (\$6.00/piece) than *Heliopora* (\$1.75/piece).

This study identified 96 species of coral fishes, and the highest fish species number (34 species) was found in Bira Island. The lowest number of fish species (9 species) was found in Genteng Island and Panggang Island (station 1) as can be seen in table below.

Table 14. Fish distribution in Seribu Islands

No.	Island and station	Number of species	Individual	Value (\$)
1.	Pandan (station 1)	20	312	281.05
2.	Pandan (station 2)	20	500	506.20
3.	Pandan (station 3)	24	476	261.30
4.	Opak	24	334	261.15
5.	Bira	34	217	222.60
6.	Putri	18	98	73.05
7.	Melinjo	12	55	62.95
8.	Genteng	9	81	47.50
9.	Kotok (station 1)	12	119	94.50
10.	Kotok (station 2)	14	58	89.50
11.	Layar (station 1)	17	125	144.95
12.	Layar (station 2)	19	203	176.55
13.	Panggang (station 1)	9	56	87.45
14.	Panggang (station 2)	18	109	125.10
15.	Sekati (station 1)	11	95	82.50
16.	Sekati (station 2)	18	191	160.75

The highest number of fish (500 individuals) and the highest fish value (\$506.20) was found in Pandan Island (station 2). The lowest number of fish (55 individuals) was found in Melinjo Island, but the lowest fish value (\$47.50) was found in Genteng Island, because Genteng Island was dominated by less valuable damsel-fish (\$0.50/individual). The average number of fish was 189 individuals ( $\pm$ 145 individuals) and average fish value was \$167.32 ( $\pm$ \$118.31). The most common fish was lyre-tail-wrasse (*Thalassoma lunare*), which was found in every

station. The dominant fish was damselfish (*Chromis atripectoralis*), which found totally 422 individuals.

Table 15. Inhabitants in Seribu Islands (2001)

Villages	Inhabitants			Area km <sup>2</sup>	Density per km <sup>2</sup>	Occupation		
	Men	Women	Total			Total	Fishermen	Percentage
1. Panggang Island	2144	2046	4190	0.62	6747	2077	1733	83.44
2. Tidung Island	1903	195	2098	0.11	19248	1499	1100	73.38
3. Kelapa Island	2499	2366	4865	2.58	1882	2800	1750	62.50
4. Untungjawa	806	768	1574	1.03	1530	370	250	67.57
5. Harapan Island	955	918	1873	2.45	765	936	296	31.62
6. Pari Island	935	937	1872	0.95	1979	916	311	33.95
Seribu Islands	9242	7230	16472	7.74	2129	8598	5440	63.27

Source: Government statistic agency of North Jakarta (February, 2002).

Seribu Islands are commonly managed by two government institutions: the inhabited islands are managed by the government of Jakarta metropolitan city and conservation zones are managed by Seribu Islands Marine Nature Reserve Authority. These islands are administratively divided into 6 villages, namely Panggang Island village (13 islands), Tidung Island village (6 islands), Kelapa Island village (36 islands), Untungjawa Island village (15 islands), Harapan Island village (30 islands) and Pari Island village (10 islands). About 16,472 inhabitants are living in this area, which consist of 9,242 men and 7,230 women. The average density of human population in year 2001 is 2,129 inhabitants/km<sup>2</sup>. Most of inhabitants in Seribu Islands worked as fishermen (63.27%). The highest percentage of fishermen (83.44%) was in Panggang Island village and the lowest (31.62%) in Harapan Island village.

Table 16. Exploitation rate of fish, coral, and other invertebrate in Seribu Islands

No.	Organism	Category	Species	Exploited	Value (\$)
1.	Fish (individuals)	High	<i>Amphiprion percula</i>	24752	19801.60
		Moderate	<i>Ostracion cubicus</i>	1664	4992.00
		Low	<i>Acanthurus leucosternon</i>	9	76.50
2.	Coral (pieces)	High	<i>Gyrostoma helianthus</i>	4571	7999.25
		Moderate	<i>Clavularia viridis</i>	960	2400.00
		Low	<i>Actinodendron plumasum</i>	18	72.00
3.	Other invertebrate (individuals)	High	<i>Synapta maculata</i>	9464	26026.00
		Moderate	<i>Linckis laevigata</i>	1216	1580.80
		Low	<i>Periclimenes brevicarvalis</i>	27	54.00

Live corals in Seribu Islands are exploited by inhabitants for local trading and export. During the research (April 2001 to March 2002), at least 46 species of corals are exploited, which

totally 47,298 pieces. The most exploited coral is small anemone (*Gyrostoma helianthus*), which is harvested 4,571 pieces (Table 16).

Coral fishes in Seribu Islands are exploited by inhabitants for consumption and for aquarium fish (marine ornamental fish) and traded all over the world (exported). During this study, at least 87 species of fish are exploited, with totally 148,795 individuals. The most exploited fish is clown anemone fish (*Amphiprion percula*), which harvested 24,752 individuals.

Other invertebrates are also exploited by inhabitants for local and export market as ornamental for aquarium. The most exploited invertebrate is red king snake (*Synapta maculata*), which totals 9,464 individuals. Other invertebrate like blue sea star (*Linckis laevigata*) is exploited in smaller numbers (1,216 individuals).

Non-exploitative use of coral reefs in Seribu Islands is for tourism activities, such as diving and snorkelling. Seribu Islands are visited by 6,527 tourists consist of 4,095 local tourists and 2,432 foreign tourists. More than 50 % of tourist activities in Seribu Islands are diving and snorkelling (Table 17).

Table 17. Number of tourist in Seribu Islands (2001)

No.	Month	Origin		Activity		Total
		Foreign	Domestic	Diving	Snorkelling	
1.	January	92	133	98	31	225
2.	February	53	121	83	20	174
3.	March	22	99	66	10	121
4.	April	453	446	454	125	899
5.	May	235	518	354	86	753
6.	June	306	691	391	130	997
7.	July	364	808	461	154	1172
8.	August	604	735	555	176	1339
9.	September	56	132	99	19	188
10.	October	58	129	97	20	187
11.	November	99	205	177	29	304
12.	December	90	78	82	25	168
Total		2432	4095	2917	825	6527

Source: Seribu Islands Marine Nature Reserve Authority (February, 2002).

#### 4.3.2. Menjangan Island

Menjangan Island is surrounded by patch reef. The reef is dominated by *Porites*, and the highest live coral cover (22.74%) was found in station Gardeneel-1. *Porites* is also the most

widely spread genus, which was almost found in every station. About 21 genera of corals were found in Menjangan Island.

Table 18. Coral distribution in Menjangan Island

No.	Station	Coral Cover (%)	Number of genus	Value (\$)
1.	Gardeneel-1	43.98	13	5691.97
2.	Gardeneel-2	39.08	7	6086.90
3.	Wreck-1	3.14	7	364.07
4.	Wreck-2	10.10	12	1848.85
5.	Posdua-1	22.58	13	4674.67
6.	Posdua-2	8.60	7	2106.34

The best live coral cover (43.98%) was found in station Gardeneel-1, the worst (3.14%) was found in station Wreck-1, and average live coral cover was 21.25% ( $\pm 17.02\%$ ). The highest genus number (13 genera) was found in station Gardeneel-1 and the lowest (7 genera) was found in station Wreck-1. The highest coral value (\$6,086.90) was found in station Gardeneel-2, the lowest (\$364.07) was found in station Wreck-1, and the average coral value was \$3,462.13 ( $\pm \$2,339.69$ ).

The highest coral value is in station Gardeneel-2, but live coral cover and coral genera numbers are less than station Gardeneel-1, because there is more valuable coral in station Gardeneel-2. Live coral cover of high price *Acropora* (\$6.00/piece) is 3.52% in station Gardeneel-2 and only 1.02% in station Gardeneel-1, while station Gardeneel-1 is dominated by less price *Porites* (\$1.50/piece).

About 84 species of coral fishes were found around Menjangan Island. The highest number of fish species (32 species) was found in station Wreck-2 and the lowest (15 species) in station Posdua-2. The highest number of fish (233 individuals) was found in station Gardeneel-1, the lowest (115 individuals) was found in station Wreck-2, and average fish number was 174 individuals ( $\pm 45$  individuals), as can be seen in Table 19.

Table 19. Fish distribution in Menjangan Island

No.	Station	Number of species	Individual	Value (\$)
1.	Gardeneel-1	20	233	244.50
2.	Gardeneel-2	27	169	237.85
3.	Wreck-1	16	169	137.05
4.	Wreck-2	32	115	142.75
5.	Posdua-1	30	218	180.00
6.	Posdua-2	15	142	138.90



The highest value of fish (\$244.50) was found in station Gardeneel-1, the lowest (\$137.05) was found in station Wreck-1, and average fish value was \$180.18 ( $\pm$ \$49.86). The most common fish was midnight angelfish (*Centropyge nox*), which was found almost in every station.

There are no inhabitants on Menjangan Island and only 2 buildings for watching officers (*Possatu* in west and *Posdua* in east) and 2 buildings for Hinduism prayers (*Purasatu* in east and *Puradua* in north). Most people are living in the villages around the coast of Bali Island. About 39,664 inhabitants are living in 7 villages (262.47 km<sup>2</sup>), which consist of 19,002 men and 20,662 women. Average human population density is about 151 inhabitants/km<sup>2</sup> as can be seen in the Table 20.

Table 20. Inhabitants around Menjangan Island (2001)

Villages	Inhabitants			Area (km <sup>2</sup> )	Density per km <sup>2</sup>	Occupation		
	Men	Women	Total			Total	Fishermen	Percentage
1. Sumber Klampok	850	803	1653	38.80	43	823	72	8.75
2. Pejarakan	3730	3842	7572	39.60	191	3613	68	1.88
3. Sumber Kima	2949	2918	5867	30.20	194	2857	91	3.19
4. Pemuteran	3106	3283	6389	30.33	211	3009	93	3.09
5. Gilimanuk	2782	3476	6258	56.01	112	2695	80	2.97
6. Melaya	3738	4485	8223	60.74	135	3261	48	1.47
7. Candikusuma	1847	1855	3702	6.79	545	1789	112	6.26
Menjangan Island	19002	20662	39664	262.47	151	18047	564	3.13

Source: Government statistic agencies of Buleleng and Jembrana regencies (March, 2002).

Most peoples around Menjangan Island work in agricultural, only few peoples work in the marine environment (only 564 persons or 3.13% of inhabitants worked as fishermen). Unfortunately, there were illegal cyanide fishing and coral collecting in coral reefs surrounding Menjangan Island, although both activities were prohibited by West Bali Nature Reserve Authority. This research found 70 fishermen who used cyanide fishing method (26 owners with 44 labour) and 20 coral collectors (7 owners with 13 labour) who collected live corals.

This study found about 37 species of reef fishes are exploited around Menjangan Island, which totally 65,273 individuals. The most exploited fish is bicour chromis (*Chromis atripectoralis*), which is harvested 6,018 individuals. Inhabitants also exploited corals and other invertebrates in coral reef area near Bali Island. During this study, about 20 species of live corals and 7 species of other invertebrates are exploited, which total 6,713 pieces of live

corals and 1,263 individuals of other invertebrates. The most exploited coral is long tentacle anemone (*Stoichactis kentii*), which is harvested 1,231 pieces (Table 21).

Table 21. Exploitation rate of fish, coral and other invertebrate in Menjangan Island

No.	Organism	Category	Species	Exploited	Value (\$)
1.	Fish (individuals)	High	<i>Chromis atripectoralis</i>	6018	4513.50
		Moderate	<i>Dascyllus reticulatus</i>	1224	489.60
		Low	<i>Chaetodon ephippium</i>	64	208.00
2.	Coral (pieces)	High	<i>Stoichactis kentii</i>	1231	3693.00
		Moderate	<i>Euphyllia cristata</i>	341	1278.75
		Low	<i>Heliofungia sp.</i>	101	202.00
3.	Other invertebrate (individuals)	High	<i>Hapalochlaena vulgaris</i>	275	550.00
		Moderate	<i>Linckis laevigata</i>	167	217.10
		Low	<i>Dardanus megistos</i>	103	154.50

Cyanide fishing in coral reefs around Menjangan Island is also affected by tourism activity. The more tourists visited coral reefs, the smaller the chance for inhabitants to exploit fish, corals and other marine organisms. The tourist data in Menjangan Island (see table below) showed that more than 54 tourists/day visited Menjangan Island for diving and snorkelling. Fishermen could not fish around coral reefs in Menjangan Island because they would be afraid of this illegal activity being reported to the watching officers.

Table 22. Number of Tourist in Menjangan Island (2001)

No.	Month	Origin		Activity		Total
		Foreign	Domestic	Diving	Snorkelling	
1.	January	1381	270	982	555	1651
2.	February	2308	187	1505	897	2495
3.	March	196	347	299	114	543
4.	April	716	360	623	313	1076
5.	May	8	40	26	8	48
6.	June	1438	310	1037	581	1748
7.	July	2266	2241	2541	1116	4507
8.	August	2630	351	1786	1038	2981
9.	September	1549	795	1356	679	2344
10.	October	1241	499	1015	528	1740
11.	November	858	772	923	414	1630
12.	December	1043	764	1031	483	1807
Total		15634	6936	13123	6726	22570

Source: West Bali Nature Reserve Authority (March, 2002).

Around 69.27% of tourists in Menjangan Island on year 2001 are foreign tourists. Tourist activities are mainly related to coral reefs, which are 58.14% for diving and 29.80 % for snorkelling or totally for both activities are 87.94% (Table 22).

### 4.3.3. Gili Islands

Gili Islands are surrounded by a fringing reef and covered by sea-grass beds and seaweed in some parts of the reef. Based on the research done by Nature Conservation Agency in the year 2000, only 19 species of corals and 73 species of coral fishes were found in this area.

Coral reef in Gili Islands is dominated by *Fungia*, which the highest cover (20.22%) was found in Gili Meno Island (station 1). About 15 genera of coral were found in Gili Islands and *Fungia* was almost found in every station. The best condition was found in Gili Meno Island (station 1) where live coral cover was 21.94% and the worst in Gili Air Island (station 2) where live coral cover only 0.42%.

Table 23. Coral distribution in Gili Islands

No.	Station	Coral cover (%)	Number of genus	Value (\$)
1.	Gili Air-1	7.32	5	1078.86
2.	Gili Air-2	0.42	3	58.65
3.	Gili Trawangan-1	2.52	3	371.07
4.	Gili Trawangan-2	2.10	5	232.39
5.	Gili Meno-1	21.94	5	4532.05
6.	Gili Meno-2	7.60	8	747.80

The highest number of coral genus (8 genera) was found in Gili Meno Island (station 2), and the lowest (3 genera) was found in Gili Air Island (station 2) and Gili Trawangan Island (station 1). The highest coral value (\$4,532.05) is in Gili Meno Island (station 1) and the lowest (\$58.65) in Gili Air Island (station 2). Based on LIPI classification (Suharsono, 2001), there was no station can be categorized as good condition because the highest live coral cover only 21.94%. Coral condition in Gili Islands also affected by widely coral bleaching in year 1998. Coral started to grow in the beginning of year 1999 but unfortunately blast fishing still intensively done until the end of year 1999. After June 2000, blast fishing was totally banned by the authority.

About 65 coral fish species were found during this study. The highest number of fish species (20 species) was found in Gili Air Island (station 1) and Gili Trawangan Island (station 1 and 2) and the lowest (16 species) in Gili Meno Island (station 1). The highest number of fish (665 individuals) was found in Gili Meno Island (station 1), the lowest (73 individuals) was found in Gili Air Island (station 2), and average fish number was 254 individuals ( $\pm 210$  individuals). The highest fish value (\$366.20) was in Gili Meno Island (station 1), the lowest

(\$103.10) was found in Gili Air Island (station 2), and average fish value was \$164.91 ( $\pm$ \$100.17). The most common fish was Klein's butterfly-fish (*Chaetodon kleinii*), which was almost found in every station.

Table 24. Fish distribution in Gili Islands

No.	Station	Number of species	Pieces	Value (\$)
1.	Gili Air-1	20	229	141.60
2.	Gili Air-2	17	73	103.10
3.	Gili Trawangan-1	20	229	133.15
4.	Gili Trawangan-2	20	153	103.80
5.	Gili Meno-1	16	665	366.20
6.	Gili Meno-2	19	172	141.60

Gili Islands are administratively under local government of Gili Indah village. About 2,816 inhabitants lived in these islands, which consist of 1,436 men and 1,380 women. Average human density in these islands is 423 inhabitants/km<sup>2</sup>. Most of inhabitants in Gili Islands worked in the field of tourism services, such as in hotels, restaurants and transportation business. Only 323 inhabitants or 27.87% of total inhabitants worked as fishermen as can be seen in Table 25.

Table 25. Inhabitants in Gili Islands (2001)

Villages	Inhabitants			Area (km <sup>2</sup> )	Density per km <sup>2</sup>	Occupation		
	Men	Women	Total			Total	Fishermen	Percentage
1. Gili Air	616	626	1242	1.75	710	716	176	24.58
2. Gili Meno	257	228	485	1.50	323	316	97	30.70
3. Gili Trawangan	563	526	1089	3.40	320	127	50	39.37
Gili Islands	1436	1380	2816	6.65	423	1159	323	27.87

Source: Government statistic agency of West Lombok regencies (March, 2002).

Since the year 2000, cyanide fishing and coral collecting are prohibited in this area by the authority. All the area was planned to use for tourism activities. Although fishermen are allowed to exploit fish and coral only in the north area far away from Gili Islands and in the reefs area near Lombok Island, their fishing ground is still relative close to the area and sometimes in the area. About 30 species of reef fishes are exploited, which totally 11,642 individuals. The most exploited fish is blue stark cleaner wrasse (*Labroides dimidiatus*), which are harvested 1,295 individuals (Table 26).

Table 26. Exploitation rate of fish, coral and other invertebrate in Gili Islands

No.	Organism	Category	Species	Exploited	Value (\$)
1.	Fish (individuals)	High	<i>Labroides dimidiatus</i>	1295	1036.00
		Moderate	<i>Pterois antennata</i>	357	714.00
		Low	<i>Pomacentrus mollucensis</i>	60	36.00
2.	Coral (pieces)	High	<i>Radianthus ritterii</i>	891	2227.50
		Moderate	<i>Heliofungia actiniformis</i>	354	619.50
		Low	<i>Plerogyra sinuasa</i>	151	264.25
3.	Other invertebrate (individuals)	High	<i>Sabellastarte indica</i>	1069	1603.50
		Moderate	<i>Stenopus hispidus</i>	454	590.20
		Low	<i>Palinurus ornatus</i>	153	306.00

Live corals and other invertebrates are also exploited in the reefs area near Lombok Island. About 13 species of live corals and 8 species of other invertebrates are exploited, which totally 4,127 pieces of live corals and 4,874 individuals of invertebrates. The most exploited coral is mixed colour anemone (*Radianthus ritterii*), which is harvested 891 pieces. Other invertebrate that is highly exploited (1,069 individuals) is feather tube worms (*Sabellastarte indica*).

Domestic tourists are dominant in Gili Islands and it is only 10.98% foreign tourists in year 2001. Tourist activities are not dominated by diving and snorkelling (only 10.87% of total tourists), which consist of 6.52% diving and 4.35% snorkelling. The number of tourist and tourism activities can be seen in Table 27.

Table 27. Number of tourist in Gili Islands (2001)

No.	Month	Origin		Activity		Total
		Foreign	Domestic	Diving	Snorkelling	
1.	January	461	7937	548	365	8398
2.	February	126	3297	223	149	3423
3.	March	1862	2403	278	185	4265
4.	April	148	4705	317	211	4853
5.	May	674	5220	385	256	5894
6.	June	981	10147	726	484	11128
7.	July	1212	10190	744	496	11402
8.	August	1420	11410	837	558	12830
9.	September	1101	8643	636	424	9744
10.	October	1364	7955	608	405	9319
11.	November	1133	8423	623	416	9556
12.	December	1131	13799	974	649	14930
Total		11613	94129	6898	4599	105742

Source: Marine Tourism Park Authority of Gili Indah (March, 2002).

Field measurements showed that the highest live coral cover (62.86%), coral genus (18 genera) and coral value (\$26,589.40) was found in Seribu Islands. The lowest coral cover (0.42%), coral genus (3 genera), and coral value (\$58.65) was found in Gili Islands, while moderate coral condition was in Menjangan Island. In contrast, Seribu Islands has the worst fish distribution than other locations, as can be seen in variation of fish species number, fish number and fish value per station. Although Seribu Islands has the highest fish species number than two other locations, the distribution of fish was varied among stations, which was indicated by the great standard deviation of fish number. This condition was affected by the human activity related to coral reefs, which can be seen in the intensity of cyanide fishing and coral collecting in Seribu Islands.

The high anthropogenic threats to coral reefs can be seen in Seribu Islands due to the high density of human population. For example, 2,098 inhabitants lived on 0.11 km<sup>2</sup> small island (Tidung Island) or human density was about 19,248 inhabitants/km<sup>2</sup>. Most of land in this island was only used for housing and related facilities, no other remains land for agricultural activity neither for industrial activity. Compared to Gili Trawangan Island, about 1,089 inhabitants lived on 3.40 km<sup>2</sup> of land or human density was only 320 inhabitants/km<sup>2</sup>. Inhabitants of this island still have enough land to cultivate palm tree, corn and cassava, while another inhabitants work in the field of tourism service such as in hotels, restaurants and transportation business. The situation around Menjangan Island was very different because inhabitants lived on Bali Island, which average human density was only 151 inhabitants/km<sup>2</sup>. Inhabitants on this island have enough land for agricultural and small industry activity.

The highest density of inhabitants and the lack of alternative for income generating on Seribu Islands have pushed community to the activity related directly to the coral reefs. The data showed that the number of fishermen on Seribu Islands was higher than two other locations, based on percentage of fishermen and fishermen number, the number of fishermen on Seribu Islands are 5,440 persons (63.27% of total manpower), around Menjangan Island are 564 persons (3.13% of total manpower), and on Gili Islands are 323 persons (27.87% of total manpower). As a consequence, the number of inhabitants on Seribu Islands who worked in coral reefs are also relative more than two other locations.

The photographic method is usually used for monitoring the biological condition, growth, mortality and recruitment of corals in a permanent quadrat (English *et al*, 1994). However, in this study the photographic method was used for mapping and assessment of the cover of

coral life form categories and benthic groups, instead of line intercept transect (LIT). The photographic method was used at the beginning and at the end of study. It has advantages, but also disadvantages.

Photographic methods need little time in the field for assessment of the substrate coverage compared to LIT. It also provides details and allows for careful observation, a permanent record and non-destructive sampling (English *et al*, 1994). However, it needs a relatively flat area (English *et al*, 1994), which sometimes is difficult to find. The photographic method is costly compared to LIT, because this method needs camera set and negative film, and then requires the negative film to be scanned into digital picture. Finally, too much time was consumed to determine the life form categories and measure the cover in the computer. Another limitation was that photograph resolution was not enough to determine all corals to the genus level, so coral genus was determined during photographing. The real contour of reef could not be measured with this method, since it only gives a two-dimensional picture. The photographic method, however, fulfilled most of the important requirements for substrate mapping better than LIT.

According to Russell *et al* (1978), the fundamental problem in quantitative assessments of fish on coral reef is caused by the sampling. Whereas many fishes are highly mobile, others are sedentary (Russell *et al*, 1978). Underwater visual census (UVC) has errors and biases, caused by the observer, the proper fish behaviour, and the sampling method, most of which result in an underestimation of the population densities (Chapman *et al* 1974, Brock 1982, Buckley & Hueckel 1989, Greene & Alevizon 1989, English *et al* 1994, Harvey *et al* 2002 and Labrosse *et al* 2002). Using UVC Brock (1982) counted only 65% of the fish species that were collected by rotenone (poison) at the same area, and only saw 26% of the cryptic species. Accordingly, Sale & Sharp (1983) underestimated the density of fish from 11.1% to 26.7% in a 1-m wide transect.

The ability to spot all fishes present was also depending on the fish behaviour and the divers activity: there are neutral, shy, curious and secretive fishes (Chapman *et al* 1974, Kulbicki 1998). Activities and the swimming speed of the observer also contributed to the bias (Chapman *et al*, 1974). If the observer moves too slowly, an overestimation will be the result, and vice versa (Sale & Sharp 1983, Smith 1998). The air bubbles originating from an open circuit SCUBA also influence the behaviour of the fish (Chapman *et al*, 1974). While writing data on a slate, the observer might have overlooked fish when starting again to count (Sale &

Sharp 1983). The other sources of bias were the distance of the diver from the substratum, the diver experience, and the diver's physiology in the aquatic environment (Sale & Sharp 1983, Smith 1988, Harvey *et al* 2001, Labrosse *et al* 2002). The surrounding environment also gave some limitations for UVC, the visibility of the water, the state of the ocean and the weather conditions (Labrosse *et al*, 2002). However, according to Bell *et al* (1985), a trained observer provides consistency in estimating abundance and length frequency estimations of the same population.

During this study only one observer counted all the fishes, in order to minimise errors and to keep the bias constant (also done by Samoily & Carlos 2000). The UVC was done between 10.00 am and 03.00 pm to avoid the diurnal-nocturnal change of fish behaviour. During the preliminary study a list of fish species was developed from all surveyed islands to minimise miss-identification, and to include also those fish that were caught by net during the study.

#### **4.4. Characteristics of Coral Reefs Uses in Selected Areas**

##### **4.4.1. Cyanide Fishing**

There were 126 cyanide fishermen (39 boat owners and 87 labours) on Seribu Islands, 70 cyanide fishermen (26 boat owners and 44 labours) around Menjangan Island, and 29 cyanide fishermen (11 boat owners and 18 labours) on Gili Islands. On Seribu Islands, 89 cyanide fishermen (25 boat owners and 64 labours) are not fully depended on cyanide fishing as a source for their family incomes, because other family members also operated seaweed culture. About 30 cyanide fishermen (9 boat owners and 21 labours) around Menjangan Island also have other sources of their family incomes from their family members who work in land-based agriculture. Other family members of all cyanide fishermen on Gili Islands also work in land-based agriculture and seaweed culture.

Most of cyanide fishermen (88.46% on Seribu Island, 92.31% around Menjangan Island, and 54.55% on Gili Islands) have a wide range of fishing grounds. Their main fishing grounds are coral reefs areas, which have good live coral conditions, although in tourism and conservation areas. Species target of cyanide fishing are very broad (almost all coral fishes species), but the first target are the high price fish species, such as emperor angle-fish and blue ring angle-fish in Seribu Islands, emperor angle-fish, yellow face angel-fish, and blue face angle-fish in Menjangan Island, and emperor angle-fish and powder blue surgeon-fish in Gili Islands.

Cyanide fishing is a daily activity, but fishermen on Seribu Islands are not fishing on fridays (54 days/year) and local holidays (113 days/year), fishermen around Menjangan Island are not



fishing on sundays (54 days/year) and local holidays (69 days/year), and fishermen on Gili Islands are not fishing on fridays (54 days/year) and local holidays (69 days/year). Unfriendly wind and wave during December to February (90 days/year) on Seribu Islands, during December and January (62 days/year) on Menjangan Island and Gili Islands, are limiting environmental condition to cyanide fishing. Thus, total annual fishing days are only 108 on Seribu Islands, 180 on Menjangan Island and Gili Islands. Fishermen usually start their activities around 7.00 am and are back to their fishing base on 4.00 pm on Seribu Islands, 5.00 pm around Menjangan Island, and 3.00 pm on Gili Islands. Thus, total working hours per day are 8 hours on Seribu Islands, 9 hours around Menjangan Island, and 7 hours on Gili Islands.

Table 28. Characteristics of cyanide fishing

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Fishermen			
	a. owner (person)	39	26	11
	b. labour (person)	87	44	18
2.	Fishing boat			
	a. total number (unit)	39	26	11
	b. maximum length (m)	8	9	6
	c. minimum length (m)	4	4	4
	d. modus length (m)	5	6	4
3.	Annual fishing boat maintenance			
	a. maximum (times)	6	12	6
	b. minimum (times)	3	2	3
	c. average (times)	4	7	4
4.	Engine			
	a. total number (unit)	25	24	6
	b. maximum power (HP)	8.0	12.0	5.0
	c. minimum power (HP)	4.5	4.0	4.0
	d. modus power (HP)	4.5	5.5	4.5
5.	Annual engine maintenance			
	a. maximum (times)	6	12	6
	b. minimum (times)	3	3	4
	c. average (times)	6	6	5
6.	Fish harvest			
	a. total species number	87	37	30
	b. total (individual)	148795	65273	11642
	c. average (individual/fishing boat)	3815	2511	1058

All cyanide fishermen use hand made wooden boats and most of boats are 6 m long with 5.5 HP inboard-engine on Seribu Islands, 6 m long with 5.5 HP outboard-engine on Menjangan Island, and 4 m long with 4.5 HP outboard-engine on Gili Islands. Only 12 fishermen

(30.77%) on Seribu Islands, 2 fishermen (7.69%) on Menjangan Island, and 5 fishermen (45.45%) on Gili Islands used non-engine boats. Fishing boats and engines are repaired more often than 3 times per year. Fishing gears, like scoop net, goggle, and floating basket, are renewed annually, while sodium cyanide is prepared daily. Other materials that must be prepared daily are fuel for engine, food and beverages for fishing crews.

Cyanide fishing in Seribu Islands was higher than other locations, which was indicated by the highest number of fisherman, fishing boat, and fish harvest. The highest number of fish species and average harvest per boat in Seribu Islands also indicated that cyanide fishing in this location was more intensive than other locations.

There are strong correlations between fuel consumption and engine size ( $r = 0.83$  in Seribu Islands,  $r = 0.72$  in Menjangan Island, and  $r = 0.96$  in Gili Islands), and between food and beverages number and crew number in fishing boat ( $r = 0.73$  in Seribu Islands,  $r = 0.97$  in Menjangan Island, and  $r = 0.91$  in Gili Islands). Correlations between fishing boat size and size of engine, and between fishing boat size and the number of fishing crew are strong in Menjangan Islands ( $r = 0.77$  and  $r = 0.82$  respectively) but weak in Seribu Islands ( $r = 0.36$  and  $r = 0.26$  respectively) and Gili Islands ( $r = 0.16$  and  $r = 0.37$  respectively). It shows that cyanide fishing is well organised in Menjangan Island than in Seribu Islands and Gili Islands. Fishing boat size in Seribu Islands is smaller than in Menjangan Island but the number of fishing crews are greater.

Most of fishermen on Seribu Islands used 50 grams cyanide a day, while those on Menjangan Island and Gili Islands used 60 grams cyanide a day. One cyanide tablet (2000 mg) is mixed with water (about 3 litre) in a plastic bag (in Seribu Islands) or in a plastic bottle (in Menjangan Island and Gili Islands). Thus, cyanide concentration is about 666.67 mg/l. Fishermen dived to coral areas where fishes hide, then squirted cyanide liquid to stun those fishes. Fishermen caught those shocked fishes using small scoop nets and then put them into floating baskets. Almost all of cyanide fishermen are free divers (diving without underwater breathing equipment), and it is only one fishing boat in Menjangan Island that is facilitated by a compressor (*hokah*).

#### **4.4.2. Coral Collecting**

There were 60 coral collectors (18 owners and 42 labours) on Seribu Islands (1.10% of total fishermen), 20 coral collectors (7 owners and 13 labours) around Menjangan Island (3.55% of

total fishermen), and 10 coral collectors (5 owners and 5 labours) on Gili Islands (3.09% of total fishermen). On Seribu Islands, only 16 coral collectors (2 boat owners and 14 labours) are fully depended on coral collecting as a source for their family incomes. Only 3 coral collectors (1 boat owner and 2 labours) around Menjangan Island had no other source for their family incomes, while on Gili Islands other family members of all coral collectors worked in land-based agriculture and seaweed culture.

Table 29. Characteristics of coral collecting

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Coral collectors			
	a. owner (person)	18	7	5
	b. labour (person)	42	13	5
2.	Collecting boat			
	a. total number (unit)	18	7	5
	b. maximum length (m)	9	6	5
	c. minimum length (m)	4	4	3
	d. modus length (m)	4	4	3
3.	Annual collecting boat maintenance			
	a. maximum (times)	6	6	4
	b. minimum (times)	3	3	3
	c. average (times)	3	5	3
4.	Engine			
	a. total number (unit)	6	3	
	b. maximum power (HP)	12.0	5.0	
	c. minimum power (HP)	6.0	5.0	
	d. modus power (HP)	6.5	5.0	
5.	Annual engine maintenance			
	a. maximum (times)	6	6	
	b. minimum (times)	4	4	
	c. average (times)	6	5	
6.	Coral and invertebrate harvest			
	a. total species number	54	27	21
	b. total (pieces)	60247	7976	9001
	c. average (pieces/unit fishing boat)	3347	1139	1800

Coral collecting grounds for non-engine boats are limited to the area near the collecting base. There are only 6 collectors on Seribu Islands and 3 collectors on Menjangan Island with engine boats who have wide range collecting grounds without exception of tourism area and conservation area. All of coral species are the target of coral collecting, especially the high price corals (*Acropora sp.* and *Euplexaura sp.*). Coral collectors also collected other invertebrates, such as lobster, sea star, sea urchin, coral crab, and octopus.

Similar to cyanide fishing activity, coral collecting is also a daily activity, but there was no activity on Friday (on Seribu Islands and Gili Islands) or on Sunday (on Menjangan Island) and several local holidays. Annual collecting day and daily working hours are also similar to cyanide fishing.

All coral collectors used hand made wooden boats and most of boats are 4 m long (on Seribu Islands and Menjangan Island) and 3 m long (on Gili Islands) without engine. Only 6 collectors (33.33%) on Seribu Islands and 3 collectors (42.86%) on Menjangan Island used about 5.0 to 6.0 HP engine boats. Coral collecting boats and engines are repaired more than 3 times annually. Coral collecting gears like chisel, hammer, goggle, and collecting box, are renewed annually. Other materials must be prepare daily are fuel for engine, food and beverages for collecting crews.

Coral collecting in Seribu Islands was also higher than other locations, which was indicated by the highest number of coral collectors, collecting boat, and coral harvest. The highest number of coral and invertebrate species and average harvest per boat also indicated that coral collecting in this location was more intensive than at other locations.

Most of collectors did not use underwater breathing equipment. Only one collector boat on Seribu Islands was completed by compressor with 4 rubber pipes and 4 mouth-pieces. Thus, most of collectors are free divers. Coral targets are identified by snorkelling and then one or more collectors dived to that coral area. Corals are taken by collectors using chisel and hammer, and then carefully put into collecting boxes.

#### **4.4.3. Tourism**

There were 6 tourism operators on Seribu Islands, 7 tourism operators around Menjangan Island, and 6 tourism operators on Gili Islands, which provided services for diving and snorkelling activities. Besides diving and snorkelling equipments, these tourism operators were also completed with accommodation and transportation facilities, such as hotels, cottages, restaurants, and piers. Other tourism operators only provided accommodations for family holidays, meetings and conferences, which were not correlated directly to coral reefs.

Table 30. Characteristics of tourism

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Tourism operator (unit)	6	7	6
2.	Labour (person)	138	216	603
3.	Tourism facilities			
	a. hotel (unit)	2	5	6
	b. cottage (unit)	4	2	15
	c. restaurant (unit)	5	12	22
	d. pier (unit)	4	5	3
4.	Tourism equipment			
	a. boat (unit)	12	52	47
	b. diving and snorkelling equipment (unit)	62	90	59
	c. compressor (unit)	6	6	6
5.	Sample of tourist (person)	37	41	22
6.	Origin of tourist (from sample)			
	a. foreign (person)	33	34	20
	b. domestic (person)	4	7	2
7.	Tourist activity (from sample)			
	a. Diving (person)	25	20	14
	b. Snorkelling (person)	12	21	8

The number of tourism facilities (especially cottages and restaurants) on Gili Islands were highest among other selected areas, though the number of diving operators is quite similar. These facilities were considered to be included in the analysis because these cottages and restaurants also offered snorkelling equipment for domestic tourists. These traditional cottages and restaurants were operated by local communities, which led to the high involvement of local labour.

#### 4.5. Benefits of Coral Reefs Uses

This study directly measured benefit of cyanide fishing, coral collecting and tourism (diving and snorkelling). Benefit of cyanide fishing was calculated from daily fish harvest records (individual/species) of the whole cyanide fishermen on Seribu Islands, Menjangan Island, and Gili Islands and then multiplied by fish price (US\$/individual) for each fish species. Fish prices are market prices, collected from fish exporters in Jakarta and Bali.

Fish harvest compositions were varied from the highest price blacktip reef-shark (\$25.00/individual) to the lowest price blue-green chromis (\$0.50/individual) on Seribu Islands, from the highest price emperor angelfish (\$23.00/individual) to the lowest price reticulated damselfish (\$0.40/individual) on Menjangan Island, and from the highest price royal emperor angelfish (\$11.00/individual) to the lowest price yellow damselfish

(\$0.50/individual) on Gili Islands. This broad range of fish harvest price can be clearly seen in the standard deviation, which is higher than the average fish price. Fishing benefits also varied among fishing units, which were indicated by the high standard deviation.

Table 31. Benefit of cyanide fishing

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Fish price (US\$/individual)			
	a. maximum	25.00	23.00	11.00
	b. minimum	0.50	0.40	0.50
	c. average	2.94	4.29	2.30
	d. standard deviation	3.89	5.25	2.48
2.	Fishing benefit			
	a. total (US\$)	235160.31	233452.45	26451.70
	b. maximum (US\$)	17099.86	24594.20	4269.70
	c. minimum (US\$)	696.00	3126.05	1038.00
	d. average (US\$/unit)	6029.75	8978.94	2404.70
	e. standard deviation (US\$)	4779.92	5311.95	1098.16

Total cyanide fishing benefit in Menjangan Island was almost equal to Seribu Islands, although cyanide fishing in Seribu Islands was higher than in Menjangan Island. This situation showed that cyanide fishing target in Menjangan Island was more selective than in Seribu Islands. The abundance of high price reef fishes in Seribu Islands have started to decline, which can be seen in fish distribution where coral reefs in Seribu Islands were inhabited by lower price fishes (average fish price = \$0.88/individual) compared to Menjangan Island (average fish price = \$1.03/individual).

Similar procedure was carried out to calculate benefit of coral collecting. Coral and other invertebrate harvest (piece/species) were recorded daily from the whole coral collectors on Seribu Islands and then multiplied by coral and other invertebrate prices for each species (US\$/piece). Coral and other invertebrate prices were market prices, which were collected from live coral exporters in Jakarta and Bali.

Coral harvest compositions were varied from the highest price mushrooms green hairy (\$8.00/individual) to the lowest price star polyps metallic green (\$1.00/individual) on Seribu Islands, from the highest price brown gorgonian (\$5.00/piece) to the lowest price red sea star (\$1.00/individual) on Menjangan Island, and from the highest price brown branch coral (\$6.00/piece) to the lowest price red sea star (\$1.00/individual) on Gili Islands. This broad range of coral harvest price can be seen in high standard deviations of coral price. Collecting

benefit also varied among collecting units as can be seen in higher standard deviations compared to average benefit.

Table 32. Benefit of coral and other invertebrate collecting

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Coral price (US\$/piece)			
	a. maximum	8.00	5.00	6.00
	b. minimum	1.00	1.00	1.00
	c. average	1.48	2.55	2.38
	d. standard deviation	1.47	0.99	1.29
5.	Collecting benefit			
	a. total (US\$)	163430.00	21991.00	17730.90
	b. maximum (US\$)	122159.00	5468.50	4540.10
	c. minimum (US\$)	347.00	1758.25	2806.85
	d. average (US\$/unit)	9079.44	3141.57	3546.18
	e. standard deviation (US\$)	27622.93	1352.98	729.71

Total benefit from coral collecting in Menjangan Island was lower than in Seribu Islands, although average coral price was higher in Menjangan Island than in Seribu Islands. This situation showed that coral collecting in Seribu Islands was higher than in Menjangan Island. It can be seen in relatively higher coral harvest in Seribu Islands rather than in Menjangan Island.

Benefits of tourism were calculated based on tourist expenditure data, which were collected from the sample. These data include tourist expenditures for food and beverage, hotel, transportation, and diving and snorkelling equipment rent. Average tourist expenditure was multiplied by tourist number data in year 2001, which were collected from local authorities, to calculate annual tourism benefit.

Table 33. Benefit of tourism

No.	Items	Seribu Islands	Menjangan Island	Gili Islands
1.	Tourist expenditure			
	a. maximum (US\$)	570.00	423.33	476.00
	b. minimum (US\$)	190.00	158.33	234.00
	c. average (US\$/person)	430.95	317.93	340.27
	d. standard deviation	105.18	65.37	77.95
2.	Tourist number (person)	2936	20218	11497
3.	Tourism benefit (US\$)	1265257.30	6427844.63	3912115.55

Total benefit of tourism in Menjangan Island was higher than other locations. Although average tourism expenditure in Menjangan Island was the lowest, the number of tourists was highest among other locations. Therefore, tourism operators on Menjangan Island must provided the higher number of diving and snorkelling equipment.

#### 4.6. Costs of Coral Reefs Uses

Costs of coral reefs uses can be divided into two groups, private costs and environmental costs. Private costs are the costs that must be paid directly to generate benefit from the use of coral reefs resources. On the other hand, destructive effects from coral reefs uses are calculated as environmental costs. The calculation of environmental costs also included variances calculation, which will be used to compare the results among actual activities in each selected location.

##### 4.6.1. Private Costs

Private costs of cyanide fishing include investment costs and operational costs. Investment costs are needed for buying a boat and engine. Fishermen in all selected areas renewed their fishing boats and engines every 5 years. Investment costs of cyanide fishing activity can be seen in Table 34.

Table 34. Investment costs of cyanide fishing

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Boat price			
	a. maximum (US\$/unit)	700.00	2000.00	300.00
	b. minimum (US\$/unit)	60.00	50.00	80.00
	c. average (US\$/unit)	297.95	534.04	164.55
	d. standard deviation (US\$/unit)	169.42	433.31	65.69
2.	Total boat investment (US\$)	11620.00	13885.00	1810.00
3.	Engine price			
	a. maximum (US\$/unit)	600.00	1500.00	200.00
	b. minimum (US\$/unit)	100.00	40.00	80.00
	c. average (US\$/unit)	255.29	308.13	125.83
	d. standard deviation (US\$/unit)	186.85	270.04	39.83
4.	Total engine investment (US\$)	8290.00	7395.00	755.00
5.	Total investment (US\$)	19910.00	21280.00	2565.00

Total investments of cyanide fishing on Menjangan Island were higher than on Seribu Islands. Although fishing boat and engine number on Seribu Islands was higher than on Menjangan Island. Most fishermen on Seribu Islands used smaller boats and engines.



Operational costs of cyanide fishing include labour cost, and costs for buying fishing gear (scoop net, goggle, floating basket) and logistics (food, beverage, fuel and cyanide). Maintenance costs are included in the maintenance costs for boat and engine. Operational and maintenance costs of cyanide fishing activity can be seen in Table 35.

Table 35. Operational and maintenance costs of cyanide fishing

No.	Cost	Total (US\$)	Maximum (\$/unit)	Minimum (\$/unit)	Average (\$/unit)	Std. Dev. (\$/unit)
1.	Total Seribu Islands	20185.38				
	a. Fishing gear	299.30	19.20	1.70	7.67	4.59
	b. Fuel	3099.60	324.00	32.40	114.80	71.41
	c. Logistic	7921.80	864.00	54.00	203.12	174.14
	d. Maintenance	1887.00	190.00	3.00	48.38	48.27
	e. Labour	6977.68	525.16	25.84	178.91	138.65
2.	Total Menjangan Isl.	17081.82				
	a. Fishing gear	506.40	37.10	6.50	19.48	8.65
	b. Fuel	4816.80	540.00	54.00	200.70	121.52
	c. Logistic	2863.80	291.60	14.40	110.15	81.63
	d. Maintenance	3301.00	560.00	6.00	126.96	120.50
	e. Labour	5593.82	618.10	84.01	215.15	117.96
3.	Total Gili Islands	2209.90				
	a. Fishing gear	153.40	19.00	9.60	13.95	3.60
	b. Fuel	486.00	108.00	64.80	81.00	14.62
	c. Logistic	518.40	72.00	21.60	47.13	15.82
	d. Maintenance	358.00	64.00	9.00	32.55	17.52
	e. Labour	694.10	128.37	20.91	63.10	36.07

Total operational and maintenance cost of cyanide fishing on Seribu Islands was higher than on Menjangan Island due to the higher labour and logistics cost on Seribu Islands (especially for food and beverage). In contrast, the costs for fishing gear, fuel and maintenance were higher on Menjangan Island due to the bigger boat and engine size. This situation was caused by the number of labour used, which was higher on Seribu Islands than on Menjangan Island. However, the high population density and the lack of employment alternatives have forced the unemployed to seek a part of the work force job in the marine sector. There was no regulation to limit the number of labour in traditional fishing boat (boat size under 30 gross tonnages). Local fishery agencies only offered a fishing permit, while the proper test of fishing boat was carried out by local transportation agency.

Private costs of coral collecting include investment costs and operational costs. Investment costs are needed for buying boat and engine, which are renewed every 5 years. Unlike in

cyanide fishing, the total investment cost for coral collecting on Seribu Islands was higher than on Menjangan Island. The number of coral collecting boats and engine were higher on Seribu Islands, and size and price of boat and engine were also higher than on Menjangan Island (Table 36).

Table 36. Investment costs of coral collecting

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Boat price			
	a. maximum (US\$/unit)	900.00	400.00	80.00
	b. minimum (US\$/unit)	60.00	80.00	40.00
	c. average (US\$/unit)	264.44	180.00	56.00
	d. standard deviation (US\$/unit)	246.02	117.11	14.97
2.	Total boat investment (US\$)	4760.00	1260.00	280.00
3.	Engine price			
	a. maximum (US\$/unit)	1000.00	250.00	
	b. minimum (US\$/unit)	300.00	150.00	
	c. average (US\$/unit)	475.00	200.00	
	d. standard deviation (US\$/unit)	244.52	40.82	
4.	Total engine investment (US\$)	2850.00	600.00	
5.	Total investment (US\$)	7610.00	1860.00	280.00

Operational costs of coral collecting include labour cost, and costs for buying collecting gear (chisel, hammer, goggle, collecting box) and logistics (food, beverage, and fuel). Maintenance costs are included in the maintenance costs for boat and engine. Operational and maintenance costs of coral collecting are presented in Table 37.

Total operational and maintenance cost of coral collecting on Seribu Islands was higher than on Menjangan Island, not only because the greater size of boat and engine, but also the number of labour involved in this activity was higher. Here once more the effect of population density and lack of alternative income generating on Seribu Islands can be seen.

Private costs of tourism include investment costs and operational costs. Investment costs are needed for building tourism facilities (hotel, cottage, restaurant, and pier), and for buying equipment (boat, engine, diving and snorkelling equipment). Tourism equipment is renewed every 10 years, while tourism facilities can be used for more than 25 years. Investment costs of tourism facilities and equipment can be seen in Table 38.

Table 37. Operational and maintenance costs of coral collecting

No.	Cost	Total (US\$)	Maximum (\$/unit)	Minimum (\$/unit)	Average (\$/unit)	Std. Dev. (\$/unit)
1.	Total Seribu Islands	10711.44				
	a. Gear	317.40	196.80	2.20	17.63	43.98
	b. Fuel	1188.00	540.00	54.00	198.00	161.48
	c. Logistic	4217.40	2160.00	32.40	234.30	495.41
	d. Maintenance	836.50	480.00	3.00	46.47	108.18
	e. Labour	4152.14	2081.81	20.35	230.67	488.49
2.	Total Menjangan Isl.	1703.27				
	a. Gear	104.60	19.00	9.60	14.94	3.73
	b. Fuel	324.00	117.00	99.00	108.00	7.35
	c. Logistic	379.80	72.00	27.00	54.26	16.11
	d. Maintenance	205.00	76.00	9.00	29.29	21.51
	e. Labour	689.87	295.14	34.16	98.55	83.28
3.	Total Gili Islands	254.54				
	a. Gear	11.50	2.70	2.20	2.30	0.20
	b. Logistic	108.00	59.40	10.80	21.60	19.02
	c. Maintenance	16.00	4.00	3.00	3.20	0.40
	d. Labour	119.04	63.20	10.79	23.81	19.83

Total investment cost of tourism on Gili Islands was higher than on other islands due to the higher investment cost of tourism facilities, while investment cost of tourism equipment on Menjangan Island was higher than on other islands. The number of tourism facilities on Gili Islands was higher than on other islands, while on Menjangan Island the number of tourism equipment was higher than on other islands.

Table 38. Investment costs of tourism

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Tourism facilities			
	a. maximum (US\$/unit)	97198.00	134948.00	683745.00
	b. minimum (US\$/unit)	35100.00	38981.00	465859.00
	c. average (US\$/unit)	68709.25	95461.71	555842.67
	d. standard deviation (US\$/unit)	21999.81	30529.96	64968.40
2.	Total facilities investment (US\$)	412255.00	668232.00	3335056.00
3.	Tourism equipment			
	a. maximum (US\$/unit)	31933.00	128728.00	40223.00
	b. minimum (US\$/unit)	16539.00	21867.00	25229.00
	c. average (US\$/unit)	24058.33	42359.14	33063.67
	d. standard deviation (US\$/unit)	4867.61	35594.52	5415.82
4.	Total equipment investment (US\$)	144350.00	296514.00	198382.00
5.	Total investment (US\$)	548605.00	964746.00	3533438.00

Operational costs of tourism include labour cost, and cost for buying materials. Maintenance costs are included in the maintenance costs for tourism facilities and equipment. Operational and maintenance costs of tourism activity can be seen in Table 39.

Table 39. Operational and maintenance costs of tourism

No.	Cost	Total (US\$)	Maximum (\$/unit)	Minimum (\$/unit)	Average (\$/unit)	Std. Dev. (\$/unit)
1.	Total Seribu Islands	340354.00				
	a. Material	218766.00	51889.00	18487.00	36461.00	11552.25
	b. Labour	86940.00	20790.00	7560.00	14490.00	4615.22
	c. Maintenance	34648.00	8003.00	3259.00	5774.63	1599.37
2.	Total Menjangan Isl.	568885.32				
	a. Material	363924.00	73746.00	26262.00	51989.14	15208.98
	b. Labour	135216.00	27544.00	10016.00	19316.57	5593.40
	c. Maintenance	69745.32	15211.66	7951.24	9963.62	2368.98
3.	Total Gili Islands	2683736.63				
	a. Material	2172236.76	477887.16	304095.07	362039.46	58378.13
	b. Labour	319590.00	64660.00	39750.00	53265.00	8522.68
	c. Maintenance	191909.88	39082.68	26534.00	31984.98	3771.15

Total operational and maintenance cost of tourism on Gili Islands was higher than on other locations, although the number of tourist was lower than on Menjangan Island. Average tourism expenditure on Gili Islands (\$340.27) was also higher than on Menjangan Island (\$317.93).

#### 4.6.2. Environmental Costs

Environmental cost or external cost is the cost derived from the impact of each activity in coral reefs (Barton, 1994). Pearce and Turner (1990) also called indirect cost because every activity that uses biological resources and every activity that is related to biological resources always has an impact on the resources. These impacts would reduce the abundance of the resource and the capability of the environment to reproduce the resource respectively.

Cyanide fishing, coral collecting and tourism also affect coral reef resources. These resource uses directly eliminate coral cover and indirectly eliminate coral fishes abundance. This study measured direct effects of resource uses to live coral cover. Each activity on a coral reef was observed to measure its benefit and its impact to the coral reef. Cyanide fishing and coral collecting benefits were calculated by multiplying the harvest with market price of each species, while tourism benefit was calculated by multiplying the number of tourist with average tourism expense.

The impact of cyanide fishing was calculated by direct measurements of coral cover damages due to cyanide solutions, fishing boat anchors, and fishermen trampling on corals. The impact of coral collecting was calculated by direct measurements of coral cover damage due to chisel effects, boat anchors, and collectors trampling on corals. The impact of tourism was calculated by direct measurements of coral cover damage due to boat anchors, and tourists holding, kicking and trampling on corals. Coral cover damages (per genus) were multiplied by market prices (average price per genus per piece) to estimate coral damage values.

Table 40. Impacts of actual activities to live coral covers

No.	Activity	Benefit (US\$)	Impact to live coral cover		
			cm <sup>2</sup>	%	US\$
1.	Cyanide fishing				
	a. maximum	15.60	18280.00	0.002585	203.11
	b. minimum	3.30	1050.00	0.000148	12.50
	c. average	8.25	4711.25	0.000666	53.47
	d. standard deviation	4.56	5004.24	0.000708	55.31
2.	Coral collecting				
	a. maximum	16.00	12113.00	0.001713	117.67
	b. minimum	1.75	631.00	0.000089	6.83
	c. average	4.60	3097.53	0.000438	30.29
	d. standard deviation	3.67	3387.63	0.000479	32.37
3.	Tourism				
	a. maximum	5370.00	57000.00	0.002902	190.00
	b. minimum	800.00	21000.00	0.001069	70.00
	c. average	2805.08	40384.62	0.002056	133.85
	d. standard deviation	1353.33	13054.62	0.000665	42.53

Linear equations that described impacts of measured activities to the corals were used to predict destructive effects of actual activities. The equations were constructed to estimate the destructive effects on the corals from measured activities (as described in Chapter 3):

$$Cef_c = a_1 + b_1Bf \quad (4)$$

$$Cec_c = a_4 + b_4Bc \quad (8)$$

$$Ced_c = a_7 + b_7Bd \quad (12)$$

where  $Cef_c$  = environmental cost (\$) of fishing,  $Bf$  = fish catch value or benefit of fishing (\$),  $Cec_c$  = environmental cost (\$) of coral collecting,  $Bc$  = coral collection value or benefit of coral collecting (\$),  $Ced_c$  = environmental cost (\$) of tourism, and  $Bd$  = tourism value or benefit of tourism (\$).

The impacts of measured activities to the reef fish were estimated by the linkages between fish values (\$) and live coral covers (cm<sup>2</sup>). Several linear equations were constructed to estimate these impacts (as described in Chapter 3):

$$Cef_f = a_2 + b_2Ef \quad (5)$$

$$Cec_f = a_5 + b_5Ec \quad (9)$$

$$Ced_f = a_8 + b_8Ed \quad (13)$$

$$Ce_{jf} = a_j + b_jE_j \quad (15)$$

where  $E_f$  = coral cover damage (cm<sup>2</sup>) of fishing,  $E_c$  = coral cover damage (cm<sup>2</sup>) of coral collecting,  $E_d$  = coral cover damage (cm<sup>2</sup>) of tourism,  $E_j$  = coral cover damage (cm<sup>2</sup>) of each activity, and  $Ce_{jf}$  = environmental cost of each activity (\$). All parameters of these linear equations were estimated by OLS (ordinary least square) and the results are presented in Table 41.

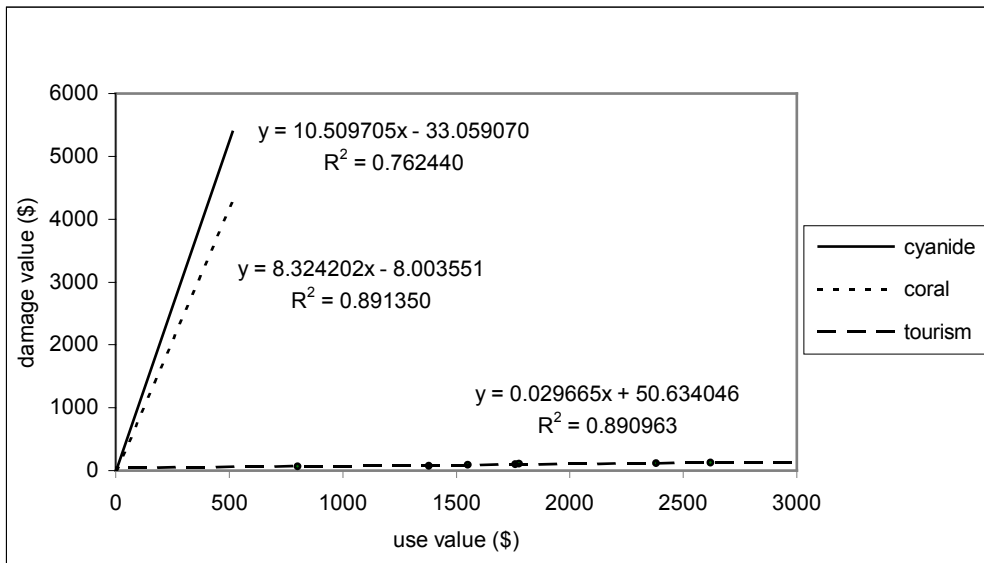
Table 41. The results of parameter estimations of environmental cost equations

No	Dependent variable	Independent variable	Intercept ( $a_i$ )	Parameter ( $b_i$ )	P-value	Adjusted $R^2$
4.	Coral damage (\$)	Fish catch (\$)	-33.05907 (17.317807)	10.5097049 <sup>*)</sup> (1.85513181)	0.000208044	0.738684
8.	Coral damage (\$)	Coral collection (\$)	-8.00355 (4.682146)	8.32420 <sup>*)</sup> (0.806049)	0.000000124	0.882992
12.	Coral damage (\$)	Tourist activity (\$)	50.63404639 (9.6740858)	0.02966482 <sup>*)</sup> (0.00312897)	0.000001256	0.881051
5.	Coral damage (cm <sup>2</sup> )	Fish catch (\$)	-3104.72447 (1575.32942)	949.30864 <sup>*)</sup> (168.753684)	0.000219805	0.735864
9.	Coral damage (cm <sup>2</sup> )	Coral collection (\$)	-861.238001 (535.976771)	860.602463 <sup>*)</sup> (92.270452)	0.000000401	0.859989
13.	Coral damage (cm <sup>2</sup> )	Tourism activity (\$)	14438.89514 (2552.33629)	9.24955748 <sup>*)</sup> (0.82552432)	0.000000235	0.912114
15.	Fish value (\$)	Coral cover (cm <sup>2</sup> )	123.78579 (15.6129712)	0.00015651 <sup>*)</sup> (0.00002853)	0.000009394	0.518569

\*) significant at  $\alpha=0.05$ , the value in parentheses are standard errors

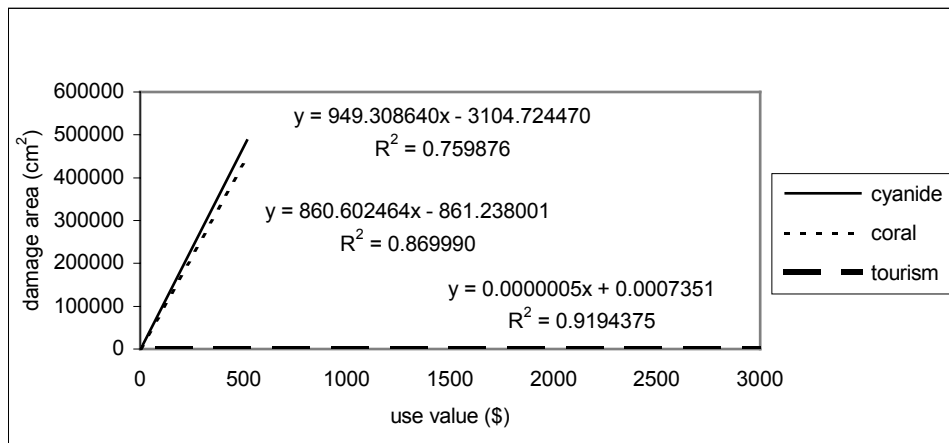
The results of parameter estimations showed that cyanide fishing and coral collecting generate higher coral damage rates than tourism, as can be seen in the slopes of equations 4 and 8 or in the corresponding parameter values ( $b_1$  and  $b_4$ ). Parameters of coral damage values from cyanide fishing and coral collecting (10.51 and 8.32 respectively) were higher than tourism (0.03). It can be clearly seen in Figure 6.

Figure 6. Impact of coral reefs uses to live coral cover value



Cyanide fishing and coral collecting also generate higher coral damage rates than tourism, as can be seen in the slopes of equations 5 and 9 or in the corresponding parameter values ( $b_2$  and  $b_5$ ). Parameters of coral damage values from cyanide fishing and coral collecting (949.31 and 860.60 respectively) were higher than from tourism (9.25). The different of these parameter values can be easily seen in Figure 7.

Figure 7. Impact of coral reefs uses to live coral cover area



Parameter estimations showed that all parameter values ( $b_i$ ) are statistically significant at  $\alpha=0.05$  because  $t^* = \hat{b}_i / \hat{\sigma}_{b_i}$  are greater than  $t_{0.025}$  or less than  $-t_{0.025}$ . The  $P$ -value of each  $b_i$  ( $P < 0.001$ ) showed the probability of a result occurring by chance in the long run if  $b_i \neq 0$  was true (Quinn and Keough, 2002). Therefore the results of these parameter estimations can be used to calculate total destructive effects from each activity in each location.

Benefits of coral reefs uses that were calculated in previous sub-chapters, were used in those equations to estimate environmental costs of coral reefs uses. The results of these estimations are listed in Table 42.

Each activity derived coral and fish value losses. These estimations showed that cyanide fishing and coral collecting derived higher value losses than benefits, but tourism generated smaller loss than benefit. The highest environmental cost was caused by cyanide fishing, and the lowest was caused by tourism.

Table 42. Environmental costs of coral reefs uses

No.	Items	Cyanide fishing	Coral collecting	Tourism	Total activity
1.	Total Seribu Islands	2506495.03	1382552.88	39542.33	3928590.24
	1. Effect to coral				
	a. value (\$)	2471432.40	1360416.31	37584.62	3869433.33
	b. standard dev. (\$)	979975.77	284534.56	3664.85	1268175.17
	c. % of total activity	63.87	35.16	0.97	100.00
	2. Effect to fish				
	a. value (\$)	35062.63	22136.57	1957.71	59156.92
	b. standard dev. (\$)	13157.06	8283.73	689.60	22130.39
	c. % of total activity	59.27	37.42	3.31	100.00
2.	Total Menjangan Island	2488292.18	186135.21	200164.82	2874592.21
	1. Effect to coral				
	a. value (\$)	2453483.29	183049.52	190733.40	2827266.21
	b. standard dev. (\$)	972858.41	38279.80	18650.88	1029789.09
	c. % of total activity	86.78	6.47	6.75	100.00
	2. Effect to fish				
	a. value (\$)	34808.89	3085.69	9431.42	47326.00
	b. standard dev. (\$)	13061.39	1108.92	3494.98	17665.29
	c. % of total activity	73.55	6.52	19.93	100.00
3.	Total Gili Islands	282019.91	150099.47	121891.30	554010.67
	1. Effect to coral				
	a. value (\$)	277966.50	147587.59	116101.91	541656.00
	b. standard dev. (\$)	110200.78	30862.68	11347.94	152411.41
	c. % of total activity	51.32	27.25	21.43	100.00
	2. Effect to fish				
	a. value (\$)	4053.41	2511.88	5789.38	12354.67
	b. standard dev. (\$)	1471.40	894.90	2123.72	4490.03
	c. % of total activity	32.81	20.33	46.86	100.00

#### 4.7. Effects of Coral Reefs Uses Overtime

Coral reef uses generated destructive effects to live coral. These effects will reduce natural growth of live corals. If natural growth of corals can compensate effects of resource uses, net annual growth rates will be positive. In other words, live corals will grow with smaller than their natural growths rates. Net annual growth of live corals will affect the harvests potential



in the next period. Thus, benefits and costs of resource uses in the next periods are affected by today's resource uses.

Destructive effects of resource uses were calculated based on percentage of live coral cover losses (as described in Chapter 3). The linear equations for calculating destructive effects are as follows:

$$Df_t = a_{10} + b_{10}Yf_t \quad (20)$$

$$Dc_t = a_{11} + b_{11}Yc_t \quad (21)$$

$$Dd_t = a_{12} + b_{12}Yd_t \quad (22)$$

where  $Df_t$  = destructive effect to live coral cover caused by cyanide fishing (%) at time  $t$  (year),  $Dc_t$  = destructive effect caused by coral collecting (%) at time  $t$  (year), and  $Dd_t$  = destructive effect caused by tourism (%) at time  $t$  (year),  $Yf_t$  = yield of fishing per species (individual),  $Yc_t$  = yield of coral collecting per species (pieces), and  $Yd_t$  = tourist number (person). All parameters of these linear equations were estimated by OLS and the results are presented in Table 43.

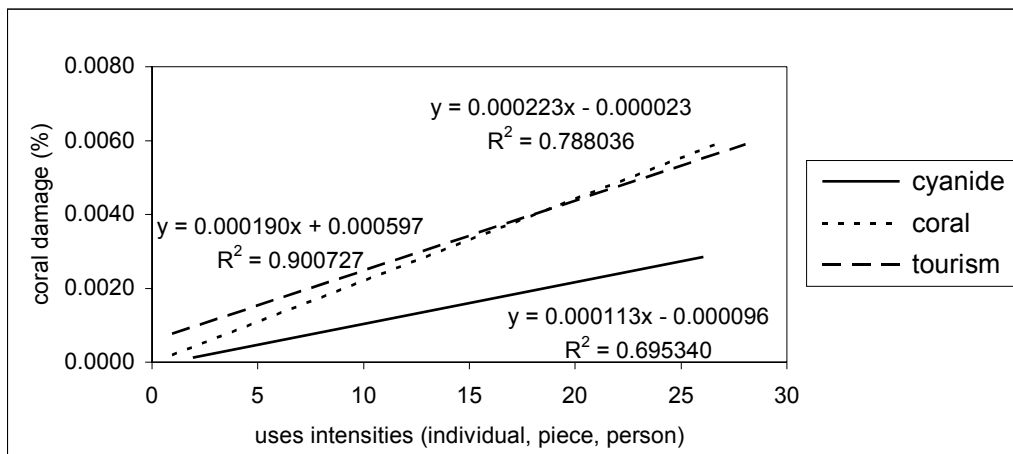
Table 43. The results of parameter estimations of live coral damage equations

No.	Dependent variable	Independent variable	Intercept ( $a_i$ )	Parameter ( $b_i$ )	$P$ -value	Adjusted $R^2$
20.	Coral damage (%)	Fish catch (individuals)	-0.00009617 (0.00019863)	0.0001129 <sup>*</sup> (0.0000236)	0.000748668	0.6648737
21.	Coral damage (%)	Coral collect (piece)	-0.0000227 (0.0000888)	0.000223 <sup>*</sup> (0.0000321)	0.000010036	0.7717310
22.	Coral damage (%)	Tourist (person)	0.000597282 (0.00015811)	0.0001896 <sup>*</sup> (0.0000189)	0.000000746	0.8917019

<sup>\*</sup>) significant at  $\alpha=0.05$ , the value in parentheses are standard errors

The results of parameter estimations showed that cyanide fishing generated lower coral damage rates than coral collecting and tourism activities, as can be seen in the slope of equation 20 or in the corresponding parameter value ( $b_{10}$ ). The parameter of coral damage percentage from cyanide fishing (0.0001129) was lower than from coral collecting and tourism (0.000223 and 0.0001896 respectively). The different among parameters can be easily seen in Figure 8.

Figure 8. Impact of coral reefs uses to live coral cover percentage



Parameter estimations showed that all parameter values ( $b_i$ ) are statistically significant at  $\alpha=0.05$  because  $t^* = \hat{b}_i / \hat{\sigma}_{b_i}$  are greater than  $t_{0.025}$  or less than  $-t_{0.025}$ . The  $P$ -value of each  $b_i$  ( $P < 0.001$ ) showed the probability of a result occurring by chance in the long run if  $b_i \neq 0$  was true (Quinn and Keough, 2002). Thus, the results of these parameter estimations can be used to calculate annual destructive effects from each activity in each location. Annual coral cover damage of each activity in each location can be calculated by substituting annual fishing yield, coral collecting yield and tourist number into the equations.

Total cyanide fishing harvest (individual), coral collecting harvest (piece) and the number of tourists (person) from coral reefs uses that were described in previous sub-chapters, were inserted into equation 20 to 22 to estimate annual destructive effects of each activity. The results of these estimations can be seen in Table 44.

Table 44. Annual destructive effects of actual coral reef uses

No.	Activity	Yield	Destructive effect (%)	Standard deviation (%)
1.	Total Seribu Islands		30.80	12.13
	a. Cyanide fishing	148795 individuals	16.81	7.84
	b. Coral collecting	60247 pieces	13.43	4.17
	c. Tourism	2936 persons	0.56	0.12
2.	Total Menjangan Island		12.99	4.83
	a. Cyanide fishing	65273 individuals	7.37	3.44
	b. Coral collecting	6828 pieces	1.78	0.55
	c. Tourism	20218 persons	3.83	0.84
3.	Total Gili Islands		5.50	1.72
	a. Cyanide fishing	11642 individuals	1.31	0.61
	b. Coral collecting	9001 pieces	2.01	0.62
	c. Tourism	11497 persons	2.18	0.48

The result of estimations showed that total effect of all activities in Seribu Islands (30.80%) was higher than in other locations due to the high effect of cyanide fishing (16.81%) and coral collecting (13.43%). The impact of coral collecting in Seribu Islands was higher than the total impacts of all activities in other locations. This situation showed that cyanide fishing and coral collecting in Seribu Islands were very intensive.

Cyanide fishing in Seribu Islands and Menjangan Island generated the most destructive effects compared to other activities, while tourism generated the most destructive effects in Gili Islands. The lowest impact was generated by tourism in Seribu Islands, by coral collecting in Menjangan Islands, and by cyanide fishing in Gili Islands.

The natural growth rate of corals in Seribu Islands, which are dominated by *Acropora*, is 10.55 cm or 22.21% annually. In Menjangan Island where corals are dominated by *Porites*, the natural growth rate of corals is 2.80 cm or 5.68% annually. While the natural growth rate of corals in Gili Islands, which are dominated by *Fungia*, is 1.80 cm or 3.63% annually (CSO, 2001). Thus, the net annual growth rates of coral reefs that are affected by actual coral reefs uses are negative (-8.59% in Seribu Islands, -7.31% in Menjangan Island, and -1.87% in Gili Islands). These net annual growth rates of coral reefs are integrated in extended cost benefit analysis as variables that affected potential benefits and costs overtime.

#### 4.8. Variance Analysis

There are 19 variables in the stochastic model for economic analysis of coral reefs uses, which have different variances for each variable in each selected location. The variances of the variables are described in Table 46. Total variances in the model were calculated according to the equations 19, 23 and 24 with assumptions that there were no correlations among variables in each activity, between each activity, and among time periods. Therefore equations 34, 35 and 36 were used to calculated variances of incorporated variables as follows:

$$\text{var}(Gn_t) = \text{var}(Df_t) + \text{var}(Dc_t) + \text{var}(Dd_t)$$

$$\text{var}(Bt_t) = \text{var}(Bf_t) + \text{var}(Bc_t) + \text{var}(Bd_t)$$

$$\text{var}(PVB_t) = \{(1+i)^t\}^2 \cdot \text{var}(B_t)$$

$$\text{var}\left(\sum_{t=1}^n PVB_t\right) = (PVB_t \cdot Gn_t)^2 \left\{ \text{var}(PVB_t) (PVB_t)^{-2} + \text{var}(Gn_t) (Gn_t)^{-2} \right\}$$

$$\text{var}(Ce_t) = \text{var}(Cef_{ct}) + \text{var}(Cef_{ft}) + \text{var}(Cec_{ct}) + \text{var}(Cec_{ft}) + \text{var}(Ced_{ct}) + \text{var}(Ced_{ft})$$

$$\text{var}(Cd_t) = \text{var}(Cdf_i) + \text{var}(Cdf_t) + \text{var}(Cdc_i) + \text{var}(Cdc_t) + \text{var}(Cdd_i) + \text{var}(Cdd_t)$$

$$\text{var}(Ct_t) = \text{var}(Ce_t) + \text{var}(Cd_t)$$

$$\text{var}(PVC_t) = \{(1+i)^t\}^2 \cdot \text{var}(C_t)$$

$$\text{var}\left(\sum_{t=1}^n PVC_t\right) = (PVC_t \cdot Gn_t)^2 \left\{ \text{var}(PVC_t)(PVC_t)^{-2} + \text{var}(Gn_t)(Gn_t)^{-2} \right\}$$

$$\text{var}(NPV) = \text{var}\left(\sum_{t=1}^n PVB_t\right) + \text{var}\left(\sum_{t=1}^n PVC_t\right)$$

Table 45. The variances of variables in selected locations

No.	Variable	Variance ( $s^2$ or $\sigma^2$ )		
		Seribu Islands	Menjangan Island	Gili Islands
1.	$Bf_t$	22847588.77	28216846.72	1205949.38
2.	$Bc_t$	763026209.70	1830542.19	532475.36
3.	$Bd_t$	95365337702.56	1746609458892.86	803207342689.14
4.	$Cdf_i$	123820.25	478130.33	17610.33
5.	$Cdf_t$	178551.28	194796.45	8585.76
6.	$Cdc_i$	256853.40	47653.06	8320.00
7.	$Cdc_t$	1590381.28	26199.51	7821.40
8.	$Cdd_{if}$	483991627.08	932078681.06	4220892424.89
9.	$Cdd_{ie}$	23693616.89	1266970089.27	29331095.89
10.	$Cdd_t$	314572359.51	405847689.38	4351625645.04
11.	$Cef_{ct}$	193464062216.63	190664089380.93	2446464897.93
12.	$Cef_{ft}$	40951674.61	40358286.25	512174.06
13.	$Cec_{ct}$	17352519434.29	314073906.44	204154941.13
14.	$Cec_{ft}$	16233250.08	290906.58	189455.17
15.	$Ced_{ct}$	2772498.92	71805625.09	26582385.14
16.	$Ced_{ft}$	112499.14	2889641.73	1066959.19
17.	$Df_t$	12.37	2.38	0.08
18.	$Dc_t$	3.73	0.07	0.08
19.	$Dd_t$	0.003	0.147	0.048

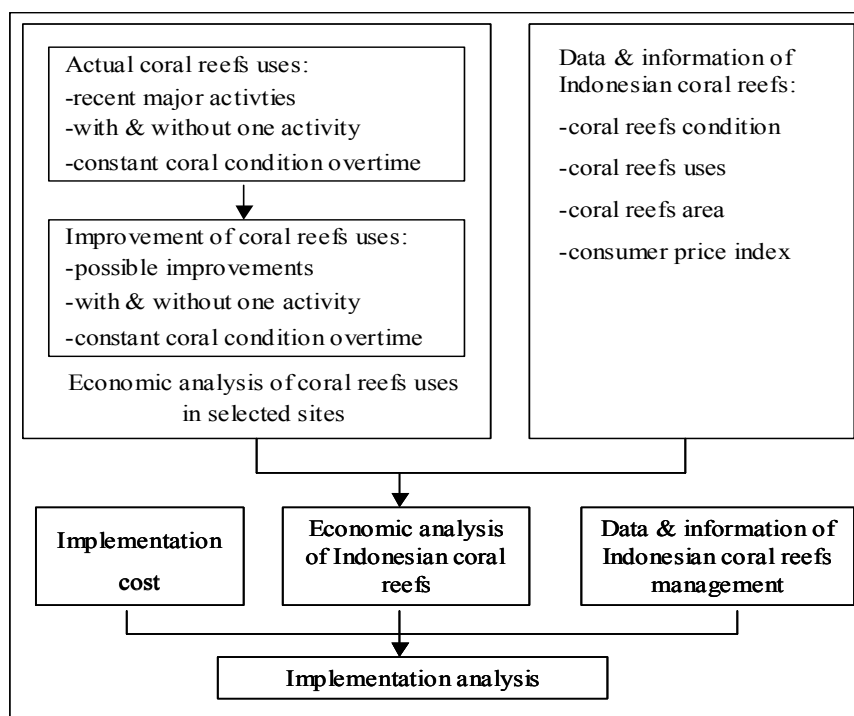
The variances in Table 45 were calculated using equation 29 (see Chapter 3), which generated different results for each variable depended on the variability and the value of each variable. Therefore the variance among variables could not be compared without their variables values. These variances were used to calculated total variance of expected net present values. The variables in Table 45 are  $Cef_{ct}$  = cyanide fishing impact to live coral (\$),  $Cef_{ft}$  = cyanide fishing impact to the fish (\$),  $Bf_t$  = benefit of cyanide fishing (\$),  $Bc_t$  = benefit of coral collecting (\$),  $Cec_t$  = total environmental cost of coral collecting (\$),  $Cec_{ct}$  = coral collecting impact to the coral (\$),  $Cec_{ft}$  = coral collecting impact to the fish (\$),  $Bd_t$  = benefit of tourism (\$),  $Ced_t$  = total environmental cost of tourism (\$),  $Ced_{ct}$  = tourism impact to the coral (\$),  $Ced_{ft}$  = tourism impact to the fish (\$),  $Cdf_t$  = private costs of cyanide fishing (\$),  $Cdc_t$  = private costs of coral collecting (\$),  $Cdd_t$  = private costs of tourism (\$),  $Df_t$  = destructive impact of cyanide fishing to live coral cover at year t (%),  $Dc_t$  = destructive impact of coral collecting at year t (%),  $Dd_t$  = destructive impact of tourism at year t (%).

## CHAPTER 5. ECONOMIC ANALYSIS OF CORAL REEFS

Economic analyses of natural resources were carried all over the world to help natural resource management by selecting the best alternative of resource use. Most of economic analyses of coral reefs, as reviewed in previous chapters, calculated deterministic net present value (Sawyer, 1992; Cesar, 1996; Pet-Soede *et al*, 1999; Cesar, 2000). Only Hodgson and Dixon (1988) used regression to estimate coral reefs degradation but did not concern stochastic value. Other studies that calculated both deterministic and stochastic values were carried out to help rubber production management, but the variance of stochastic values were simulated based on deterministic results (Purnamasari, 1999).

Stochastic net present values are calculated in this study and the variances incorporated are calculated according to the assumptions of normal distribution of original data. Of course several assumptions are needed to simplify calculations (see Chapter 3), otherwise variances calculation will be complicated and needed further analysis of statistical model. The most important analyses are the scenarios, which can be divided in actual coral reefs uses and the improvement of coral reefs uses. These analyses are started from an economic analysis of actual coral reefs uses in selected sites and will be completed by implementation analysis of coral reefs use improvements on Indonesian coral reefs (see Figure 9).

Figure 9. Flow of economic analysis

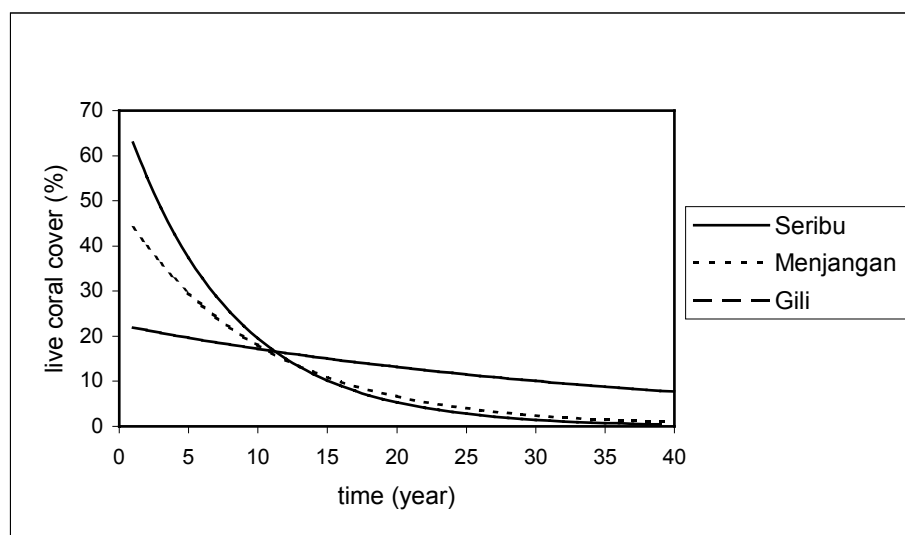


Based on economic analyses of coral reefs uses in selected areas and condition and uses of Indonesian coral reefs, net present values were estimated with similar scenarios. Implementation costs and recent coral reefs management in Indonesia were considered for implementation analysis of coral reefs use improvements.

### 5.1. Economic Analysis of Coral Reefs Uses in Selected Areas

All variances were held in relation to the assumptions of normal distribution of original data in this stochastic model of economic analysis. Therefore the time period of analysis was calculated based on linear regression of destructive effects of coral reefs uses and live coral cover in each selected site related to the natural coral growth rates. The result of this calculation is presented in Figure 10.

Figure 10. Live coral cover overtime due to actual coral reefs uses



The figure showed that live coral covers were 2.78% in Seribu Islands, 4.08% in Menjangan Island, and 11.57% in Gili Islands after 25 years of coral reefs uses. These coral conditions are very poor, but coral fishes are estimated still to exist, although fish values are very low. Hence the time period of analysis of 25 years was considerable. Cesar (1996) also used this time period in economic analysis for all activities in Indonesian coral reefs based on deterministic proxies of coral reefs destruction.

The 10% discount rate is usually used for economic analysis of renewable resource developments (Barton, 1994). Ruitenbeek (1991) used 10% discount rate based on World Bank recommendation for economic analysis in Indonesia. Cesar (1996), Cesar (2000), and Pet-Soede *et al* (1999) also used 10% discount rate in their economic analysis of coral reefs

uses in Indonesia. This study also used 10 % discount rate as a base for economic analysis, but a range of discount rates from 0 % to 50 % was used in the sensitivity analysis.

### 5.1.1. Actual Coral Reef Uses

The results from costs and benefits identification of actual coral reefs uses were used to calculate net present value, which consider parameter changes during the time period of analysis. Benefits, costs, and coral condition will be changed due to impacts of activities. Live coral damages, which were caused by today's activities, will reduce the natural growth of coral. Decreasing of coral condition will affect benefits and costs of activities in following period. This situation will continue until coral resource uses will no longer be generating profit.

Annual natural growth of coral is 22.21% on Seribu Islands, 5.68% on Menjangan Island, and 3.63% on Gili Islands. Actual coral reefs uses caused live coral damages 30.80%, 12.99%, and 5.50% respectively. Thus, live coral cover will decrease 8.59%, 7.31%, and 1.87% annually due to the impacts of resource uses (see Figure 10). If it assumes that coral reefs users reduce their efforts due to decreasing benefits of their activities, benefits and costs of coral reefs uses would also decrease. The changes of benefits and costs were also assumed equal to the decrease of live coral cover. The results of extended cost benefit analysis based on these assumptions can be seen in Table 46.

Table 46. Expected Net Present Value (NPV) of actual coral reefs uses

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	-14.678	17.249	2.257
2.	Standard deviation (million \$)	3.148	2.103	0.532
3.	Coefficient of variation	-0.214	0.122	0.236

The result showed that actual coral reefs uses on Seribu Islands generated negative expected NPV, while expected NPVs are positive on Menjangan Island and Gili Islands. This negative expected NPV was affected by the high environmental costs from cyanide fishing and coral collecting. Coefficient variations were higher on Seribu Islands and Gili Islands than on Menjangan Island due to variability of inputs used in cyanide fishing on Seribu Islands and Gili Islands, as can be seen in a weak correlation between labour and boat size.

From previous calculations, it was clearly seen that cyanide fishing generated the highest environmental cost. If cyanide fishing was prohibited, the growth of live coral only affected by coral collecting and tourism. Thus, annual net coral growth will be equal to 8.22% in Seribu Islands, 0.07% in Menjangan Island, and -0.55% in Gili Islands. The results of calculation after prohibiting cyanide fishing are presented in Table 47.

Table 47. Expected NPV of actual coral reefs uses without cyanide fishing

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	-12.387	46.472	4.983
2.	Standard deviation (million \$)	1.859	0.671	0.420
3.	Coefficient of variation	-0.150	0.014	0.088

The result shows that even without cyanide fishing, coral reefs uses on Seribu Islands still generate a negative expected NPV. This indicates that environmental cost of coral collecting on Seribu Islands is considerable to eliminate benefits. Here can also be seen that cyanide fishing affects coefficient of variation, which is reduced considerably without cyanide fishing.

If coral collecting was also prohibited, tourism was the only activity that affected annual growth. Thus annual net coral growth will be equal to 21.66% in Seribu Islands, 1.84% in Menjangan Island, and 1.45% in Gili Islands. The results of NPV calculation after prohibiting cyanide fishing and coral collecting can be seen in Table 48.

Table 48. Expected NPV of actual coral uses without cyanide fishing and coral collecting

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	41.140	54.960	7.485
2.	Standard deviation (million \$)	0.246	0.600	0.274
3.	Coefficient of variation	0.006	0.011	0.038

After prohibiting cyanide fishing and coral collecting, expected NPV of actual coral reefs use in Seribu Islands is positive. Although costs of coral reef use increased due to idle capital and foregone benefits from cyanide fishing and coral collecting, the benefit of tourism is still high enough to generate a positive expected NPV. The variability of coral collecting can be seen on the reduction of coefficient of variation, which was higher in Seribu Islands and Gili Islands than in Menjangan Island. Compared to the previous calculation, the probability values in all locations are increased. It shows that cyanide fishing and coral collecting are more risky in terms of variance (Levy and Sarnat, 1999).



### 5.1.2. Improvement of Coral Reef Uses

Previous calculations of destructive effects from major actual activities showed that coral reefs resources were reduced overtime without improvements of coral reefs uses. Two possibilities to improve coral reefs uses were:

- 1) intensity arrangement of actual activities, and
- 2) technical improvement of coral reefs uses.

#### 5.1.2.1. Intensity Arrangement of Coral Reef Uses

Intensity arrangements of coral reef uses are carried out to estimate the number of activities to maintain actual coral reef condition overtime. Constant coral conditions will be achieved if the number of activities are arranged to generate total impacts equal to the natural growth of coral. The number of each actual activity should be reduced or added to achieve the equal impacts on natural growth of coral and a positive net present value. As described in previous chapters, natural growth of coral are 22.21% in Seribu Islands, 5.68% in Menjangan Island, and 3.63% in Gili Islands, while total impact of coral reef uses are 30.80% in Seribu Islands, 12.98% in Menjangan Island, and 5.50% in Gili Islands. If all actual coral reef uses should be kept, the number of cyanide fishing must be reduced by 50.19% in Seribu Islands, 87.05% in Menjangan Island, and 50.00% in Gili Islands. The number of coral collecting must be reduced by 13.55% in Seribu Islands, 50.00% in Menjangan Island, and 60.42% in Gili Islands, while tourism must be increased by 300.00% in Seribu Islands, and should remain constant in Menjangan Island and Gili Islands.

As a consequence of intensity changes of actual coral reefs uses, benefits and costs of all activities on Seribu Islands will be adjusted, while tourism activities on Menjangan Island and Gili Islands are held constant. The results of calculations that considered these consequences are presented in Table 49.

Table 49. Expected NPV of actual coral reefs uses with intensity arrangement

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	9.335	46.681	5.132
2.	Standard deviation (million \$)	4.650	1.008	0.414
3.	Coefficient of variation	0.498	0.022	0.081

The results show that intensity arrangement of actual coral reefs uses would generate a positive expected NPV. Here also showed that coefficient of variation on Seribu Islands was higher than other locations, which was caused by the high variability in cyanide fishing.

### 5.1.2.2. Technical Improvement of Coral Reef Uses

Technical improvement of coral reefs uses is carried out to modify actual coral reefs uses by better means for better coral reefs condition overtime. The objectives of resource use improvements are to reduce environmental costs. Previous calculations of environmental costs showed that cyanide fishing generated highest environmental cost than other activities. Thus, the cyanide fishing method must be changed by another method. Field measurement showed that fishermen in the study area have the ability to operate barrier net fishing without significant difficulties. Although this fishing method highly reduced the damaging impact on coral, the impact from fishing operation and boat anchor cannot be avoided. Fishing boat anchor and the bottom part of the barrier net still destroys coral reefs, but this destruction effects are smaller than cyanide fishing impacts. The results of field measurement of impact from barrier net fishing operation are presented in Table 50.

Table 50. Impact of barrier net fishing to live coral cover

No.	Item	Benefit (US\$)	Impact to live coral cover		
			cm <sup>2</sup>	%	US\$
1.	Total	98.80	23165.00	0.00328	262.88
2.	Maximum	15.65	9140.00	0.00129	101.56
3.	Minimum	3.00	320.00	0.00005	3.56
4.	Average	8.23	1930.42	0.00027	21.91
5.	Standard deviation	4.60	2427.52	0.00034	26.80

The impact of tourism (diving and snorkelling) is twofold: impact from tourists due to their expertise in diving and snorkelling, and impact from tourism boat anchors. The impact of tourism boat anchor can be reduced by building mooring buoys in favourite tourism zones. Based on the previously preferred diving and snorkelling zones in each site, it was needed to built 6 mooring buoys on Seribu Islands, 3 mooring buoys on Menjangan Island, and 4 mooring buoys on Gili Islands, to avoid damages from tourism boat anchor on coral reefs. Thus, impacts of this improved tourism are reduced as can be seen in Table 51.

Table 51. Impact of improved tourism to live coral cover

No.	Item	Benefit (US\$)	Impact to live coral cover		
			cm <sup>2</sup>	%	US\$
1.	Total	36466.00	189000.00	0.009622	626.67
2.	Maximum	5370.00	30000.00	0.001527	100.00
3.	Minimum	800.00	6000.00	0.000305	20.00
4.	Average	2805.08	14538.46	0.000740	48.21
5.	Standard deviation	1353.33	7229.75	0.000368	23.63

There is no other single method to reduce the impact of coral collecting until now. Although coral harvest management is applied by the so-called *rotation method*, it was only spread out the impacts. The total impacts were similar but it were divided and distributed to the separated areas. If the impacts from barrier net fishing and improved tourism activities are assumed to be linear, as described in previous equations, the results from parameters estimation of barrier net fishing and improved tourism can be seen in Table 52.

Table 52. Parameter estimations of environmental cost equations of improved activities

No	Dependent variable	Independent variable	Intercept ( $a_i$ )	Parameter ( $b_i$ )	$P$ -value	Adjusted $R^2$
1.	Coral damage (\$)	Fish catch (\$)	-14.420613095 (11.25596513)	4.4121977219 <sup>*)</sup> (1.205770396)	0.00439463854	0.5297136
3.	Coral damage (\$)	Tourism activity (\$)	16.6444044498 (12.45024161)	0.0112512864 <sup>*)</sup> (0.004026890)	0.01745995267	0.3619279
4.	Coral damage (cm <sup>2</sup> )	Fish catch (\$)	-1357.7473128 (1020.800863)	399.37214325 <sup>*)</sup> (109.3510371)	0.00444606572	0.5286775
6.	Coral damage (cm <sup>2</sup> )	Tourism activity (\$)	4742.88174158 (3768.719330)	3.4920895453 <sup>*)</sup> (1.218949663)	0.01538300989	0.3752369
8.	Coral damage (%)	Fish catch (\$)	-0.0000756275 (0.000107917)	0.0000516468 <sup>*)</sup> (0.000012845)	0.00243562298	0.5796102
10.	Coral damage (%)	Tourism activity (\$)	0.00020581902 (0.000216325)	0.0000694617 <sup>*)</sup> (0.000025970)	0.02161320209	0.3389824

\*) significant at  $\alpha=0.05$ , the value in parentheses are standard errors

Parameter estimations showed that all parameter values ( $b_i$ ) are statistically significant at  $\alpha=0.05$  because  $t^* = \hat{b}_i / \hat{\sigma}_{b_i}$  are greater than  $t_{0.025}$  or less than  $-t_{0.025}$ . The  $P$ -value of each  $b_i$  ( $P<0.05$ ) showed the probability of a result occurring by chance in the long run if  $b_i \neq 0$  was true (Quinn and Keough, 2002). Thus, the results of these parameter estimations can be used to calculate total destructive effects of barrier net fishing and improved tourism. Benefits of coral reefs uses that were presented in previous tables, were used in the equations to estimate environmental costs. The results of this estimation can be seen in Table 53.

Table 53. Environmental costs of improved coral reefs uses

No.	Location	Barrier net	Improved tourism	Total
1.	Total Seribu Islands	889178.21	15068.61	904246.82
	1. Effect to coral			
	a. value (\$)	876635.48	14252.55	890888.03
	b. standard deviation (\$)	533744.03	4716.54	538460.57
	2. Effect to fish			
	a. value (\$)	12542.73	816.06	13358.79
	b. standard deviation (\$)	4667.34	283.95	4951.30
2.	Total Menjangan Island	139544.27	75976.58	215520.85
	1. Effect to coral			
	a. value (\$)	137472.97	72338.89	209811.86
	b. standard deviation (\$)	83689.89	24003.09	107692.98
	2. Effect to fish			
	a. value (\$)	2071.30	3637.69	5708.99
	b. standard deviation (\$)	731.51	1315.52	2047.04
3.	Total Gili Islands	85520.95	46295.30	131816.25
	1. Effect to coral			
	a. value (\$)	84204.29	44032.62	128236.91
	b. standard deviation (\$)	51256.17	14604.44	65860.61
	2. Effect to fish			
	a. value (\$)	1316.67	2262.67	3579.34
	b. standard deviation (\$)	456.26	802.35	1258.61

Fishermen revenues will decrease from \$235,160.31 to \$198,687.91 on Seribu Islands, from \$233,452.45 to \$31,160.75 on Menjangan Island, and from \$26,451.70 to \$19,087.70 on Gili Islands, if the results from field measurements of barrier net fishing are applied to previous fishing harvest data. Five species of fishes, such as angelfish (*Pomacanthus sp.*), polkadot box fish (*Ostracion cubicus*), long finned bat fish (*Platax pinnatus*), psychedelic fish (*Synchiropus picturatus*), and marine beta (*Calloplelesiopt altivelis*), cannot be captured by barrier net due to their hiding behaviour in coral reefs. The use of barrier net fishing method will also affect fishing cost. Private cost will decrease because annual costs for purchasing cyanide (\$4,455.00 on Seribu Islands, \$1,791.00 on Menjangan Island, and \$518.40 on Gili Islands) are higher than annual costs for buying barrier nets (\$205.50 on Seribu Islands, \$371.00 on Menjangan Island, and \$114.00 on Gili Islands). Environmental costs of fishing also decrease from \$2,506,495.03 to \$889,178.21 on Seribu Islands, from \$2,488,292.18 to \$139,544.27 on Menjangan Island, and from \$282,019.91 to \$85,520.95 on Gili Islands.

Private cost of tourism will increase due to the cost of mooring buoy (\$3,600.00 on Seribu Islands, \$1,800.00 on Menjangan Island, and 2,400.00 on Gili Islands), but environmental cost will decrease from \$39,542.33 to \$15,068.61 on Seribu Islands, from \$200,164.82 to

\$75,976.58 on Menjangan Island, from \$121,891.30 to \$46,295.30 on Gili Islands. The prohibition of coral collecting will make the benefit and cost from this activity equal to zero. On the other hand, labour and capital from this activity will be idle and the opportunity cost of this capital and labour together with foregone benefit must be taken into account in the economic analysis.

The results of parameter estimations were also used to calculate annual destructive effects of improved coral reefs uses by inserting annual fishing yield and tourist number into the equations. This calculation showed that total effects of improved coral reefs uses to live coral cover were 7.37% on Seribu Island, 3.20% on Menjangan Island, and 1.32% on Gili Islands. Net annual growths of corals, which were calculated from natural growth minus total effects, were 14.85% on Seribu Islands, 2.47% on Menjangan Island, and 2.31 % on Gili Islands. The changes of benefits and costs were assumed to be proportional to the increase of live coral cover. The results of NPV calculations with this assumption are presented in Table 54.

Table 54. Expected NPV of coral reef uses with technical improvement

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	0.010	61.003	8.568
2.	Standard deviation (million \$)	0.009	1.114	0.423
3.	Coefficient of variation	0.972	0.018	0.049

The results show that improved coral reef uses on Seribu Islands generated smallest expected NPV due to the relatively higher fishing and lower tourism. Although the change of fishing method highly reduced the impact on live coral cover, the environmental cost are still very high due to high fishing intensity. If this result is compared to the intensity arrangement of coral reefs uses, expected NPV of actual coral reefs uses with intensity arrangement on Menjangan Island and Gili Islands are less than expected NPV of coral reefs uses with technical improvement. It seems that it is possible to combine technical improvement and intensity arrangement of coral reefs uses as will be described in the next sub-chapter.

### 5.1.2.3. Combination of Technical Improvement and Intensity Arrangement

A positive expected NPV can be generated from coral reefs uses by applying technical improvement or intensity arrangement. The aim of technical improvement is to achieve better coral condition overtime compared to the actual coral condition. Better coral condition overtime will increase net benefits of coral reefs uses. It is also possible to increase benefits of coral reefs uses by arranging improved resource uses to achieve constant coral condition

overtime. If this possibility is applied, the intensity of barrier net fishing on Seribu Islands, Menjangan Island, and Gili Islands can be increased by 181.66%, 59.37%, and 441.95% respectively, while improved tourism can be increased by 900.00% on Seribu Islands, 100.00% on Menjangan Island, and remained constant on Gili Islands.

As a consequence of increasing barrier net fishing and improved tourism, benefits and costs of coral reefs uses will also increase. This consequence is considered in the economic analysis of coral reefs uses. The results of economic analysis of improved coral reefs uses with intensity arrangement can be seen in Table 55.

Table 55. Expected NPV of improved coral reefs uses with intensity arrangement

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Expected NPV (million \$)	55.717	100.360	6.356
2.	Standard deviation (million \$)	23.468	2.651	0.501
3.	Coefficient of variation	0.421	0.026	0.079

The results show that a combination of technical improvement and intensity arrangement of coral reefs uses generates positive expected NPVs in all locations. These positive expected NPVs are higher than expected NPVs from technical improvement alone or intensity arrangement alone, except on Gili Islands. The highest expected NPV of coral reefs uses on Gili Islands is gained if only technical improvement is applied to coral reefs uses.

### 5.1.3. Implementation of Improved Coral Reefs Uses

After several previous calculation of expected NPV, it is important to consider the possibilities of applying improved coral reefs uses. The costs that are needed to implement the improved coral reef uses such as costs for supporting fishermen to change their fishing method, for controlling fishing yields, and for patrolling fishing grounds. The cost for supporting fishermen can be formed as price incentive where price for fishing yields are increased with certain value if fishermen use barrier net. Patrolling cost is needed to monitor the use of barrier net fishing method and the use of mooring buoys. Controlling cost is needed to check fish harvest before sold to fish traders (see Table 56).

Table 56. Annual implementation costs of improved coral reefs uses

No.	Items	Seribu Island	Menjangan Island	Gili Islands
1.	Price incentive (\$)	6419.68	1489.80	742.63
2.	Patrolling cost (\$)	65895.00	76877.50	32947.50
3.	Controlling cost (\$)	7200.00	8400.00	3600.00
Total implementation cost		79514.68	86767.30	37290.13

Based on interviews with fish traders, the average increase of fish price that they are willing to pay for healthy fish is about 3.79%/individual on Seribu Islands, 3.29%/individual on Menjangan Island, and 3.65% on Gili Islands. These implementation costs were considered in NPV calculation and of course the result will be less than previous calculation, as can be seen in Table 57.

Table 57. Expected NPV of improved coral reefs uses with implementation costs

No.	Item	Seribu Islands	Menjangan Island	Gili Islands
1.	Intensity arrangement			
	a. Expected NPV (million \$)	6.681	45.907	4.800
	b. Standard deviation (million \$)	4.776	1.011	0.416
	c. Coefficient of variation	0.715	0.022	0.087
2.	Technical improvement			
	a. Expected NPV (million \$)	-3.171	60.046	8.163
	b. Standard deviation (million \$)	3.173	1.117	0.425
	c. Coefficient of variation	-1.101	0.019	0.052
3.	Combination of improvement			
	a. Expected NPV (million \$)	48.499	98.785	6.017
	b. Standard deviation (million \$)	20.992	2.656	0.503
	c. Coefficient of variation	0.433	0.027	0.084

The most likely implementation on Seribu Islands is to improve coral reefs uses and arrange their intensity, which will generate the highest expected NPV and the lowest coefficient of variation. The highest expected NPV and the lowest coefficient of variation on Gili Islands would be achieved if technical improvement of coral reefs uses is applied. The highest expected NPV on Menjangan Island will be achieved if improved coral reefs uses is arranged, but the lowest coefficient of variation will be achieved if technical improvement of coral reefs uses is applied. Based on the E-V rule, the rule to choose the best alternative resource allocation based on expected values and variances (Levy and Sarnat, 1999), it was preferred to choose a combination of improved coral reefs uses on Seribu Islands and Menjangan Island, and technical improvement of coral reefs uses on Gili Islands.

#### 5.1.4. Other Scenarios of Coral Reefs Uses

There are other ways to manage coral reefs uses, which have not been considered in the previous analysis. These scenarios are:

1. Actual coral reefs uses without tourism activity (AWD),
2. Only cyanide fishing activity (AOF),
3. Only coral collecting activity (AOC),
4. Actual coral reefs uses without coral collecting activity (AWC),
5. Only barrier net fishing activity (IOF),
6. Only improved tourism activity (IOD), and
7. Intensity arrangement of improved tourism activity only (IAOD).

These scenarios are considered in the economic analysis for such reasons as follows:

- a. to calculate the potential losses or gains if one or more resource uses are prohibited,
- b. to construct the basic representative resource use models for further analyses in similar resource uses in other areas of Indonesian coral reefs.

Foregone benefits, idle capital, and implementation costs are also considered in the NPV calculation. The results of calculation of these scenarios are presented in Table 58.

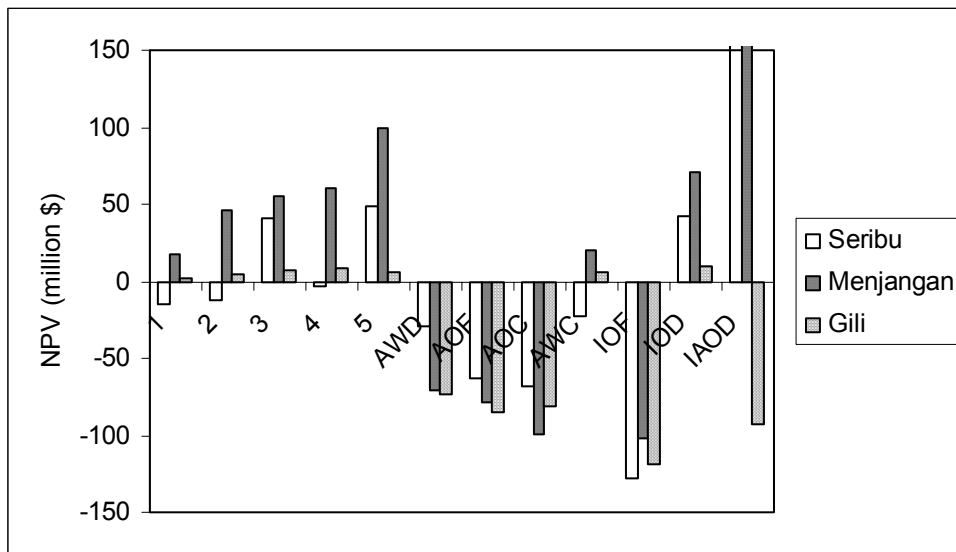
Table 58. The results of other scenarios of coral reefs uses

No.	Simulation	Seribu Islands		Menjangan Island		Gili Islands	
		<i>E</i> (NPV)	Coef. var.	<i>E</i> (NPV)	Coef. var.	<i>E</i> (NPV)	Coef. var.
1.	AWD	-29.821	-0.131	-71.187	-0.043	-73.642	-0.010
2.	AOF	-62.522	-0.078	-78.991	-0.040	-85.037	-0.006
3.	AOC	-67.854	-0.041	-99.075	-0.006	-81.340	-0.006
4.	AWC	-22.312	-0.158	20.034	0.107	6.253	0.068
5.	IOF	-128.370	-0.040	-101.988	-0.010	-119.297	-0.003
6.	IOD	42.056	0.008	71.035	0.013	9.189	0.043
7.	IAOD	740.540	0.035	203.201	0.030	-93.468	-0.025

The results of analysis showed that the highest expected NPV on Seribu Islands and Menjangan Island will be gained if only improved tourism is allowed and increased to maintain constant coral condition overtime. The highest expected NPV on Gili Islands will be gained if only improved tourism is allowed to achieve better coral condition overtime. If the choice of alternative of coral reefs uses is mainly based on coefficient of variation, improved tourism generates the lowest variability among positive expected NPVs in all locations. The comparison among the results of calculation of these scenarios and the results from previous calculation can be seen in Figure 11.



Figure 11. Results of calculation of different scenarios



The different results among selected locations are caused by the different intensities of activities and different actual live coral covers. Although the intensities of cyanide fishing and coral collecting on Seribu Islands are high and on Menjangan Island are moderate, actual live coral covers are better than on Gili Islands. This also indicates that coral reef degradation on Gili Islands is caused by other, that is previous blast fishing activities, while the increase of cyanide fishing and coral collecting on Seribu Islands and Menjangan Island have already started to destroy coral reef. This economic analysis used a 10 % discount rate to the whole analyses. Various discount rates can be used in sensitivity analysis and will be described in Chapter 5.1.5.

### 5.1.5. Sensitivity Analysis

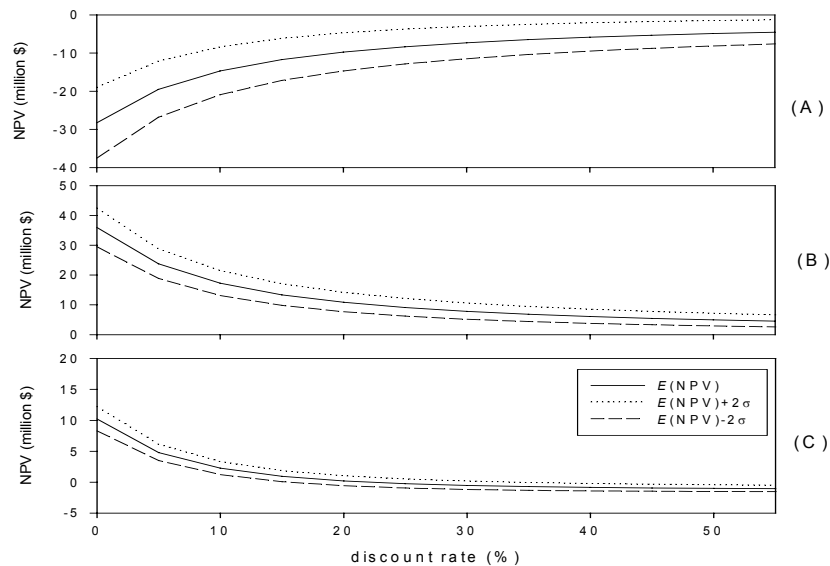
Sensitivity analysis has usually been confined to adjust economic factors such as the discount rates and price assumptions (Barton, 1994). In previous studies sensitivity analyses were conducted for different purposes. Sawyer (1992) used sensitivity analysis to show the impact of declining fish catch and the variation of discount rates. A sensitivity analysis was also carried through by Cesar (1996) to check how robust the results are for variations in the assumptions. Pet-Soede *et al* (1999) used the same reason as Cesar (1996) in their sensitivity analysis.

This study also carried out sensitivity analysis to check how robust the results are for variations of the discount rates. Various discount rates between 0% to 55% were used to check the results of economic analysis of actual coral reefs uses, coral reefs uses with

technical improvement, coral reefs uses with intensity arrangement, and coral reefs uses with combination of technical improvement and intensity arrangement. The result of sensitivity analysis of actual coral reefs uses are presented in Figure 12.

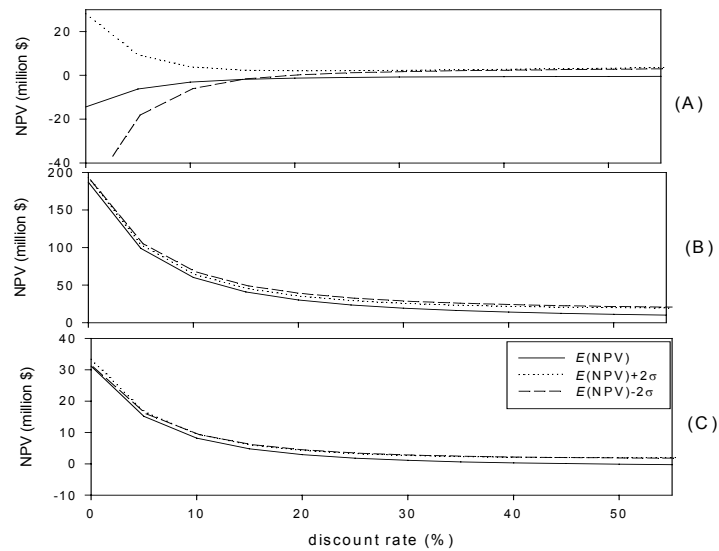
Decisions over discount rates will be influenced by political situations. High rates might speed up renewable resource depletion rates, and might imply extinction of more species being economically efficient. Low rates will increase the level of resource extraction (Hanley and Spash, 1994). A range of 0% to 10% discount rates is usually used in stable political situations, 10% to 20 % in unstable political situations, 20% to 30% in very unstable political situations, and more than 30% in extremely unstable political situations.

Figure 12. Sensitivity analysis of actual coral reefs uses on Seribu Islands (A), Menjangan Island (B), and Gili Islands (C)



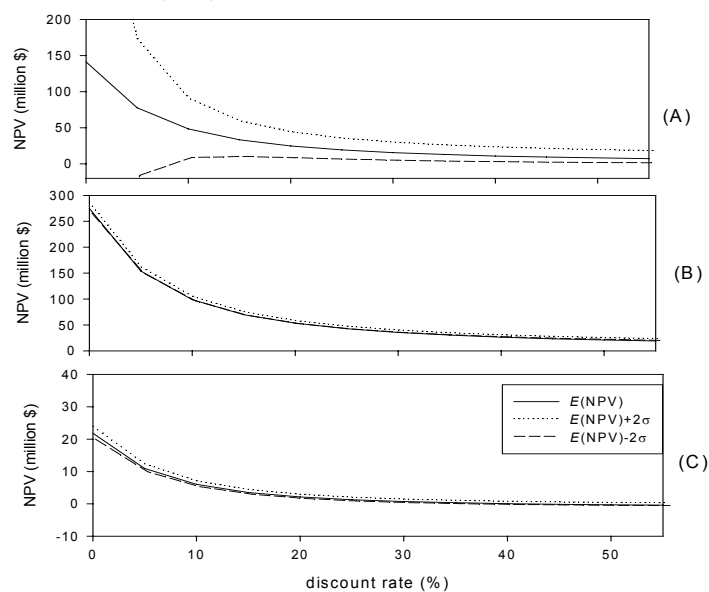
The result showed that expected NPV of actual coral reefs uses on Seribu Islands are always negative for various discount rates, while expected NPV of actual coral reefs uses on Menjangan Islands are always positive. On Gili Islands, expected NPV of actual coral reefs uses will be negative for a 25% discount rate. Therefore, the actual coral reefs uses on Gili Islands will generate negative expected NPV in very unstable political situations. Sensitivity analysis was also carried out to the technical improvements of coral reefs uses, and the results of this sensitivity analysis can be seen in Figure 13.

Figure 13. Sensitivity analysis of coral reefs uses with technical improvement on Seribu Islands (A), Menjangan Island (B), and Gili Islands (C)



The sensitivity analysis of coral reefs uses with technical improvement showed similar result to actual coral reefs uses, where expected NPV on Seribu Islands are always negative for various discount rates. In contrast, expected NPV of improved coral reefs uses on Menjangan Island are always positive for various discount rates. Expected NPV of coral reefs uses with technical improvement on Gili Islands will be negative for a 50% discount rate. Technical improvement of coral reefs uses on Gili Islands generates a higher expected NPV, and also generates an expected NPV that is less sensitive towards changes in the discount rate.

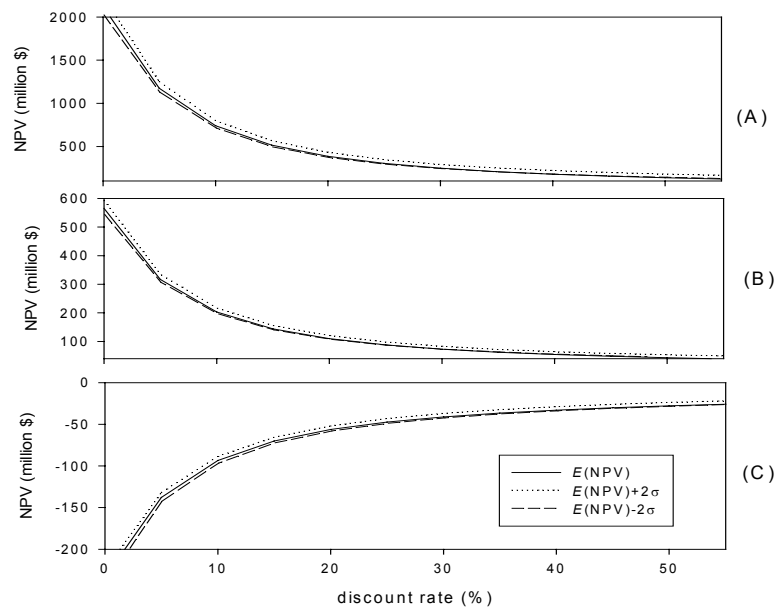
Figure 14. Sensitivity analysis of combination of improved coral reefs uses on Seribu Islands (A), Menjangan Island (B), and Gili Islands (C)



The results of the sensitivity analysis of coral reefs uses that included technical improvements and an intensity arrangement (Figure 14) showed that expected NPVs are always positive on Seribu Islands and Menjangan Islands for various discount rates. The result of this sensitivity analysis on Gili Islands is almost similar to previous sensitivity analysis where the expected NPV is negative for a 45% discount rate.

A sensitivity analysis is also carried out for the case of the best alternative coral reefs uses, especially for Seribu Islands and Menjangan Island, which is only improved tourism is allowed. The results of this sensitivity analysis are presented in Figure 15.

Figure 15. Sensitivity analysis of improved tourism activity with intensity arrangement on Seribu Islands (A), Menjangan Island (B), and Gili Islands (C)



The results of this sensitivity analysis showed that the expected NPVs in Seribu Islands and Menjangan Island are always positive for various discount rates. Expected NPV on Seribu Islands is higher than on Menjangan Island due to the great increase of tourism to maintain the constant coral condition overtime. Negative expected NPV on Gili Islands for various discount rates indicate that tourism should keep constant to reach better coral condition overtime. Therefore the best alternative of coral reefs uses on Gili Islands is to apply technical improvement of coral reefs uses to achieve better coral condition overtime.

Table 59. Sensitivity analysis due to decreasing number of tourist

No.	Number of tourist	Expected NPV (\$)		
		Seribu Islands	Menjangan Island	Gili Islands
1.	Normal	7359718.38	18984608.66	8162730.56
2.	Decrease 19.17%	2949757.03	14503850.09	3084.47
3.	Decrease 19.18%	2947456.58	14501512.73	-1171.99
4.	Decrease 31.99%	581.00	11507328.18	-5453705.45
5.	Decrease 32.00%	-1719.44	11504990.80	-5457961.91
6.	Decrease 81.22%	-11324530.99	403.59	-26408289.51
7.	Decrease 81.23%	-11326831.44	-1933.79	-26412545.98

Sensitivity analysis is also carried out based on fluctuation of tourist number. The result showed that the most sensitive expected NPV is on Gili Islands, where decreasing of 19.18% tourist number will generate negative expected NPV. In contrast, expected NPV on Menjangan Island is still positive although tourist number decrease 81.22%.

## 5.2. Economic Analysis of Indonesian Coral Reefs

### 5.2.1. Actual Coral Reefs Uses

Cyanide fishing, coral collecting, and tourism with the different intensities were practised in Indonesian coral reefs. Based on field observation, data from CSO (2001), and Hopley and Suharsono (2000), the combinations of coral reefs uses formed several uses patterns as can be seen in Table 60.

Table 60. Actual coral reefs use patterns in Indonesia

No.	Use patterns	Area (km <sup>2</sup> )	Percentage (%)
1.	Only cyanide fishing	3571.13	4.17
2.	Only coral collecting	12498.94	14.58
3.	Only tourism	7142.25	8.33
4.	Cyanide fishing and coral collecting	23212.31	27.08
5.	Cyanide fishing and tourism	5356.69	6.25
6.	Coral collecting and tourism	8927.81	10.42
7.	Cyanide fishing, coral collecting, tourism	24997.88	29.17
Total		85707.00	100.00

Source: Field observation (2001), CSO (2001), and Hopley and Suharsono (2000).

Live coral cover (m<sup>2</sup>) of each coral area in Indonesia is calculated based on the data of percentage live coral cover (%) and coral area (km<sup>2</sup>), which are summarised in Table 12. The results from this calculation are inserted into the linear regression between live coral cover (m<sup>2</sup>) and fish value (\$) of the data from selected locations (Table 61) to calculate potential benefits of cyanide fishing in Indonesia. Potential benefits of coral collecting in Indonesia are calculated by inserting live coral cover of each area into the linear regression between live

coral cover (m<sup>2</sup>) and coral value (\$) of the data from selected locations (Table 61). Afterwards these potential benefits are adjusted by *consumer price index* (CPI) for each coral reefs area in Indonesia.

The adjusted potential benefit of cyanide fishing of each area are inserted into the linear regression between benefit and cost of the cyanide fishing data from selected locations (see Table 61) to calculate potential costs of cyanide fishing in Indonesia. Potential costs of coral collecting in Indonesia are calculated by inserting adjusted potential benefit of coral collecting of each area into the linear regression between benefit and cost of the coral collecting data from selected locations (Table 61). Of course the corresponding variances are calculated using similar procedure as previous.

Table 61. Parameter estimations of regression equations of actual coral reefs uses

No	Dependent variable	Independent variable	Intercept ( $a_i$ )	Parameter ( $b_i$ )	$P$ -value	Adjusted $R^2$
1.	Fish value (\$)	Coral cover (m <sup>2</sup> )	123.24713347 (15.90033547)	1.5579303996 <sup>*)</sup> (0.290437347)	0.00001288899	0.5070599
2.	Coral value (\$)	Coral cover (m <sup>2</sup> )	1725.4158068 (419.492749)	124.0408105 <sup>*)</sup> (7.66250256)	0.00000000004	0.9062670
3.	Cyanide cost (\$)	Cyanide benefit (\$)	1.98982396 (29.1609825)	0.09697395 <sup>*)</sup> (0.00343015)	0.00000000002	0.9141142
4.	Coral cost (\$)	Coral benefit (\$)	165.1908382 (63.7524768)	0.047783462 <sup>*)</sup> (0.0028161167)	0.00000000003	0.9082011

<sup>\*)</sup> significant at  $\alpha=0.05$ , the value in parentheses are standard errors

All coral reefs areas in Indonesia have a potential to develop for tourism (diving and snorkelling) because tourism facilities have already provided. The data of tourism sector also shows that every province in Indonesia had been visited by foreign tourism (see Appendix 47). Coral reefs areas in Bangka Island, Belitung Island, Mentawai Islands, Nias Island, Riau Islands, Enggano Islands, Sunda Strait, Derawan Island, Bunaken Island, Banda Island, and Komodo Island, have been used for diving and snorkelling with different intensities (see Appendix 44). The potential number of tourist is estimated by the data of tourism sector and the potential benefits and costs are calculated based on benefits and costs of tourism in selected locations with three categories: high, moderate and low. The results of this calculation are also adjusted by *consumer price index*.

The data in selected locations showed the different intensity of major actual coral reefs uses. The highest intensities of cyanide fishing and coral collecting are on Seribu Islands and the lowest are on Gili Islands, which can be seen in the number of fishermen, fish harvest, and

coral harvest. The highest intensity of tourism is on Menjangan Island and the lowest is on Seribu Islands, which indicated by the number of diving and snorkelling. Thus, Seribu Islands represents high cyanide fishing and coral collecting, and low tourism. Menjangan Island represents moderate cyanide fishing and coral collecting, and high tourism. Gili Islands represents low cyanide fishing and coral collecting, and moderate tourism. These representations of coral reef uses are considered to calculate environmental costs of Indonesian coral reefs uses by inserting potential benefits and costs of each coral reefs use in each coral reefs area into the equations 4-15 in Chapter 4 with parameters in Table 41. The results of this calculation for Sumbawa Island (as an example) are presented in Table 62.

Table 62. The results of calculation of actual coral reefs uses in Sumbawa Island

No.	Item	Cyanide fishing	Coral collecting	Tourism
1.	Potential benefit (million \$)	83.34	66.36	6547.51
2.	Potential direct cost (million \$)	10.07	4.82	677.74
3.	Intensity	Low	Low	Low
4.	Environmental cost (million \$)	888.22	561.25	379.80

The calculation of expected NPV for a 25 years period include coral reefs growth rates, which are affected by the dominant species in each coral reefs area (see Appendix 44). The potential benefits are inserted into the equations 20-22 in Chapter 4 with parameters in Table 43, to calculate the effects of actual coral reefs uses overtime. The results of NPV calculation of Indonesian coral reefs are presented according to the use patterns as can be seen in Table 63.

Table 63. Expected NPV of actual coral reefs uses in Indonesia

No.	Use patterns	Area (km <sup>2</sup> )	E(NPV) (million \$)	Standard deviation	Coefficient of variation
1.	Only cyanide fishing	3571.13	-1736.547	386.480	-0.223
2.	Only coral collecting	12498.94	-3504.835	710.698	-0.203
3.	Only tourism	7142.25	650.957	91.082	0.140
4.	Cyanide fishing and coral collecting	23212.31	-250.568	195.192	-0.779
5.	Cyanide fishing and tourism	5356.69	258.185	214.982	0.833
6.	Coral collecting and tourism	8927.81	223.018	81.135	0.364
7.	Cyanide fishing, coral collecting, tourism	24997.88	67.208	57.328	0.853
	Total	85707.00	-4292.583	1736.898	-0.405

The expected NPV of actual coral reefs uses in Indonesia is negative due to intensive cyanide fishing and coral collecting in 45.83% Indonesian coral reefs areas. In area with low cyanide fishing or coral collecting, the expected NPV will be negative if there is no actual tourism. In contrast, tourism will generate positive expected NPV if there are no high cyanide fishing or coral collecting. This situation is caused by the environmental costs of cyanide fishing and

coral collecting that are higher than their benefits, while benefit of tourism is higher than environmental costs of cyanide fishing, coral collecting, and tourism (see Table 62 as an example). The uncertainty of cyanide fishing and coral collecting are also higher than tourism, which can be seen in the coefficient of variation.

### 5.2.2. Technical Improvement of Coral Reefs Uses

The technical improvements of Indonesian coral reefs uses are carried out with the similar scenario as the selected locations where cyanide fishing and coral collecting had to be banned and should be substituted by barrier net fishing. Potential benefit and cost of barrier net fishing is calculated by the similar procedure to cyanide fishing, but parameters of regression are changed because five fish species cannot be captured by barrier net fishing, and fishermen do not need to buy cyanide (see Table 64).

Table 64. Parameter estimations of regression equations of improved coral reefs uses

No	Dependent variable	Independent variable	Intercept ( $a_i$ )	Parameter ( $b_i$ )	P-value	Adjusted $R^2$
1.	Fish value (\$)	Coral cover ( $m^2$ )	120.346269504 (16.049054366)	1.54568037869 <sup>*)</sup> (0.29315386338)	0.0000163901	0.4981432
2.	Fishing cost (\$)	Fishing benefit (\$)	29.73870638539 (4.68622147056)	0.08235823885 <sup>*)</sup> (0.00779576810)	0.00000000001	0.5959231

<sup>\*)</sup> significant at  $\alpha=0.05$ , the value in parentheses are standard errors

Potential benefit of tourism is calculated with the same procedure as actual coral reefs uses, but potential cost will increase to built 288 mooring buoys in tourism zones. The environmental costs are calculated by inserting the potential benefits into equations 4-15 in Chapter 4 with parameters in Table 52. The calculation of potential benefits and costs of improved coral reefs uses in Indonesia also adjusted by CPI and include variance calculation. The results of this calculation for Sumbawa Island (as an example) can be seen in Table 65.

Table 65. The results of calculation of improved coral reefs uses in Sumbawa Island

No.	Item	Barrier net fishing	Tourism
1.	Potential benefit (million \$)	82.69	6547.51
2.	Potential direct cost (million \$)	30.42	681.41
3.	Intensity	Low	Low
4.	Environmental cost (million \$)	478.59	217.86

The effects of improved coral reefs uses to coral condition overtime are calculated by inserting the potential benefits into the equations 20-22 in Chapter 4 with parameters in Table



43. The implementation costs are also taken into account in the economic analysis and the results are presented in Table 66.

Table 66. Expected NPV of Indonesian coral reefs uses with technical improvement

No.	Use patterns	Area (km <sup>2</sup> )	E(NPV) (million \$)	Standard deviation	Coefficient of variation
1.	Only barrier net fishing	3571.13	-247.813	65.528	-0.264
2.	Only barrier net fishing	12498.94	-541.946	56.684	-0.105
3.	Only improved tourism	7142.25	859.998	168.686	0.196
4.	Only barrier net fishing	23212.31	-84.072	29.508	-0.351
5.	Improved coral reefs uses	5356.69	391.212	172.439	0.441
6.	Improved coral reefs uses	8927.81	301.504	89.846	0.298
7.	Improved coral reefs uses	24997.88	566.100	276.280	0.488
Total		85707.00	1244.982	858.972	0.690

The results show that after technical improvement was applied in Indonesian coral reefs uses, expected NPV increased although in several coral reefs sites were negative. The negative expected NPVs are caused by intensive barrier net fishing in 45.83% Indonesian coral reefs areas. Although barrier net fishing reduces the impact, the environmental costs are still higher than benefits (see Table 65 as an example). Therefore, the intensity of improved coral reefs uses must be regulated.

### 5.2.3. Combination of Improvement of Coral Reefs Uses

The results from the above calculation show that barrier net fishing must be reduced and tourism must be introduced (to the areas without tourism in the past and present) and must be increased (to the areas with low tourism intensity). This scenario is carried out to maintain actual coral reefs conditions overtime. Thus, the total impacts of improved coral reefs uses are retained similar to the natural coral growth rates. The result of technical improvement and intensity arrangement of Indonesian coral reefs uses are presented in Table 67.

Table 67. Expected NPV of Indonesian coral reefs uses with combination improvement

No.	Use patterns	Area (km <sup>2</sup> )	E(NPV) (million \$)	Standard deviation	Coefficient of variation
1.	Improved coral reefs uses	3571.13	153.646	125.509	0.817
2.	Improved coral reefs uses	12498.94	333.873	212.611	0.637
3.	Only improved tourism	7142.25	3578.224	2320.991	0.649
4.	Improved coral reefs uses	23212.31	298.363	276.231	0.926
5.	Improved coral reefs uses	5356.69	572.180	392.934	0.687
6.	Improved coral reefs uses	8927.81	326.466	300.927	0.922
7.	Improved coral reefs uses	24997.88	856.768	789.225	0.921
Total		85707.00	6119.519	4418.428	0.722

The Economic analysis of Indonesian coral reefs uses with technical improvement and intensity arrangement generates a positive expected NPVs. Introducing low tourism and reducing high barrier net fishing to moderate barrier net fishing will increase the expected NPVs. This analysis also takes into account implementation costs to calculate expected NPV. Therefore it is possible to manage Indonesian coral reefs for gathering constant coral condition overtime and higher expected NPV. Of course, the coefficient of variation will increase because the introduction of tourism activities in several sites will increase the uncertainty of expected NPV. The introduction of a new activity with corresponding variance will add the previous variance.

The above analyses show that the impacts from coral reefs uses can be reduced by technical improvements. Although the impact of fishing can be reduced by using barrier net, the environmental cost is still higher than benefit. In contrast, tourism always generates smaller environmental cost than benefit. The uncertainty of tourism is also smaller than fishing, but the future demand of fish is more stable than the demand of tourism. The number of tourist who visits Indonesia is depended on the national security, while Indonesia had been categorised as the risky country for several times in the last five years.

## **CHAPTER 6. THE IMPLEMENTATION OF POLICY RECOMMENDATIONS**

### **6.1. Actual Management of Indonesian Coral Reefs**

Indonesian government have ratified CITES in the year 1978 (Presidential Decree No. 43/1978) in order to regulate coral reefs exploitation. The Indonesian Science Agency have been delegated as CITES Scientific Authority, and the Directorate General of Nature Protection and Conservation (under Ministry of Forestry) have been delegated as CITES Management Authority. Destructive fishing practices were also prohibited throughout Indonesian marine waters according to the Fisheries Act No. 9 in the year 1985. Since 1990, Indonesia have concerned about management of protected areas (Presidential Decree No. 32/1990). Thereafter several marine areas have been declared as nature reserves to protect coral reefs organisms from exploitation. The exploitation of coral reefs organisms was only allowed in the use zones far away from sanctuary zones. In the year 1999, Ministry of Marine Affairs and Fisheries was created in order to manage fishery resources, including coral reefs. During the period of 1997 to 2002, the government of Indonesia has implemented of the existing policies and regulation through several projects, such as Marine Resources Evaluation Project (MREP), Coastal Resource Management Project (CRMP), and Coral Reef Rehabilitation and Management Program (COREMAP).

Unfortunately, the distribution of responsibilities of coral reefs management among different government agencies was not followed by the clear coordination mechanism. Therefore conflict of interest among agencies in central and local government and among central and local governments cannot be avoided. According to the state regulation No. 46/1993, on the one hand, the Directorate General of Fisheries (at the moment under the Ministry of Agriculture) and the Fisheries Agency of local government are allowed to give licences for exploiting coral reefs organisms. On the other hand, the Ministry of Forestry also regulates the capture of napoleon wrasse and live corals by the decree No. 62/kpts-II/1998. Meanwhile, in the state regulation No. 25/2000 about the implementation of Act No. 22/1999 (Local Autonomy), it is stated that the management of the utilisation and trading of live corals are still under the authority of the central government.

Conflict of interest between Marine Nature Reserve Authority of Seribu Islands and local government of Jakarta has led to the misallocation of coral reefs areas. This is manifested in the different land use planning programs, which were promoted by both government institutions. At present, many discussions among local stakeholders cannot be concluded

since there is no information available about cyanide fishermen and thus there is no consensus about the status of the resource and about the patterns of resource utilisation (Pet-Soede *et al*, 1999).

The Indonesian government that was elected for 5 years and hence will make short-term regulations, which will lead to short time profit oriented and centralised decisions. In contrast, coral reefs that have a long recovery time up to more than 30 years (Suharsono, 2001) cannot be managed in short time period. Government is elected or re-elected at certain times, but economic life continues for decades (Seldon, 1998). In the state regulation No. 15/1990 it was implicitly stated that the utilisation of marine resources is aimed for the government fund. It was explicitly written that the Ministry of Agriculture is allowed to give licences for exploitation of marine resources. Three years later, this state regulation is changed by the state regulation No. 46/1993, after the local government proposed to be allowed to give licences to increase the fund of local government.

The application of autonomy act only transfers the power from central government to local government rather than resource management. Politicians would rather use the issues of coral reefs management only for the extension of their power and at the end this pursuit for power will lead to the destruction of coral reefs. For example, the recent major role in coral reefs management in study areas is still held by Marine Nature Reserve Authority of Seribu Islands, West Bali Nature Reserve Authority, and Marine Tourism Park Authority of Gili Indah. These government institutions still continue patrolling, but not routinely, and apply enforcement against inhabitants who practise illegal utilisation of coral reefs organisms. National marine police and navy were included only in a sporadically few patrollings. These authorities are occasionally involved in ad hoc enforcement of the laws against destructive fishing, but no structural plan has been implemented on national or local levels (Pet-Soede *et al*, 1999). Lack of monitoring in the field caused uncontrolled exploitation, which will lead to the destruction of coral reefs area, even in the protected zone. In the future, this situation is even more severe due to destructive fishing practices by local communities to harvest more and more coral reef organisms. Although marine conservation areas have been established throughout Indonesia, it should be noted that to date many of these conservation areas occur only on paper since there has been no commitment to staffing and operational funding so far (Suharsono, 2001).

Inconsistency of regulations has led to the lack of standardisation in exploitation and trade of coral reefs organisms. On the one hand, the central government continued to give licenses to the big scale companies for exploiting coral reef organisms in certain reef locations. On the other hand, the local government gave permit for small scale fishing operations in the same reef locations. Coastal communities, which have low-level education and limited access to the capital, could not escape from the government power that reduced their traditional fishing rights. They could only provided capital for small-scale cyanide fishing and coral collecting (Erdmann, 1998). Therefore local communities tried to get as much profit from coral reefs as fast as they can without considering the methods of exploitation and the consequences of their application. However, the big scale fishing companies seem to support the open-access nature of reef fisheries, and show little interest in efforts to restrict their access. This is likely to be related to their ultra-mobile fishing vessels, which can be operated even in the remote coral reefs areas.

This is an example where open access conditions are approximated. De facto open access can arise if management regulations are ineffective. This might occur, over time, if fishermen are adaptive and can reduce or eliminate the effect of regulations that previously restricted catch (Conrad, 1995). In some cases property rights may be defined but unenforceable, and the lack of enforcement then becomes equivalent to removing the right. For example, if fishing rights are expressed in terms of areas, and others are not excluded from those areas, their encroachment will render the right meaningless (Hanna, 2001). In the scramble for open access of natural resources, some people are more equal than others. In open-waters fisheries, the advantage goes to those who can practise the most ruthless extractive technologies. Open access therefore often leads to not one tragedy, but two: the abuse of resource, and *the stealing of the commons* by powerful and wealthy interests at the expense of others (Boyce, 2002).

The above description showed that Indonesian coral reefs have been managed as an open access resources. In open access fisheries people compete for resource benefits by fishing as fast as they can and catching as much as they can, so one person's catch affects the amount of fish available to others (Hanna, 2001). Therefore the competition among coral reefs users has led to the destructive methods to harvest reef organisms. Cyanide fishing and coral collecting were the commonly used methods all over Indonesia. Both methods generated highly destructive effects to the coral reefs based on the measurements in selected locations. The environmental costs caused by both activities were almost ten times their benefits. For

example, total benefit from cyanide fishing and coral collecting on Seribu Islands were \$235,160.31 and \$163,430.00 respectively, and the environmental costs were \$2,506,495.03 and \$1,382,552.88 respectively.

The annual destructive effects of cyanide fishing and coral collecting on the coral were considerably high, particularly on Seribu Islands with high intensities of cyanide fishing and coral collecting. Cyanide fishing and coral collecting on Seribu Islands generated the highest impact of all locations. The annual damage caused by cyanide fishing on Seribu Islands (16.81%) was very high, higher than the results from McManus *et al* (1997) study in Philippines, which was only 0.4% annually. The damage is also higher than the damage from blast fishing (3.75% annually), which was calculated by Pet-Soede *et al* (1999) on Spermonde Islands (South West Sulawesi, Indonesia). Teams of divers on Seribu Islands spread high concentrations of cyanide while searching for ornamental fishes - this type of treatment may actually be worse than blasting (Pet-Soede and Erdmann, 1998).

The impact of cyanide fishing was calculated by direct measurement of the affected coral reefs areas. The measurement is based on the visual observation of the spreading cyanide solution at the time when it was squirted. In other words, this study only measured the temporal effect of cyanide. Thus, the measurement of cyanide fishing effect can be expanded by continually monitoring on this effect. As Jones and Steven (1997) state, the toxicity of cyanide to corals under experimental conditions is no proof for degradation on the scale of reef because the rate of coral loss due to cyanide fishing may be lower than the rate of natural coral growth, or it may be that under natural conditions cyanide is dissipated too rapidly by water currents to affect exposed corals.

The target of cyanide fishing is the whole fish species. The record of fish harvest from selected locations showed that about 87 species on Seribu Islands, 37 species on Menjangan Island and 30 species on Gili Islands were sold by fishermen during study period. Meanwhile, underwater visual census identified 96 species of coral fishes in Seribu Islands, 84 species in Menjangan Island, and 65 species in Gili Islands. The target fish species of cyanide fisheries in Indonesia are all species, which spawning at masses specific sites (Pet and Pet-Soede, 1999). Pet-Soede and Erdmann (1998) also indicated specifically that cyanide fishing on Seribu Islands was the most destructive fishing practice observed with a wider range of target species.

The target of coral collecting is also the whole species of corals and invertebrates. The yield record of coral collecting showed about 46 species on Seribu Islands, 20 species on Menjangan Island and 13 species on Gili Islands sold by coral collectors during the study period. Moreover, Bentley (1998) recorded about 127 to 131 coral species exported from Indonesia, although these particular trade data did not generally distinguish between live and dead coral.

In contrast, tourism generated less environmental cost. Total benefit from tourism on Seribu Islands was \$1,265,257.30, and only generated environmental cost as much as \$39,542.33 (only 3.12% of total benefit). The highest negative impact of tourism activities was present on Menjangan Island. The result from impact calculation showed that 20,218 dives and snorkels on Menjangan Island generated 3.83% coral damage, 11,497 dives and snorkels on Gili Islands generated 2.18% coral damage, and 2,936 dives and snorkels on Seribu Islands generated 0.56% coral damages. But these impacts were still within the range of impact from the similar activity in other countries as published by Schleyer and Tomalin (2000), which showed that 0-25000 dives in South Africa generated 0% to 25% coral damage. The other study that was carried out by Zakai and Chadwick-Furman (2002) in Northern Red Sea showed a higher destructive impact where 1000-4000 dives generated 8-70% coral damage.

Environmental cost of tourism was smaller than benefit, but tourism needed high investment costs. These high investment costs could be provided only by far away businessmen. On the one hand, cyanide fishing and coral collecting generated destructive effects to the coral. On the other hand, tourism needed good coral reefs condition. Therefore the conflict between tourism and cyanide fishing and coral collecting could not be avoided, although it was regulated with different use zones. Of course tourism could provide many jobs for coastal communities, but it was only for skilled labour.

Coastal communities, which have low level education, could not initiate innovation for less damaging coral reefs uses. Most of fishing boats could not be rebuilt as tourism transportation vessels due to the lack of skills, knowledge and capital. Thus, most of local inhabitants only involved in small-scale cyanide fishing and coral collecting. This situation was indicated by Pet-Soede and Erdmann (1998), who said that these small-scale fisheries create relatively high value with little capital investment required. Meanwhile, fish and coral traders who received higher benefits can easily moved to other kinds of business. These inequalities are of crucial importance in understanding the causes and consequences of coral

reefs degradation (Boyce, 2002; Field, 1994; Kolstad, 2000). The situation on Seribu Islands is a good example for this.

Extended cost benefit analysis, which internalised environmental costs to economic analysis was used to calculate the expected net present value of actual coral reefs uses. The result of this analysis showed that on Seribu Islands where cyanide fishing and coral collecting had the highest intensity and tourism had the lowest intensity, the expected NPV was negative (-\$14.68 million). In contrast, on Menjangan Island where tourism had the highest intensity and cyanide fishing and coral collecting had the moderate intensity, the expected NPV was positive (\$17.25 million). However on Gili Islands where cyanide fishing and coral collecting had the lowest intensity and tourism had the moderate intensity, expected NPV was positive (\$2.26 million). If cyanide fishing was prohibited on Seribu Islands, expected NPV was still negative (-\$12.39 million). The expected NPV on Seribu Islands will be positive (\$41.14 million) if tourism was the only activity allowed.

The results from the economic analysis of coral reefs uses in selected locations were used to estimate the expected NPV of Indonesian coral reefs regarding live coral cover, actual coral reefs uses, coral distribution, coral area, and economic condition. The extension of cyanide fishing and coral collecting practices since the last economic crisis in Indonesia has led to the increasing negative impacts to coral reefs. The high environmental costs from these activities will lead to the high economic losses of coral reefs uses. The result from this estimation showed that if these destructive fishing methods were continued for the next 25 years, the expected NPV would be negative (-4.29 billion \$).

Cyanide fishing is the fastest method to harvest reef fishes, and has increased and spread out all over coral reefs areas to change blast fishing since economic crisis in Indonesia. Export market orientation and devaluation of local currency have supported cyanide fishing and coral collecting. This situation indicated a strong global demand for Indonesian coral reefs organisms, which was consumed as high-class food (Cesar, 1996) or as ornamental aquarium fish (Bentley, 1998). The increasing of cyanide fishing and coral collecting would reduce tourism, but coastal communities were highly depended on these activities. However, tourism was highly depended on the national security, while Indonesia has been forecasted as the high-risk country (Political Risk Letter, 2002). Therefore fishing should be continued, but its environmental cost must be reduced to gain positive value.



## 6.2. The Potential of Coral Reefs Uses Improvement in Indonesia

The calculation of improvement of fishing showed that its environmental and operational costs could be reduced about 78.88% and 15.39% respectively. However, fishermen did not change their fishing method because of three reasons. First, their benefit would decrease about 49.72% because they could not catch five highly priced fish species with a barrier net. Second, the operation of barrier net needed extra set up time, usually between 10 to 30 minutes (depending on the skills of the fishermen). Third, fishermen did not bear fish mortality because usually they sell the fish quickly to the traders. Therefore there were significant difference between the prices given to fishermen and export prices. The difference was about 90% to 300% due to the high mortality of fish that must be borne by fish traders. Thus, even fishermen knew that the use of barrier net fishing would reduce fish mortality around 30% to 50%, they did not want to change their fishing method without incentive. Fish traders are willing to give price incentive from 3% to 5%, although they knew that their fish would increase 30% to 50%. Fishermen benefits decrease about 47.97% of previous benefit if they receive 3%-5% price incentive to use barrier net fishing. Therefore the price incentive should be 20%-40% of prior prices to settle up fishermen benefits as before.

It was needed to control fish harvest to ensure that fishermen did not use cyanide. The control of fish harvest was carried out by fish trader, therefore fish trader might expend this controlling cost. Thus, the benefit of fish traders would decrease about 3.88% because of controlling cost and 16.76% because of price incentive. However fish trader still received additional benefit if it was assumed all healthy fishes could be exported. The total decreasing of benefit of fish traders (20.64%) was still below the increasing of healthy fishes (30%).

Mooring buoys, which are built in favourite zones for diving and snorkelling, can reduce the negative impact from tourism boat anchors. The calculation of improvement of tourism showed that its environmental cost can be reduced about 62.02%, while investment cost only increased 0.15%. It was needed to patrol tourism zones to avoid from the disturbance of other activities. The calculation showed that the cost for patrolling was only 4.89% of operational and maintenance costs of tourism. However, mooring buoys and patrolling could not reduce the damage of diving and snorkelling itself. Information about coral reefs, which is provided to the tourist before diving and snorkelling, is an alternative. The raise of awareness of tourists can increase their carefulness in this activity.

The Coral collecting ought to be prohibited because no other single method could reduce the destruction caused by coral collecting until now. Harriott (2001) says that coral harvest will have fewer impacts and is more sustainable if the collecting effort is spread over a wider area, rather than being concentrated in small areas. Although coral harvest management is applied in form of the rotation method, the total negative impact is similar. Coral farming is only one alternative to substitute coral collecting, but not the method to reduce the damages caused by coral collecting. Harriott (2001) reported that coral farms on Solomon, Vanuatu and Fiji promoted the competitive advantage of being environmentally sensitive and socially responsible and supporting local people in their sustainable coral farms. The donors were collected from coral fragments, which are detached from coral colonies leaving the majority of the colony intact. The fragments are then attached to discs for support and mounting, and are usually kept on the farm for a period of 4-6 months before being sold and exported. *Goniopora*, *Lobophylla*, *Euphyllia*, *Catalaphyllia*, and *Plerogyra* are listed as successful for aquarium rearing.

The successful experience of coral farm in Philippine is a good example to be applied in Indonesia. Heeger and Sotto (2000) have reported that the cost for coral farm is \$2,100 annually for one hectare, which contains 6000 coral fragments. Fragments are taken 10% to 20% from donor colony, and the donor corals regenerate after six to eight weeks. It takes one to three months to grow out 6 - 8 cm with 87% survival rate (IMA, 2003). Lindahl (2003) have reported that the average increased of live coral over one year was 86%, while Carlson (1999) found that the fragments might grow 7 inches (18 cm) or more each year. This low cost technology of coral farm has provided alternative livelihood for 30 families of fishermen. Export of farm-grown corals could be an additional income of the fishermen (Heeger and Sotto, 2000). This method was quick and did not require SCUBA divers or expensive materials and equipment (Lindahl, 2003).

The benefit of application of coral farm in Indonesia was calculated based on assumptions that the cost, growth and survival rate, and fragment number of coral per hectare are similar to the Philippine, and the price of coral is similar to the average price of Indonesian corals (\$2.93/fragment). The result of calculation showed that net benefit is \$13,212.84 annually for one hectare, which is operated by 30 families. Therefore each fisherman family can generate an additional income as much as \$440.43 annually. This additional income is higher than income from coral collecting, which is only \$165.37 annually.

The implementation of coral farm will cause problems to the coral collectors and coral traders, because in the short term they do not generate income until their coral farms are successful. The poverty situation of coral collectors demands for subsidies for coral collector families. Therefore the loan for practising coral farming must include the subsidies for coral collector families. Coral farmers should payback this loan after the first harvest of their farms. Thus, another study is needed to evaluate the economic feasibility of coral farming.

The results of the economic analysis of improved coral reefs uses showed that the lowest expected NPV was gained in the area where high intensity of fishing taken place. In contrast, the highest expected NPV was generated in the area with high intensity of tourism. Therefore the intensity of coral reefs uses must be regulated to gain a higher expected NPV. For example, if tourism on Seribu Island is increased, the expected NPV will increase, vice versa. The highest expected NPV on Seribu Island will be gained if only tourism is allowed and increased to maintain constant coral condition overtime. In contrast, the highest expected NPV will be gained on Gili Islands if improved coral reefs uses are regulated for better coral condition overtime. Besides the worst live coral cover, the cost of tourism on Gili Islands is also higher than other locations. It can be seen in the result from sensitivity analysis where expected NPV on Gili Islands is more sensitive to the fluctuation of discount rate than other locations.

Economic analysis of improved coral reefs uses in Indonesia showed that the negative expected NPVs were caused by intensive fishing in 45.83% of Indonesian coral reefs areas. Although the negative impact of fishing could be reduced by using barrier net, the environmental cost was still higher than benefit. In contrast, tourism always generates smaller environmental cost than benefit. The uncertainty of tourism was also smaller than fishing, but the number of foreign tourist was depended on the national security. However, Indonesia had been predicted as the high-risk country (Political Risk Letter, 2002). Sensitivity analysis showed that expected NPV would be negative if the number of tourist decreased more than 30%. Therefore, domestic tourist will be important in the future.

Based on prior description, it is recommended to prohibit cyanide fishing and coral collecting, substitute cyanide fishing by barrier net fishing, substitute coral collecting by coral farming, build mooring buoy in tourism zone, regulate the intensity of each activity, and initiate and increase tourism (especially domestic tourism).

### **6.3. The Implementation of Policy Recommendations**

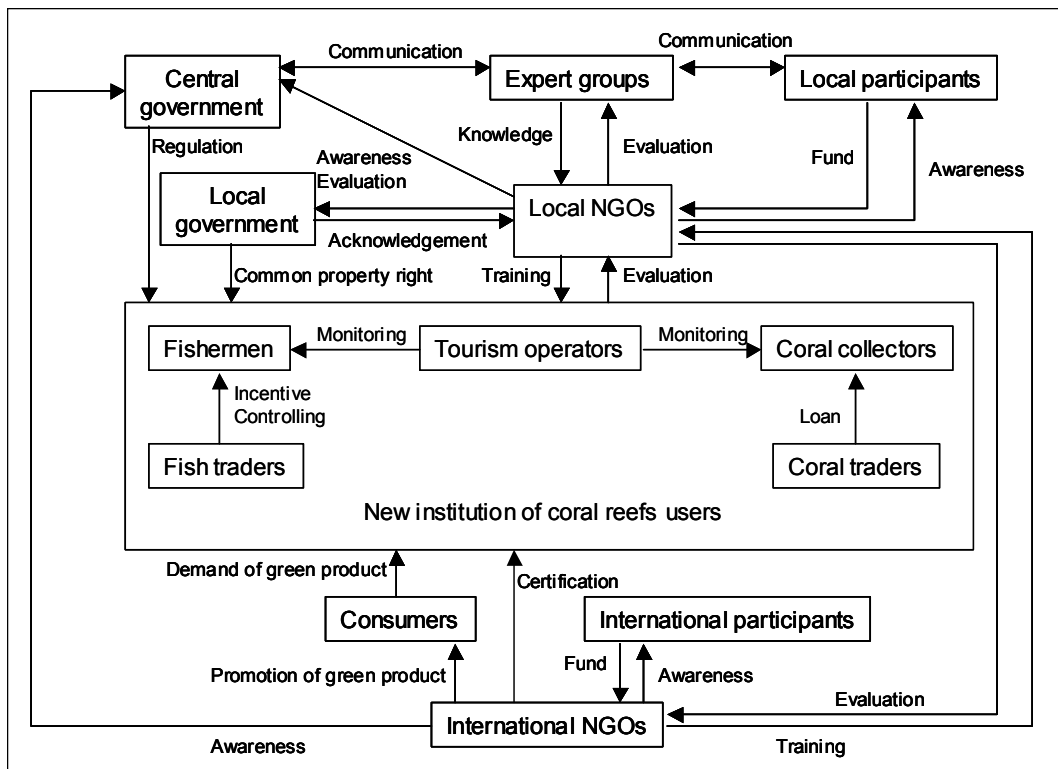
The possibility of implementation of technical improvement of coral reefs uses was analysed by internalise implementation costs into economic analysis. The result of this analysis showed that expected NPV was negative in the area where high intensity of fishing happened. If total implementation costs (3.26 million \$) were internalised into economic analysis of Indonesian coral reefs, the expected NPVs were negative (totally -873.83 million \$) in 45.83% coral reefs areas with high intensities of fishing. Therefore it is not justified to implement only technical improvement of coral reefs uses. The intensity of coral reefs uses ought to be regulated simultaneously to coral reefs management. Fishing intensity in 45.83% coral reefs locations should be reduced up to 50%, and a low-level tourism should be initiated. Thereafter the results showed that combination of coral reefs uses improvement and intensity regulation generate positive expected NPV (6.12 billion \$).

The potential of improvement of coral reefs uses can be implemented if the major stakeholders (fishermen, coral farmers, tourism operators, and fish and coral traders) receive a guarantee that they will be gratified over a certain time period. In other words, the major stakeholders in certain coral reefs area should be protected to manage their own coral reefs resource. Therefore de facto open access of coral reefs must be reformed to a limited common-property right where fishermen, coral farmers, and tourism operators share use rights of coral reefs. The share of use rights of coral reefs and their consequences can be easier specified and distributed among stakeholders if they are integrated in one institution. Rights are further specified than in the case of open access resources, but still not fully assigned to one individual so that external effects persist (Hurrelmann, 2002). Of course each member of stakeholders might then apply different investment of resource use, but the aim of this common property rights is to share use rights based on previous activities. There are also prior informal culturally embedded rules that restrict the use of resources to some extent in these cases (for example in Menjangan Island and Gili Islands).

The integration of stakeholders is possible since the separated informal groups are exist, such as fishermen group (including fish traders), coral collector group (including coral trader), and tourism operator group. These groups have been formed based on similarity of activity and administrative level (village), while certain coral reefs area might covers more than one village. The fish and coral traders must be involved because they play important role in coral reefs uses. As usual in Indonesian open access resource utilisation, traders are the top decision makers. The traders, which have accessibility to the demand of renewable resources,

can create local demand. Resource users usually do not know about the market of their harvests, and very often that these activities are stimulated by traders. There is also a gap between traditional groups (fishermen and coral collector groups) and modern group (tourism operator group). Local NGOs is needed to initiate the integration of these groups into one formal institution based on coral reefs area. Local NGOs is also important to correlate this institution to the national expert groups (INCoM and ICRWG). The national expert group can help to initiate motivation of innovation of a new technique of resource uses.

Figure 16. The implementation system of coral reefs improvement



Local NGOs can provide stakeholders with information on improved coral reefs uses and encourage local leaders to embark on the management of coral reefs area. In short time, in the process of resource management there are three streams of thought which must be reconciled: the wish of the stakeholders to share in the benefits from coral reefs resources while protecting their coral reefs area from outsiders, the desire of local governments to extract resource rents and the push by expert groups and other participants to develop viable local coral reefs management. It is also necessary to define the institution structures, powers and responsibilities within the framework of provincial and national legislation, to provide local institutions with more capacity to deal with external threats and become involved in development planning, execution and evaluation. Therefore in the short time it is needed costs for gathering information, coordinating users, organizing decision making and enforcing

rules (price incentive, monitoring and controlling costs). These costs are called transaction costs (Hanna, 2001; Hurrelman, 2002). However, the transaction costs of managing the common property is lower than under a purely government management regime (Kuperan *et al*, 2001). This research found that transaction costs of managing the proposed common property (\$3.26 million for 25 years) are lower than the government project for coral reefs management (\$171.74 million for 20 years).

Besides direct regulation (common property right), a strategy to manage coral reefs can be achieved by stimulating voluntary agreements of market participants and moral suasion via conveying information to the public, direct communication, education (van den Bergh, 1996). International NGOs can also connect this new institution to the consumers of coral reef products, which are well organised by MAC (Marine Aquarium Council), to promote their green products. The involvement of international NGOs in coral reefs management can be formed as a joint work with local NGOs and government institutions. The past experiences showed that most of successful collaborations were the first format. Thus, it is important to increase the role of NGOs in Indonesian coral reefs management. But NGOs are not allowed to make greater interventions, because it will disturb self-management of coral reefs. The self-management motivation will decrease if to much interventions. The management of coral reefs area in Komodo Islands, which was previously carried out by government authority and international NGO (The Nature Conservancy), was a bad experience. Local communities complained that this authority has taken their own resource by prohibiting fishing around the islands because in the past the area was a traditional fishing ground. However, collaboration between this NGO and other profit organisations (PT Jayakarta Purindo Utama) were established to make profit from planned tourism activities (PT Putri Naga Komodo). The lower local community participation and involvement increased conflicts to the authority. The authority ought to spend a lot of money (about 500,000 \$ annually) to protect the area from illegal fishing, and sometimes this conflict caused victim of local communities. Between May and June 2003, it was reported that 3 fishermen were killed by the coast guards because they *pass through* the restricted areas of Komodo Islands (*Suara Pembaruan daily*, 2003).

The successful common property management often occurs in areas where there are a well-defined and limited community; locally-defined management rules; locally-developed institutions that are accepted; higher levels of authority which support local institutions and help to monitor and enforce compliance; and the right to exclude others from participating in

the fishery (Heylings and Cruz, 1998). Therefore government should protect this mechanism by acknowledgment of this common property right. The new institution must be acknowledged by government as an independent institution to reduce the government intervention in coral reef management. Of course the willingness of government to accept this new institution is low because the government power will be reduced. But the willingness of government can be increased by the international public awareness, which can be formed as a demand of a green product (certification issue). However, Indonesian government have allowed international NGO to manage coral reefs around Komodo Islands.

The acknowledgment of this new institution can also be used to attack illegal taxes (side payments). It can reduce the bureaucracy in exploitation and trade of coral reefs organisms, which often causes side payments. Live fishes and corals are usually transported to the export points without appropriate transportation facilities. Thus, it must be transported as fast as they can. In contrast, the checking of administration procedure is time consume, which can increase the mortality of live fishes and corals. The persons who responsible usually offer illegal taxes to pass away this procedure.

Previous discussion showed that there are several possibilities to implement the improvement of coral reefs management. Firstly, it is needed to create long-time oriented regulation for coral reefs management. This regulation must be involved in the Indonesian political system to stimulate creation of a coral reefs management act in order to accommodate the change of government policies overtime. Secondly, it is needed to create a new institution based on coral reefs area, which include the coral reefs users, traders, and tourism operators, to manage coral reefs as common property resources. This strategy can reduce the use destructive methods in coral reefs uses. Thirdly, it is needed to arise international public awareness in order to promote green products and to stimulate Indonesian government to increase the concern about coral reefs management.

## CHAPTER 7. CONCLUSION

### 7.1. Summary of Major Findings

Open access conditions of Indonesian coral reefs are approximated because government has distributed responsibilities of coral reefs management to different agencies without clear coordination mechanism, inconsistency of management regulation on coral reefs, and low law enforcement. Therefore the competition among coral reefs users have led to the destructive methods for harvesting coral reefs organisms as much and as quick as they can.

International and local non-government organisations (NGOs) have been working since 1990s to help Indonesia in coral reefs management. The successful experience of NGOs on separately aspects, ranging from bio-physic monitoring and developing public awareness of coral reefs, could not reduced destructive fishing practices. Therefore collaborative programs across local and international NGOs have been established since 2001.

Cyanide fishing, coral collecting, and tourism have been identified as the major actual activities in Indonesian coral reefs. Short-term and quick profit, low investments needed, and low and few skills needed are characteristics of cyanide and coral collecting, which are led to high intensities of both activities in Indonesian coral reefs. It has been also identified that the intensities of destructive fishing are high in the area where high human density occur and lack of alternatives of income generating, vice versa. In contrasts, tourism needs high investments and high skills, and generates long-term profit. Therefore, cyanide fishing and coral collecting are practised by local community, while tourism can be carried out only by outside businessmen.

### 7.2. Conclusion

The environmental cost of cyanide fishing was caused by destructive effects of cyanide solutions on coral heads, fishing boat anchors, and fishermen trampling on corals. Destructive effects of chisels, boat anchors, and collectors trampling on corals created the environmental cost of coral collecting. The environmental cost of tourism was generated by tourism boat anchors and tourists behaviours (holding, kicking and trampling on corals).

Cyanide fishing has been identified as the most destructive method to harvest coral reefs organisms. The environmental cost of cyanide fishing was more than ten times its benefit, while the environmental cost of coral collecting was almost ten times its benefit. However



tourism only generated environmental cost less than five percent of its benefit. The destructive effects of cyanide fishing and coral collecting were higher than the results from other similar study, while destructive effect of tourism was still within the range of other similar study.

The environmental cost of cyanide fishing can be reduced more than half if it is changed by barrier net fishing, while coral farming has been proofed as the less damage method to change coral collecting. The installation of mooring buoys in tourism zones can reduce the environmental cost of tourism more than fifty percent, while the cost of investment only increases less than one percent. Therefore these technical improvements of coral reefs uses can reduce the environmental costs of major activities in Indonesian coral reefs.

The results of extended cost benefit analysis, which internalises environmental costs in ecological economic model, shows that if these high intensities of anthropogenic threats are not quickly reformed, long-term economic loss of coral reefs uses in Indonesia will be very high. Based on estimation in this study, as much as \$4.29 billion economic loss due to actual coral reefs uses during the next 25 years. The technical improvement of coral reefs uses can reduce economic loss to be economic gain (\$1.24 billion), but economic losses are still happened in almost half of coral reefs areas. The reduction of fishing and introduction of tourism can increase economic gain to be \$6.12 billion.

The improvement of coral reefs uses can be implemented if the use right of coral reefs is changed to more responsible and acceptable common property right. The major actual stakeholders (fishermen and fish traders, coral collectors and coral traders, and tourism operators) in certain coral reefs area can be integrated in one institution to share the use rights of coral reefs and responsibilities of coral reefs management.

### **7.3. Outlook**

Resource abundance of coral reefs and fishes are measured by underwater visual census following the standard method from English *et al* (1994). Therefore it is necessary to place the sampling sites surrounding each island, in order to have a better understanding of coral reef and fish distribution. The destructive effects of coral reefs uses are measured at the same time when it was happened. Therefore it is necessary to measure the long time effects of each coral reefs use, in order to have better understanding of the long effects to the resource abundance. Therefore although the equations in this study are statistically significant, in the

application to other locations must be carefully done due to the great variations of coral reefs condition among locations. At least, similarity of ecological characteristics and use patterns must be considered before applying the result of this study to evaluate coral reefs use in other areas.

The valuation of environmental costs is based on the market prices, which only calculated the use value. Therefore it is necessary to calculate non-use value by applying appropriate valuation technique, such as the contingent valuation method, the hedonic pricing method, and the travel cost method. The environmental costs are internalised in the extended cost benefit analysis by using linear equations in order to simplify the ecosystem complexity. Thus it is important to study the interrelationships and the process of changes in complex coral reefs ecosystems. The calculation of net present values includes variance analysis based on the assumptions of the normal distribution. However, another sampling distributions are possible to apply to have better understanding of probability of net present values.

The results of economic analyses showed that benefit of tourism was higher than fishing and coral collecting, although it were improved to reduce their environmental costs. The variability of tourism was also smaller than fishing and coral collecting. These conditions were based on the data during study period. However the situation in Indonesia has changed in the recent year. Terrorism issue, national security, and uncertainty of political change have led Indonesia to the category of high-risk country. Therefore tourism sector cannot be further developed. In contrast, the demands of reef fish (as food and ornamental) and other coral reefs organisms are more stable. Thus, in the future, fishing and coral farming have a better prospect to be further developed. Although barrier net fishing has significant environmental cost, further research on fishing method can probably reduce the environmental cost. The improvement of small-scale fishing to be economies scale may reduce the direct cost. It can be achieved by integration of small-scale fishing in certain coral reefs area.

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Appendix 2. Coral and other invertebrate collection from Seribu islands (April 2001 - March 2002)

No.	Common Name	Price (\$/p)	Collector					Total	Daily	
			1	2	3	4	5			18
Live coral										
1	Branch coral (brown)	6.00					18	180	1.67	
2	Fire anemone	4.00		18				18	0.17	
3	Small anemone	1.75	276	181	98	3168	18	502	42.32	
4	Mixed colour anemone	2.50				480		480	4.44	
5	Corn anemone	3.00			9			144	1.94	
6	Long tentacle anemone	3.00			18		18	36	0.33	
7	Plate coral	2.00					18	18	0.17	
8	Plate coral short hairy	2.50				288		288	2.67	
9	Sunflower branch	3.00				106		106	0.98	
10	Jewel coral	3.00				48		48	0.44	
11	Lemon coral	2.00				471		471	4.36	
12	Mushrooms hairy	6.00	75					163	4.95	
13	Mushrooms green hairy	8.00				192		192	1.78	
14	Elephant-ear mushrooms	3.90						541	5.01	
15	Brain coral	2.00				1920		1920	17.78	
16	Bubble coral	1.75				1767		16	1783	16.51
17a	Hammer coral cream S	2.00				1008		1008	9.33	
17b	Hammer coral cream M	2.00				1776		1776	16.44	
18	Echinopore coral	3.00				4320		4320	40.00	
19	Montipore corals	4.50				912		912	8.44	
20	Sinularia soft coral	3.50				106		106	0.98	
21	Pearl coral	3.00				1152		1152	10.67	
22a	Pineapple coral S	3.00						107	0.99	
22b	Pineapple coral M	3.00				470		470	4.35	
22c	Pineapple coral L	4.70				701		701	6.49	
23	Brain coral green metallic	5.00				576		576	5.33	
24	Pipe coral	2.00				480		480	4.44	
25	Red organ pipe coral	2.00				461		461	4.27	
26	Plate coral green	1.75						107	0.99	
27	Plate coral pink	3.50				1344		1344	12.44	
28	Grape coral fine (green)	5.00				480		480	4.44	
29	Star polyps metallic green	1.00						20	0.19	
30	Star polyps green	5.00				1008		540	1548	14.33
31	Metalic star polyp	2.50				960		960	8.89	
32	Clove polyp	1.75				720		720	6.67	
33	Cauliflower	2.00				173		173	1.60	
34	Sand polyps	2.00				720		720	6.67	
35	Umbrella sof coral	1.75				2880		2880	26.67	
36	Bird nest	4.00				240		240	2.22	
37	Soft coral	3.75				2736		2736	25.33	
38	Tree soft coral	2.00				259		259	2.40	
39	Leather soft coral	2.50				576		576	5.33	
40	Finger soft coral	2.50				2592		2592	24.00	
41	Cauliflower	3.75				2323		2323	21.51	
42	Soft coral coloured	3.75				1162		1162	10.76	
43	Sponge blue/purple	1.50				1776		1776	16.44	
44	Orange sponge	1.70				58		58	0.54	
45	Bread crumb sponge orange	1.75				278		278	2.57	
46a	Finger leather coral S	1.75				1920		1920	17.78	
46b	Finger leather coral M	3.50				480		480	4.44	
46c	Finger leather coral L	7.00				480		480	4.44	
Other invertebrate										
1	Blue star	1.30		109	65	480			1216	11.26
2	Red star	1.00	252	143	27			72	1070	9.91
3	Short-spine urchin	1.20				1056			1056	9.78
4	King snake red	2.75		789	244		173	1530	9464	87.63
5	Common octopus	2.00							53	0.49
6	Small Lobster	2.00							27	0.25
7	Red-banded shrimp	1.30							36	0.33
8	Snapping shrimp	2.00							27	0.25
T O T A L (piece)			603	1240	461	45103	227	2985	60247	557.84
T O T A L (US\$)			1185.00	2843.20	1035.00	122159.00	597.25	9404.00	163430.00	1513.24

Appendix 3. Fish catch from Menjangan island (April 2001 - March 2002)

No.	Common name	Price (\$/p)	Fishermen											Total	Daily
			Fr1	Fr2	Fr3	Fr4	Fr5	Fr6	Fr7	Fr8	Fr9	Fr10	Fr26		
1	Blue faced angel	17.50	61	26	22	30	46	21	21	67	33	46	16	721	6.68
2	Two coloured	3.00	1213	526	434	603	917	429	414	1334	659	916	330	14401	133.34
3	Blue angel	2.60	101	44	36	50	76	36	34	111	55	76	27	1198	11.09
4	Lemonpeel	5.50	25	11	9	13	19	9	9	28	14	19	7	301	2.79
5	Emperor Angle	23.00	202	88	72	101	152	71	69	222	110	153	55	2399	22.21
6	Cherubfish	5.50	51	22	18	25	39	18	17	56	27	38	14	601	5.56
7	Yellow face angelfish	17.00	7	14	17	16	17	18	18	19	19	24	22	599	5.55
8	Blue ring angelfish	13.50	51	22	18	25	39	18	17	56	27	38	14	601	5.56
9	Grey orange-Striped Angle	2.10	76	33	27	38	57	27	26	83	41	57	21	899	8.32
10	Three- Spotted Angle	9.00	101	44	36	50	76	36	34	111	38	76	27	1181	10.94
11	Zebra Angle	5.50	14	27	34	32	36	15	36	38	55	48	44	1215	11.25
12	Emperor anglefish youth	7.50	505	219	181	251	382	179	172	556	275	382	137	5996	55.52
13	Koran angle	2.50	25	11	9	13	19	9	9	28	14	19	7	301	2.79
14	Racon	4.50	10	4	4	5	8	4	3	11	5	8	3	120	1.11
15	Teardrop	2.00	51	22	18	25	38	18	17	56	27	38	14	608	5.63
16	Vogabona's	2.50	7	14	17	16	18	7	18	19	19	24	22	592	5.48
17	Saddled butterfly	3.25	5	2	2	3	4	2	2	6	3	4	1	64	0.59
18a	Yellow long nose butterflyfish S	6.50	30	13	11	15	23	11	10	33	11	23	8	358	3.31
18b	Yellow long nose butterflyfish M	7.50	4	8	10	10	11	6	11	11	16	15	13	358	3.31
19	Sunset butterfly	3.00	1	4	4	5	8	4	3	4	5	8	3	121	1.12
20	Mirror butterfly	2.10	20	9	7	10	15	7	7	22	11	15	5	239	2.21
21	Meyer.s.butterfly	3.80	10	4	4	5	8	4	3	11	5	8	3	119	1.10
22	Klein's butterflyfish	2.00	30	13	11	15	23	11	10	33	16	23	8	358	3.31
23	Red tailed	2.00	10	4	4	5	7	4	3	11	5	8	3	118	1.09
24	Sergeant mayor	0.50	101	44	36	50	76	36	34	111	55	76	27	1198	11.09
25	Molucca damsel	0.50	14	27	34	32	36	15	36	38	38	48	44	1196	11.07
26	Sebae anemones	1.25	152	66	54	75	115	54	52	167	82	115	41	1801	16.68
27	Blue velvet damsel	1.00	101	44	36	50	76	36	34	111	55	76	27	1198	11.09
28	Bicolor chromis (Bali)	0.75	507	221	181	251	383	179	172	557	277	382	137	6018	55.72
29	Yellow bellied damsel	0.50	68	137	172	160	182	73	181	190	188	242	219	5995	55.51
30	Black tailed humbug	0.50	505	219	181	251	382	179	172	556	275	382	137	6001	55.56
31	Half blue damsel	0.50	101	44	36	50	76	36	34	111	55	76	27	1198	11.09
32	Honey stripped damsel	0.50	14	27	34	32	36	15	36	38	38	48	44	1196	11.07
33	Skunk anemonfish	1.00	51	22	18	25	38	18	17	56	27	38	14	608	5.63
34	Skunk stripped anemonfish	0.80	7	14	17	16	18	10	18	19	19	24	22	592	5.48
35	Reticulated damsel	0.40	101	47	36	51	76	36	34	111	55	76	27	1224	11.33
36	White tailed damsel	0.50	14	27	34	32	36	15	36	38	38	48	44	1181	10.94
37	Clown anemon fish	0.80	27	88	72	101	71	153	69	76	75	97	55	2399	22.21
Total (individuals)			4373	2211	1946	2537	3639	1819	1888	5105	2767	3794	1669	65273	604.38
Total (US\$)			17603.30	8176.95	6992.55	9390.55	13904.80	6758.25	6734.80	19900.80	10225.90	14210.65	5698.35	233452.45	2161.60



Appendix 4. Coral and other invertebrate collection from Menjangan island (April 2001 - March 2002)

No.	Common name	Price (\$/p)	Collector							Total	Daily	
			Clr1	Clr2	Clr3	Clr4	Clr5	Clr6	Clr7			
Live coral												
1a	Brain coral S/M	2.00	150			205					355	3.29
1b	Brain coral L	2.73			105						105	0.97
2	Bread crumb sponge orange	1.75	125	135				135		120	390	3.61
3	Brown gorgonia soft	5.00						115		125	240	2.22
4	Bubble coral	1.75	110	115					101	112	328	3.04
5	Carpet anemone white	4.00			102	110					212	1.96
6	Cauliflower	3.75		110							110	1.02
7	Corn anemone	3.00				140				101	241	2.23
8	Finger soft coral	2.50				115					115	1.06
9	Fire anemone	4.00			101	122					223	2.06
10	Grape coral fine (brown)	3.75	125					115	101		341	3.16
11	Green stoney coral	2.00		115						105	220	2.04
12	Hammer coral cream	2.00	130			153	110				393	3.64
13	Long tentacle anemone	3.00			120	110			101	900	1231	11.40
14	Mixed colour anemone	2.50			110	114					224	2.07
15	Pearl coral	3.00	110		105	135	130	101			581	5.38
16	Plate coral	2.00						101			101	0.94
17	Small anemone	1.75	120	114		147	115	109			605	5.60
18	Soft coral	3.75				106				101	207	1.92
19	Soft coral coloured	3.75	130			112				125	367	3.40
20	Sponge blue/purple	1.50	124								124	1.15
Other invertebrate												
1	Red starfish	1.00	61	105							105	0.97
2	Blue starfish	1.30				37				130	167	1.55
3	Red general starfish	1.50			160						160	1.48
4	King snake red	2.75		116			130				246	2.28
5	Common octopus	2.00				173		102			275	2.55
6	Hermit crab red	1.50	297	103							103	0.95
7	Small lobster	2.00			103					104	207	1.92
Total (piece)			1124	589	643	1569	720	614	1689		7976	73.85
Total (US\$)			3160.00	1858.00	2494.65	4840.35	2411.25	1758.25	5468.50		21991.00	203.62

Appendix 5. Fish catch from Gili islands (April 2001 - March 2002)

No.	Common Name	Price (\$/p)	Fishermen											Total	Daily
			Fr1	Fr2	Fr3	Fr4	Fr5	Fr6	Fr7	Fr8	Fr9	Fr10	Fr11		
1	Allen's damsel	0.90			373					52	251			676	6.26
2	Assorted Butterfly	0.75										62		62	0.57
3	Assorted parrotfish	1.30										70		70	0.65
4	Assorted Wrasse	1.20		190										190	1.76
5	Asstd Lyretail Wrasse	1.10				73	57					152	56	338	3.13
6	Banner fish	3.00	167	156		53	52					55	52	535	4.95
7	Bicolor Angles	3.00				59	62							121	1.12
8	Blue Angle	2.60				53	51	158				53		315	2.92
9	Blue strak cleaner wrasse	0.80		151	413	53	56	54	352	152			64	1295	11.99
10	Butterflyfish	2.00				152	152					151	57	512	4.74
11	Clown Surgeon	1.50		160		174								334	3.09
12	Damsel fish	2.50					57						53	110	1.02
13	Dusky wrasse	1.50	154			54	51	53				52	51	415	3.84
14	False Blue Surgeon	6.50					56					153	52	261	2.42
15	Half blue damsel	0.50		152		51		152				51	54	460	4.26
16	Klein's butterflyfish	2.00				153	185							338	3.13
17	Mindnight Angle	2.60											119	119	1.10
18	Molucca damsel	0.60										60		60	0.56
19	Moorish Idol	2.00	153	220	231	68		151						823	7.62
20	Parrot fish	1.50		152	297	55	52							556	5.15
21	Pearl-Scale Angle	1.60		180		190		51					80	501	4.64
22	Powder-Blue Surgeon	10.00		155			160				53		75	443	4.10
23	Royal Empress Angle	11.00							253	54	154			461	4.27
24	Sergeant major	0.50				53	152					52	53	310	2.87
25	Soldier fish	0.70				152	155					59	51	417	3.86
26	Spot-Fin Lionfish	2.00					72			151		63	71	357	3.31
27	Two-lined snapper	1.00				60	64					60	55	239	2.21
28	Undulate trigger	2.40		180		153					54			387	3.58
29	White-rimmed trigger	1.30		153			157	47					59	416	3.85
30	Yellow damsel	0.50				65				52	352		52	521	4.82
Total (individuals)			474	1849	1314	1671	1591	666	605	461	864	961	1186	11642	107.80
Total (US\$)			1038.00	4269.70	1573.60	2689.10	4113.70	1054.20	3064.60	1090.40	2755.50	2159.30	2643.60	26451.70	244.92

Appendix 6. Coral and other invertebrate collection from Gili islands (April 2001 - March 2002)

No.	Common Name	Price (\$/p)	Collector					Total	Daily
			Collector1	Collector2	Collector3	Collector4	Collector5		
Live coral									
1	Branch coral (brown)	6.00					157	157	1.45
2	Small anemone	1.75	158	131	205	157	112	763	7.06
3	Mixed colour anemone	2.50	221	185	203	238	44	891	8.25
4	Fire anemone	4.00		207				207	1.92
5	Long tentacle anemon	3.00	102		191	162	103	558	5.17
6	Pineapple coral	3.00					154	154	1.43
7	Elephant-ear mushrooms	3.90					170	170	1.57
8	Plate coral green	1.75	153	201				354	3.28
9	Bubble coral	1.75					151	151	1.40
10	Plate coral	2.00			213			213	1.97
11	Stoney coral	1.75			158			158	1.46
12	Star polyps green	5.00		180				180	1.67
13	Yellow polyp	1.50		171				171	1.58
Other invertebrate									
1	Blue starfish	1.30	154	257	156	164	153	884	8.19
2	Red starfish	1.00	259	161	253	256		929	8.60
3	Feather tube worms	1.50	184	264	257	163	201	1069	9.90
4	Common octopus	2.00	251				151	402	3.72
5	Hermit crab red	1.50		162				162	1.50
6	Nudibranches assorted	1.50	153	252		255	161	821	7.60
7	Lobster	2.00					153	153	1.42
8	Red-banded shrimp	1.30			181	273		454	4.20
Total (piece)			634	1075	970	557	891	9001	38.21
Total (US\$)			2869.45	4540.10	3218.35	2806.85	4296.15	17730.90	164.18

Appendix 7. Live coral cover in each sampling station

Location	Station	Cover (cm <sup>2</sup> )	Cover (%)	Genus number	Value (\$)	Dominant genus	Dominant (%)
Seribu isls.	Pandan-A1	1467810	45.87	8	18466.94	<i>Acropora</i>	35.92
	Pandan-A2	1803616	30.42	7	26589.40	<i>Acropora</i>	20.94
	Pandan-A3	1448682	38.73	6	16081.52	<i>Acropora</i>	31.05
	Opak-B	483083	13.49	7	8103.52	<i>Acropora</i>	2.65
	Bira-C	368839	10.36	6	6553.96	<i>Acropora</i>	3.39
	Putri-D	98891	10.09	7	1106.19	<i>Acropora</i>	5.97
	Melinjo-E	83802	22.65	6	1068.70	<i>Acropora</i>	13.20
	Genteng-F	52072	14.46	6	784.45	<i>Acropora</i>	4.49
	Kotok-G1	192100	38.42	9	4369.30	<i>Porites</i>	22.82
	Kotok-G2	173600	34.72	12	6767.01	<i>Montipora</i>	12.74
	Layar-H1	233400	46.68	6	6234.52	<i>Heliopora</i>	25.10
	Layar-H2	314300	62.86	8	6313.64	<i>Heliopora</i>	47.64
	Panggang-I1	170600	34.12	6	3158.70	<i>Heliopora</i>	22.04
	Panggang-I2	218200	43.64	2	3607.87	<i>Porites</i>	43.30
	Sekati-J1	101600	20.32	8	5192.93	<i>Acropora</i>	10.06
Sekati-J2	265600	53.12	18	9359.73	<i>Acropora</i>	13.42	
Menjangan isl.	Geel-A1	219900	43.98	13	5691.97	<i>Porites</i>	22.74
	Geel-A2	195400	39.08	7	6086.90	<i>Porites</i>	13.18
	Wreck-B1	15700	3.14	7	364.07	<i>Porites</i>	1.54
	Wreck-B2	50500	10.10	12	1848.85	<i>Porites</i>	2.96
	Pdua-C1	112900	22.58	13	4674.67	<i>Montipora</i>	7.76
Pdua-C2	43000	8.60	7	2106.34	<i>Montipora</i>	4.32	
Gili isls.	Air-A1	36600	7.32	5	1078.86	<i>Cynarina</i>	2.74
	Air-A2	2100	0.42	3	58.65	<i>Fungia</i>	0.18
	Trawa-B1	12600	2.52	3	371.07	<i>Seriatopora</i>	1.14
	Trawa-B2	10500	2.10	5	232.39	<i>Fungia</i>	1.24
	Meno-C1	109700	21.94	5	4532.05	<i>Seriatopora</i>	20.22
	Meno-C2	38000	7.60	8	747.80	<i>Fungia</i>	5.74

Appendix 8. Fish distribution in each sampling station

Location	Station	Species number	Fish number (ind.)	Value (\$)	Dominant Species	Dominant (ind.)
Seribu isls.	Pandan-A1	20	312	281.05	<i>Chromis sp.</i>	117
	Pandan-A2	20	500	506.20	<i>Chromis sp.</i>	122
	Pandan-A3	24	476	261.30	<i>Chromis sp.</i>	126
	Opak-B	24	334	261.15	<i>Halichoeres sp.</i>	103
	Bira-C	34	217	222.60	<i>Chromis sp.</i>	37
	Putri-D	12	55	73.05	<i>Helichoeres hortulanus</i>	15
	Melinjo-E	18	98	62.95	<i>Abudefduf vaigiensis</i>	27
	Genteng-F	9	81	47.50	<i>Pomacentrus alexandrea</i>	52
	Kotok-G1	12	119	94.50	<i>Pomacentrus alexanderae</i>	41
	Kotok-G2	14	58	89.50	<i>Centropyge nox</i>	21
	Layar-H1	17	125	144.95	<i>Abudefduf sexfasciatus</i>	40
	Layar-H2	19	203	176.55	<i>Chromis sp.</i>	120
	Panggang-I1	9	56	87.45	<i>Centropyge nox</i>	19
	Panggang-I2	18	109	125.10	<i>Abudefduf vaigiensis</i>	17
	Sekati-J1	11	95	82.50	<i>Pomacentrus brachialis</i>	54
Sekati-J2	18	191	160.75	<i>Chromis atripectoralis</i>	101	
Menjangan isl.	Geel-A1	20	233	244.50	<i>Chromis analis</i>	80
	Geel-A2	27	169	237.85	<i>Chromis analis</i>	58
	Wreck-B1	16	169	137.05	<i>Chrysiptera caeruleolineata</i>	100
	Wreck-B2	32	115	142.75	<i>Paraglyphidodon nigrosus</i>	19
	Pdua-C1	30	218	180.00	<i>Pseudanthias squamipinnis</i>	33
	Pdua-C2	15	142	138.90	<i>Chrysiptera caeruleolineata</i>	70
Gili isls.	Air-A1	20	229	141.60	<i>Chrysiptera oxycephala</i>	120
	Air-A2	17	73	103.10	<i>Chaetodon klenii</i>	26
	Trawa-B1	20	229	133.15	<i>Chromis sp.</i>	102
	Trawa-B2	20	153	103.80	<i>Chromis analis</i>	35
	Meno-C1	16	665	366.20	<i>Chryseptera oxycephala</i>	300
	Meno-C2	19	172	141.60	<i>Chrysiptera oxycephala</i>	250

Appendix 9. Price list of reef fishes exported from Indonesia (US\$/individual)

No.	Local Name	Common Name	Scientific Name	Price (US\$)
<b>Angelfish</b>				
1	Angel abu doreng	Orange stripe angel	<i>Centropyge eibli</i>	2.00
2a	A anularis L	Blue ring angelfish L	<i>Pomacanthus annularis</i>	11.00
2b	A anularis M/S	Blue ring angelfish M/S	<i>Pomacanthus annularis</i>	13.50
3	A batman	Emperor Angle	<i>Pomacanthus imperator</i>	23.00
3a	A bluestone biasa L	Koran angelfish L	<i>Pomacanthus semicircular</i>	6.00
3b	A bluestone biasa M	Koran angelfish M	<i>Pomacanthus semicircular</i>	4.71
3c	A bluestone biasa S	Koran angelfish S	<i>Pomacanthus semicircular</i>	4.00
4	A marmud	Vermiculated angelfish	<i>Chaetodontophus mesole</i>	1.75
5a	A napoleon L	Yellow face angelfish L	<i>Euxiphipops xanthomet</i>	27.00
5b	A napoleon M/S	Yellow face angelfish M/S	<i>Euxiphipops xanthomet</i>	17.00
6	A roti	Angelfish	<i>Pomacanthus sextriatus</i>	5.50
7	A strip 6	Six- Barred Angle	<i>Euxiphipops sextriatus</i>	4.50
8	Bluestone anularis	Blue ring angelfish	<i>Pomacanthus annularis</i>	6.00
<b>Butterflyfish (kepe)</b>				
8a	Kepe auriga L	Threadfin butterflyfish 3.0"	<i>Chaetodon auriga</i>	5.00
8b	K auriga M/S	Threadfin butterflyfish 1.5 -2.5"	<i>Chaetodon auriga</i>	2.00
9	K bulan biasa	Mirror butterflyfish	<i>Chaetodon speculum</i>	2.50
10	K bulan handa	Butterflyfish	<i>Chaetodon sp.</i>	5.00
11	K campur	Mix other butterflyfish	<i>Chaetodon sp.</i>	2.00
12	K citrun item	Spot band butterflyfish	<i>Chaetodon punctatofasciatus</i>	3.00
13	K coklat	Klein's butterflyfish	<i>Chaetodon kleini</i>	2.00
14a	K falkula L	Sickle butterflyfish L	<i>Chaetodon falcula</i>	8.00
14b	K falkula M/S	Sickle butterflyfish S/M	<i>Chaetodon falcula</i>	5.00
15	K falkula palsu	Philippine chevron butterflyfish	<i>Chaetodon xanthurus</i>	3.00
16a	K gajah L	Racoon butterflyfish L	<i>Chaetodon lunula</i>	4.50
16b	K gajah M/S	Racoon butterflyfish M/S	<i>Chaetodon lunula</i>	2.50
17a	K kalong M/L	Red tailed butterflyfish M/L	<i>Chaetodon collaris</i>	4.50
17b	K kalong S	Red tailed butterflyfish S	<i>Chaetodon collaris</i>	3.00
18	K kuyit titik item	Decorated butterflyfish	<i>Chaetodon semeion</i>	6.00
19a	K layaran L	Banner fish L	<i>Heniochus acuminatus</i>	6.50
19b	K layaran M/S	Banner fish M/S	<i>Heniochus acuminatus</i>	3.00
20	K marmud	Panda butterflyfish	<i>Chaetodon flavirostris</i>	3.00
21	K merak	Triangle butterflyfish	<i>Chaetodon triangulum</i>	2.50
22a	K meyeri L	Meyer's butterflyfish L	<i>Chaetodon meyeri</i>	8.00
22b	K meyeri M/S	Meyer's butterflyfish M/S	<i>Chaetodon meyeri</i>	4.00
23a	K monalisa L	Saddleback butterflyfish L	<i>Chaetodon ephippium</i>	6.50
23b	K monalisa M	Saddleback butterflyfish M	<i>Chaetodon ephippium</i>	3.50
23c	K monalisa S	Saddleback butterflyfish S	<i>Chaetodon ephippium</i>	3.50
24a	K monyong asli ML	Yellow long nose butterflyfish	<i>Forcipiger flavissinus</i>	10.25
24b	K monyong asli S	Yellow long nose butterflyfish	<i>Forcipiger flavissinus</i>	7.50
25a	K nanas/kuning L	Raffle butterfly L	<i>Chaetodon rafflesi</i>	5.00
25b	K nanas/kuning M/S	Raffle butterfly M/S	<i>Chaetodon rafflesi</i>	3.00
26	K pasangan/kepe-kepe	Melon butterflyfish	<i>Chaetodon trifasciatus</i>	2.50
27	K strip 4	Two spot coral fish	<i>Coradion melanopus</i>	2.50
28	K strip 8	Eight stripped butterflyfish	<i>Chaetodon octofasciatus</i>	2.00
29	K tiker ekor item	Vagabond's butterflyfish	<i>Chaetodon vagabundus</i>	2.50
30	K tiker ekor putih	Butterflyfish	<i>Chaetodon baronessa</i>	2.00
31	Kambangan tanduk	Humphead bannerfish	<i>Heniochus varius</i>	2.50
<b>Damselfish (betok)</b>				
32	Balong	Spinecheek clown	<i>Premnas biaculatus</i>	0.80
33	Betok ekor kuning	Half blue damsel	<i>Chrysiptera hemicyana</i>	0.50
34	Betok ekor putih	Spiny chromis	<i>Acanthochromis polyacanthus</i>	0.70
35	Betok ijo	Blue green chromis	<i>Chromis viridis</i>	0.50
36	Betok kuning	Molucca damsel	<i>Pomacentrus mollucensis</i>	0.60
37	Betok strip biru	Honey damselfish	<i>Stegastes mellis</i>	0.50
38	Betok susu	Damsel fish	<i>Dischistodus melanotus</i>	2.50
39	Blueband/doger	Blue streak devil	<i>Paraglyphidodon oxyodon</i>	0.90
40	Bluedevil polos	Blue devil	<i>Chrysiptera cyanea</i>	0.50
41	Bluestar	Allen's damsel	<i>Pomacentrus alleni</i>	0.90
42	Clownfish	Clown anemon fish	<i>Amphiprion percula</i>	0.80
148	Crossboy bicolor	Two-lined snapper	<i>Scolopsis bilineatus</i>	1.00
<b>Miscellaneous</b>				
149	Brajanata merah/mata belo	Soldier fish	<i>Myripristis sp.</i>	0.70
150	Brosso kuning	Pennant glyder	<i>Valenciennesa strigata</i>	1.80
151	Brosso pravit	Grubfishes	<i>Parapercis hexophthalma</i>	2.00
152	Brosso pulau/janggo	Grubfishes	<i>Parapercis stricticeps</i>	2.00
153	Capungan merah	Polkadot cardinal fish	<i>Sphaerama nematoptera</i>	0.75
154	Hiu tempel	Blacktip reefshark	<i>Carcharhinus melanopterus</i>	25.00
155	Kakak tua ijo	Parrot fish	<i>Scarus sp.</i>	1.50
156	Kakak tua merah	Parrot fish	<i>Scarus sp.</i>	1.50
157	Kodok biasa	Frog fish	<i>Antennarius sp.</i>	2.75
158	Pari	Blue spotted stingray	<i>Taeniura lymna</i>	5.00
159	Piso piso	Shrimp fish	<i>Aeoliscus strigatus</i>	0.60
160	Putri solo/gramistes	Sixstripe soapfish	<i>Gramistes sexlineatus</i>	2.70
161	Sebelah	Eyed flounder (mixed)	<i>Bothus ocellatus</i>	0.75
162	Sembilang	Catfish	<i>Plotosus angularis</i>	0.60
163	Sutera	Dusky brotulid	<i>Brotulina tusca</i>	1.00

Source:

1. PT Cahaya Baru, Jakarta, Indonesia (February 2002)
2. PT Golden Marindo, Jakarta, Indonesia (February 2002)
3. CV Dinar Marine & Fish, Coral & Invertebrates, Bali, Indonesia (January, 2002)
4. Indonesian Coral, Shell, and Ornamental Fish Association (January 2002)
5. County Status Overview of Indonesian Coral Fisheries 2001, Ministry of Marine and Fisheries (April 2001)

Appendix 10. Price List of live corals and other invertebrates exported from Indonesia (US\$/piece)

No.	Local name	Common name	Scientific name	Price (US\$)
Live corals				
1	Acropora biasa	Branch coral (brown)	<i>Acropora sp</i>	6.00
2	Acropora warna	Branch coral (color)	<i>Acropora sp</i>	12.50
3	Akar bahar	Brown gorgonia soft	<i>Euplexaura sp</i>	5.00
4	Aut aut	Brown xenia	<i>Xenia sp.</i>	4.00
5	Batu Yo cabang	Sunflower branch	<i>Goniopora lobata</i>	3.00
6	Batu Yo cabang ijo	Jewel coral	<i>Goniopora sp</i>	3.00
7	Batu Yo jeruk	Lemon coral	<i>Goniopora sp</i>	2.00
8a	Blastomussa biasa L	Encruasting coral	<i>Blastomussa wellsi</i>	7.00
8b	Blastomussa biasa M	Encruasting coral	<i>Blastomussa wellsi</i>	4.00
8c	Blastomussa biasa S	Encruasting coral	<i>Blastomussa wellsi</i>	3.00
9	Jamur biasa	Mushrooms grey	<i>Ricordia florida</i>	3.50
10	Jamur bulu	Mushrooms hairy	<i>Discosoma florida</i>	6.00
11	Jamur bulu ijo	Mushrooms green hairy	<i>Discosoma florida</i>	8.00
12	Jamur kuping gajah	Elephant-ear mushrooms	<i>Rhodactis maeandrinae</i>	3.90
13	Jamur kuping gajah ijo	Green elephant-ear mushrooms	<i>Rhodactis maeandrinae</i>	10.00
14a	Jamur mangkok L	Giant cup mushroom L	<i>Rhodactis gigantea</i>	9.75
14b	Jamur mangkok M	Giant cup mushroom M	<i>Rhodactis gigantea</i>	7.50
14c	Jamur mangkok S	Giant cup mushroom S	<i>Rhodactis gigantea</i>	5.00
15	Jamur merah	Red mushroom	<i>Actinodiscus sp.</i>	5.60
16a	Jamur metalik L	Metalic mushroom L	<i>Mecedium elephantutum</i>	15.00
16b	Jamur metalik M	Metalic mushroom M	<i>Mecedium elephantutum</i>	10.00
16c	Jamur metalik S	Metalic mushroom S	<i>Mecedium elephantutum</i>	7.50
17	Kar. Putat jepara	Putat flower coral	<i>Euphyllia cristata</i>	2.50
18	Kar. Putat jepara cabang	Grape coral brown	<i>Euphyllia cristata</i>	5.00
19	Kar. Putat jepara cabang ijo	Flat coral modern	<i>Scolymia sp.</i>	2.34
20	Kar. Putat jepara cabang kuning	Beef coral	<i>Lobophyllia sp.</i>	5.00
21	Karang anemon	Stoney coral	<i>Euphyllia sp.</i>	1.75
22	Karang anemon ijo	Green stoney coral	<i>Euphyllia sp.</i>	2.00
23	Karang daging biasa	Brain coral	<i>Lobophyllia sp.</i>	2.00
24	Karang Hydnopora	Horn coral	<i>Hydnopora sp.</i>	3.00
25a	Karang Kolang k. kembang L	Meat coral L	<i>Catalophyllia plicata</i>	13.50
25b	Karang Kolang k. kembang M	Meat coral M	<i>Catalophyllia plicata</i>	10.75
25c	Karang Kolang k. kembang S	Meat coral S	<i>Catalophyllia plicata</i>	9.00
26	Karang Kolang kaling biasa	Bubble coral	<i>Plerogyra sinuosa</i>	1.75
27	Karang koreng	Durian coral	<i>Galaxea sp.</i>	2.00
28	Karang kuku cabang	Hammer coral cream	<i>Euphyllia glabrescens</i>	2.00
29a	Karang kuku cabang ijo L	Hammer coral cream L	<i>Euphyllia glabrescens</i>	8.00
29b	Karang kuku cabang ijo M	Hammer coral cream M	<i>Euphyllia glabrescens</i>	5.00
29c	Karang kuku cabang ijo S	Hammer coral cream S	<i>Euphyllia glabrescens</i>	3.00
30a	Karang kuku ijo L	Hammer head coral green L	<i>Euphyllia fimbriata</i>	10.00
30b	Karang kuku ijo M	Hammer head coral green M	<i>Euphyllia fimbriata</i>	4.00
30c	Karang kuku ijo S	Hammer head coral green S	<i>Euphyllia fimbriata</i>	2.75
31	Karang kuku kuning	Hammer head coral brown	<i>Euphyllia fimbriata</i>	2.00
32a	Karang kuku L	Hammer coral cream L	<i>Euphyllia glabrescens</i>	4.00
32b	Karang kuku S	Hammer coral cream S	<i>Euphyllia glabrescens</i>	2.00
33	Karang kuku pucuk/cab kuning	Hammer head coral brown	<i>Euphyllia fimbriata</i>	5.00
34	Karang lidah	Tongue coral	<i>Polyphyllia sp.</i>	4.00
35	Karang lidah garis	Tongue coral	<i>Polyphyllia sp.</i>	4.71
36	Karang lidah garis ijo	Tongue coral	<i>Polyphyllia sp.</i>	5.00
108	Anemon pantat merah	Long tentacle anemon	<i>Stoichactis kentii</i>	3.00
Other invertebrates				
1	Bintang biru	Blue starfish	<i>Linckis laevigata</i>	1.30
2	Bintang jenderal coklat	Brown general starfish	<i>Pentaceraster tuberculatus</i>	1.30
3	Bintang jenderal merah	Red general starfish	<i>Protoreaster linckii</i>	1.50
4	Bintang laba-laba	Feather starfish	<i>Comanthus spec</i>	1.30
5	Bintang merah	Red starfish	<i>Fromia elegans</i>	1.00
6	Bintang merah spesial	Red starfish special	<i>Echinaster purpureus</i>	1.00
7	Bulu babi	Short-spine urchin	<i>Echinometra spec</i>	1.20
8	Cacing biasa coklat	Feather tube worms	<i>Sabellastarte indica</i>	1.50
9	Cacing biasa merah/putih	King snake red	<i>Synapta maculata</i>	2.75
10	Gurita campur	Common octopus	<i>Hapalochlaena vulgaris</i>	2.00
11	Keong terbang	Flying slug	<i>Thuridilla sp.</i>	2.00
12	Kepiting anemon	Hermit crab red	<i>Dardanus megistos</i>	1.50
13	Lintah campur	Nudibranches assorted	<i>Thuridilla sp.</i>	1.50
14	Udang anemon	Anemone shrimp	<i>Hymenocera picta</i>	2.00
15	Udang lobster	Lobster	<i>Palinurus ornatus</i>	2.00
16	Udang merah putih	Red-banded shrimp	<i>Stenopus hispidus</i>	1.30
17	Udang ronggeng	Snapping shrimp	<i>Periclimenes brevicarvalis</i>	2.00
18	Udang wayang	Puppet shrimp	<i>Rhynchocinetes regulosus</i>	1.30

Source:

1. PT Cahaya Baru, Jakarta, Indonesia (February 2002)
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4. Indonesian Coral, Shell, and Ornamental Fish Association (January 2002)
5. County Status Overview of Indonesian Coral Fisheries 2001, Ministry of Marine and Fisheries (April 2001)

## Appendix 11. Facility, equipment, and cost of tourism operator

## Seribu Islands

Facility & Equipment	Kotok	Buana	Paradise	Matahari	Sepa	BTN	TOTAL
Hotel	0	1	0	1	0	0	2
Cottages	1	0	1	0	1	1	6
Restaurant	1	1	1	1	1	1	6
Cafe	1	1	1	1	1	3	8
Pier	0	1	1	1	1	0	4
Boat	2	2	2	3	2	1	12
Diving equipment	8	10	14	15	9	6	62
Compressor	1	1	1	1	1	1	6
Labour	17	23	31	33	22	12	138

Cost	Kotok	Buana	Paradise	Matahari	Sepa	BTN	TOTAL
Facility	48143.78	70673.18	91853.24	97197.74	69287.56	35100.00	412255.50
Equipment	21571.00	23703.00	27967.00	31933.00	22637.00	16539.00	144350.00
Total Investment	69714.78	94376.18	119820.24	129130.74	91924.56	51639.00	556605.50
Material	27151.00	36613.00	48811.00	51889.00	35815.00	18487.00	218766.00
Labour	10710.00	14490.00	19530.00	20790.00	13860.00	7560.00	86940.00
Maintenance	4564.29	5903.96	7389.36	8053.19	5728.08	3408.90	35047.77
Total O & M	42425.29	57006.96	75730.36	80732.19	55403.08	29455.90	340753.77

## Menjangan Island

Facility & Equipment	Wakas	Trimbaw	Matahari	Mimpi	Archipel	Lovina	TNBB	TOTAL
Hotel	1	1	1	1	1	1	0	6
Cottages	0	0	0	0	0	0	1	1
Restaurant	1	1	1	1	1	1	2	8
Cafe	2	0	0	0	0	2	0	4
Pier	0	0	1	1	1	1	1	5
Boat	2	2	2	2	2	2	40	52
Diving equipment	22	17	9	15	8	11	8	90
Compressor	1	1	1	1	1	1	0	6
Labour	23	31	41	44	30	31	16	216

Cost	Wakas	Trimbaw	Matahari	Mimpi	Archipel	Lovina	TNBB	TOTAL
Facility	70969.00	91464.00	127451.00	134948.00	97463.00	106956.00	38981.00	668232.00
Equipment	36931.00	31551.00	22943.00	29399.00	21867.00	25095.00	128728.00	296514.00
Total Investment	107900.00	123015.00	150394.00	164347.00	119330.00	132051.00	167709.00	964746.00
Material	38592.00	52038.00	69372.00	73746.00	50886.00	53028.00	26262.00	363924.00
Labour	14398.00	19406.00	25666.00	27544.00	18780.00	19406.00	10016.00	135216.00
Maintenance	7951.24	8642.94	9941.36	11036.78	8034.48	8926.86	15211.66	69745.32
Total O & M	60941.24	80086.94	104979.36	112326.78	77700.48	81360.86	51489.66	568885.32

## Gili Islands

Facility & Equipment	Air1	Air2	Meno1	Trawa1	Trawa2	Trawa3	TOTAL
Hotel	1	1	1	1	1	1	6
Cottages	13	16	15	12	17	14	15
Restaurant	1	1	1	1	1	1	6
Cafe	3	2	2	3	3	3	16
Pier	1	0	1	0	1	0	3
Boat	2	3	4	3	5	4	21
Diving equipment	8	11	13	7	12	8	59
Compressor	1	1	1	1	1	1	6
Labour	75	91	105	93	122	117	603

Cost	Air1	Air2	Meno1	Trawa1	Trawa2	Trawa3	TOTAL
Facility	465859.00	539257.00	683745.00	533160.00	562794.00	550241.00	3335056.00
Equipment	25229.00	33525.00	38288.00	27146.00	40223.00	33971.00	198382.00
Total Investment	491088.00	572782.00	722033.00	560306.00	603017.00	584212.00	3533438.00
Material	304115.61	369277.37	477887.16	304095.07	369297.92	347563.63	2172236.76
Labour	39750.00	48230.00	55650.00	49290.00	64660.00	62010.00	319590.00
Maintenance	26534.00	31189.86	39082.68	30177.22	33127.02	31799.10	191909.88
Total O & M	370399.61	448697.23	572619.83	383562.29	467084.94	441372.73	2683736.63

Appendix 12. Fishing cost in Seribu islands

No.	Fishermen	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Fr1	4000.00	5000.00	800.00	1000.00	1000.00	600.00	190.00	2700.00	4104.00	3885.44	14279.44
2	Fr2	2600.00	1200.00	520.00	240.00	120.00	45.00	50.00	432.00	972.00	914.67	3293.67
3	Fr3	1200.00	0.00	240.00	0.00	80.00	0.00	40.00	0.00	540.00	418.14	1318.14
4	Fr4	3500.00	3000.00	700.00	600.00	400.00	300.00	96.00	1296.00	2700.00	1741.88	7833.88
5	Fr5	1000.00	0.00	200.00	0.00	120.00	0.00	65.00	0.00	3240.00	1869.61	5494.61
6	Fr6	3000.00	2500.00	600.00	500.00	360.00	360.00	111.00	864.00	1728.00	1311.60	5834.60
7	Fr7	1200.00	0.00	240.00	0.00	90.00	0.00	44.00	0.00	540.00	465.80	1379.80
8	Fr8	1000.00	0.00	200.00	0.00	45.00	0.00	37.00	0.00	540.00	348.80	1170.80
9	Fr9	3600.00	2500.00	720.00	500.00	240.00	210.00	69.00	756.00	1890.00	1878.20	6263.20
10	Fr10	2800.00	1800.00	560.00	360.00	180.00	120.00	59.00	540.00	1512.00	1302.28	4633.28
11	Fr11	3000.00	2500.00	600.00	500.00	750.00	300.00	75.00	1080.00	2700.00	2335.20	8340.20
12	Fr12	4000.00	4000.00	800.00	800.00	600.00	450.00	165.00	1944.00	3780.00	3356.14	11895.14
13	Fr13	600.00	0.00	120.00	0.00	30.00	0.00	17.00	0.00	540.00	258.44	965.44
14	Fr14	4800.00	3800.00	960.00	760.00	300.00	240.00	77.00	1080.00	2592.00	3063.04	9072.04
15	Fr15	1200.00	0.00	240.00	0.00	75.00	0.00	37.00	0.00	540.00	447.30	1339.30
16	Fr16	1000.00	0.00	200.00	0.00	40.00	0.00	38.00	0.00	540.00	379.20	1197.20
17	Fr17	2400.00	1000.00	480.00	200.00	100.00	40.00	47.00	324.00	702.00	772.10	2665.10
18	Fr18	2800.00	1800.00	560.00	360.00	160.00	100.00	54.00	540.00	1350.00	1342.40	4466.40
19	Fr19	3000.00	1800.00	600.00	360.00	160.00	140.00	64.00	540.00	1458.00	1344.92	4666.92
20	Fr20	1000.00	0.00	200.00	0.00	45.00	0.00	35.00	0.00	540.00	288.60	1108.60
21	Fr21	3600.00	2600.00	720.00	520.00	270.00	210.00	73.00	864.00	1998.00	1941.10	6596.10
22	Fr22	1200.00	0.00	240.00	0.00	60.00	0.00	42.00	0.00	540.00	412.62	1294.62
23	Fr23	3600.00	2600.00	720.00	520.00	260.00	220.00	71.00	864.00	1998.00	1933.30	6586.30
24	Fr24	6500.00	5400.00	1300.00	1080.00	320.00	260.00	80.00	1188.00	2916.00	4757.25	11901.25
25	Fr25	2000.00	3000.00	400.00	600.00	300.00	250.00	71.00	1296.00	1188.00	1299.74	5404.74
26	Fr26	5000.00	5500.00	1000.00	1100.00	900.00	750.00	186.00	2160.00	3240.00	3649.75	12985.75
27	Fr27	900.00	0.00	180.00	0.00	60.00	0.00	65.00	0.00	1188.00	765.78	2258.78
28	Fr28	2000.00	0.00	400.00	0.00	100.00	0.00	42.00	0.00	540.00	632.76	1714.76
29	Fr29	3200.00	2200.00	640.00	440.00	210.00	180.00	65.00	648.00	1998.00	1546.32	5727.32
30	Fr30	4000.00	3100.00	800.00	620.00	280.00	220.00	74.00	972.00	2268.00	2390.00	7624.00
31	Fr31	2800.00	1800.00	560.00	360.00	150.00	90.00	57.00	648.00	1458.00	1250.70	4573.70
32	Fr32	3200.00	2000.00	640.00	400.00	200.00	160.00	67.00	648.00	1728.00	1582.46	5425.46
33	Fr33	3400.00	2200.00	680.00	440.00	220.00	180.00	66.00	756.00	1620.00	1668.40	5630.40
34	Fr34	7000.00	6000.00	1400.00	1200.00	1000.00	900.00	192.00	3240.00	8640.00	5210.76	21782.76
35	Fr35	3500.00	3000.00	700.00	600.00	450.00	420.00	116.00	1620.00	2052.00	2286.10	8244.10
36	Fr36	800.00	0.00	160.00	0.00	40.00	0.00	27.00	0.00	540.00	279.90	1046.90
37	Fr37	2800.00	1600.00	560.00	320.00	140.00	60.00	52.00	540.00	1458.00	1130.26	4260.26
38	Fr38	7000.00	6000.00	1400.00	1200.00	450.00	360.00	95.00	1296.00	3780.00	5251.60	13832.60
39	Fr39	6000.00	5000.00	1200.00	1000.00	800.00	600.00	182.00	2160.00	7560.00	4064.20	17566.20
Total (thousand Rp)		116200.00	82900.00	23240.00	16580.00	11105.00	7765.00	2993.00	30996.00	79218.00	69776.76	241673.76
Total (US\$)		11620.00	8290.00	2324.00	1658.00	1110.50	776.50	299.30	3099.60	7921.80	6977.68	24167.38



Appendix 13. Coral collecting cost in Seribu islands

No.	Collector	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Collector1	1200.00	0.00	240.00	0.00	75.00	0.00	37.00	0.00	324.00	448.80	1124.80
2	Collector2	4000.00	3000.00	800.00	600.00	200.00	260.00	126.00	864.00	1620.00	1706.76	6176.76
3	Collector3	2000.00	0.00	400.00	0.00	100.00	0.00	38.00	0.00	648.00	648.90	1834.90
4	Collector4	9000.00	10000.00	1800.00	2000.00	3000.00	1800.00	1968.00	5400.00	21600.00	20818.06	58386.06
5	Collector5	1200.00	0.00	240.00	0.00	80.00	0.00	40.00	0.00	324.00	396.20	1080.20
6	Collector6	900.00	0.00	180.00	0.00	60.00	0.00	28.00	0.00	324.00	242.38	834.38
7	Collector7	600.00	0.00	120.00	0.00	30.00	0.00	22.00	0.00	324.00	203.50	699.50
8	Collector8	800.00	0.00	160.00	0.00	40.00	0.00	27.00	0.00	324.00	238.62	789.62
9	Collector9	5000.00	3500.00	1000.00	700.00	210.00	180.00	168.00	1296.00	3240.00	2021.50	8815.50
10	Collector10	1200.00	0.00	240.00	0.00	60.00	0.00	22.00	0.00	324.00	314.46	960.46
11	Collector11	1200.00	0.00	240.00	0.00	90.00	0.00	34.00	0.00	324.00	472.80	1160.80
12	Collector12	1000.00	0.00	200.00	0.00	45.00	0.00	37.00	0.00	324.00	280.10	886.10
13	Collector13	1000.00	0.00	200.00	0.00	45.00	0.00	35.00	0.00	324.00	270.88	874.88
14	Collector14	1000.00	0.00	200.00	0.00	120.00	0.00	40.00	0.00	324.00	290.26	974.26
15	Collector15	3500.00	3000.00	700.00	600.00	180.00	240.00	52.00	540.00	972.00	1380.96	4664.96
16	Collector16	7000.00	5000.00	1400.00	1000.00	600.00	450.00	252.00	2160.00	6480.00	8517.10	20859.10
17	Collector17	1000.00	0.00	200.00	0.00	40.00	0.00	38.00	0.00	324.00	289.36	891.36
18	Collector18	6000.00	4000.00	1200.00	800.00	240.00	220.00	210.00	1620.00	4050.00	2980.80	11320.80
Total (thousand Rp)		47600.00	28500.00	9520.00	5700.00	5215.00	3150.00	3174.00	11880.00	42174.00	41521.44	122334.44
Total (US\$)		4760.00	2850.00	952.00	570.00	521.50	315.00	317.40	1188.00	4217.40	4152.14	12233.44

Appendix 14. Fishing cost in Menjangan island

No.	Fishermen	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Fr1	10000.00	4000.00	2000.00	800.00	1800.00	960.00	265.00	4320.00	2700.00	3698.45	16543.45
2	Fr2	5500.00	3000.00	1100.00	600.00	780.00	360.00	196.00	2160.00	1080.00	1774.55	8050.55
3	Fr3	5000.00	2500.00	1000.00	500.00	600.00	300.00	165.00	1512.00	900.00	1637.84	6614.84
4	Fr4	5500.00	3000.00	1100.00	600.00	800.00	360.00	211.00	2160.00	1170.00	2153.37	8554.37
5	Fr5	7000.00	3500.00	1400.00	700.00	1200.00	480.00	286.00	2700.00	1440.00	3383.73	11589.73
6	Fr6	4500.00	2500.00	900.00	500.00	600.00	300.00	192.00	1350.00	900.00	1663.64	6405.64
7	Fr7	4000.00	2500.00	800.00	500.00	480.00	280.00	190.00	1080.00	720.00	1740.00	5790.00
8	Fr8	15000.00	5000.00	3000.00	1000.00	2160.00	1800.00	365.00	5400.00	2880.00	4123.19	20728.19
9	Fr9	6000.00	3000.00	1200.00	600.00	900.00	480.00	265.00	2592.00	1260.00	2277.11	9574.11
10	Fr10	8500.00	4000.00	1700.00	800.00	1800.00	600.00	292.00	3240.00	2430.00	3056.82	13918.82
11	Fr11	5000.00	2500.00	1000.00	500.00	600.00	300.00	171.00	2160.00	900.00	1716.00	7347.00
12	Fr12	4000.00	2500.00	800.00	500.00	450.00	240.00	186.00	1080.00	720.00	1726.31	5702.31
13	Fr13	5000.00	2500.00	1000.00	500.00	720.00	300.00	175.00	2160.00	972.00	1804.83	7631.83
14	Fr14	20000.00	15000.00	4000.00	3000.00	2000.00	3600.00	371.00	3888.00	2916.00	6180.99	25955.99
15	Fr15	2000.00	1200.00	400.00	240.00	360.00	160.00	111.00	864.00	360.00	1386.24	3881.24
16	Fr16	6000.00	3000.00	1200.00	600.00	960.00	480.00	282.00	2160.00	1440.00	2375.82	9497.82
17	Fr17	7500.00	3600.00	1500.00	720.00	840.00	600.00	290.00	2592.00	1800.00	3364.80	11706.80
18	Fr18	6000.00	3000.00	1200.00	600.00	800.00	360.00	216.00	1728.00	1260.00	2326.40	8490.40
19	Fr19	750.00	1000.00	150.00	200.00	240.00	120.00	75.00	540.00	216.00	1052.12	2593.12
20	Fr20	3000.00	2000.00	600.00	400.00	400.00	240.00	182.00	1080.00	648.00	1561.76	5111.76
21	Fr21	2000.00	1250.00	400.00	250.00	360.00	180.00	116.00	864.00	540.00	1498.25	4208.25
22	Fr22	500.00	0.00	100.00	0.00	180.00	0.00	65.00	0.00	216.00	1018.16	1579.16
23	Fr23	500.00	0.00	100.00	0.00	60.00	0.00	65.00	0.00	144.00	1008.50	1377.50
24	Fr24	2000.00	1000.00	400.00	200.00	360.00	80.00	96.00	810.00	270.00	1102.26	3318.26
25	Fr25	600.00	400.00	120.00	80.00	220.00	120.00	71.00	648.00	216.00	840.14	2315.14
26	Fr26	3000.00	2000.00	600.00	400.00	400.00	240.00	165.00	1080.00	540.00	1466.94	4891.94
Total (thousand Rp)		138850.00	73950.00	27770.00	14790.00	20070.00	12940.00	5064.00	48168.00	28638.00	55938.15	213378.15
Total (US\$)		13885.00	7395.00	2777.00	1479.00	2007.00	1294.00	506.40	4816.80	2863.80	5593.82	21337.82

Appendix 15. Coral collecting cost in Menjangan island

No.	Collector	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Clr1	1000.00	0.00	200.00	0.00	160.00	0.00	116.00	0.00	540.00	671.79	1687.79
2	Clr2	800.00	0.00	160.00	0.00	120.00	0.00	96.00	0.00	270.00	341.55	987.55
3	Clr3	2000.00	1500.00	400.00	300.00	200.00	120.00	182.00	1080.00	648.00	824.70	3754.70
4	Clr4	3000.00	2000.00	600.00	400.00	240.00	150.00	186.00	1080.00	720.00	1011.00	4387.00
5	Clr5	800.00	0.00	160.00	0.00	90.00	0.00	111.00	0.00	360.00	363.00	1084.00
6	Clr6	1000.00	0.00	200.00	0.00	210.00	0.00	165.00	0.00	540.00	735.30	1850.30
7	Clr7	4000.00	2500.00	800.00	500.00	480.00	280.00	190.00	1080.00	720.00	2951.40	7001.40
Total (thousand Rp)		12600.00	6000.00	2520.00	1200.00	1500.00	550.00	1046.00	3240.00	3798.00	6898.74	20752.74
Total (US\$)		1260.00	600.00	252.00	120.00	150.00	55.00	104.60	324.00	379.80	689.87	2075.27

Appendix 16. Fishing cost in Gili islands

No.	Fishermen	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Fr1	1000.00	0.00	200.00	0.00	210.00	0.00	165.00	0.00	540.00	291.60	1406.60
2	Fr2	3000.00	2000.00	600.00	320.00	400.00	240.00	165.00	1080.00	540.00	1150.35	4495.35
3	Fr3	800.00	0.00	160.00	0.00	90.00	0.00	96.00	0.00	270.00	209.10	825.10
4	Fr4	2000.00	800.00	400.00	160.00	240.00	120.00	186.00	648.00	540.00	560.03	2854.03
5	Fr5	2000.00	1000.00	400.00	200.00	360.00	80.00	106.00	810.00	270.00	1283.70	3509.70
6	Fr6	800.00	0.00	160.00	0.00	120.00	0.00	111.00	0.00	360.00	237.90	988.90
7	Fr7	2000.00	1500.00	400.00	300.00	220.00	120.00	101.00	648.00	216.00	984.90	2989.90
8	Fr8	1000.00	0.00	200.00	0.00	160.00	0.00	116.00	0.00	540.00	244.50	1260.50
9	Fr9	2000.00	1250.00	400.00	250.00	360.00	180.00	116.00	864.00	540.00	697.20	3407.20
10	Fr10	1500.00	0.00	300.00	0.00	200.00	0.00	182.00	0.00	648.00	680.18	2010.18
11	Fr11	2000.00	1000.00	400.00	200.00	360.00	120.00	190.00	810.00	720.00	601.58	3401.58
Total (thousand Rp)		18100.00	7550.00	3620.00	1430.00	2720.00	860.00	1534.00	4860.00	5184.00	6941.03	27149.03
Total (US\$)		1810.00	755.00	362.00	143.00	272.00	86.00	153.40	486.00	518.40	694.10	2714.90

Appendix 17. Coral collecting cost in Gili islands

No.	Collector	Boat	Engine	Boat/year	Eng/year	BtMaint	EgMaint	Gear/year	Fuel	Logistic	Labour	TotCost
1	Clr1	600.00	0.00	120.00	0.00	30.00	0.00	22.00	0.00	108.00	172.39	452.39
2	Clr2	600.00	0.00	120.00	0.00	30.00	0.00	22.00	0.00	162.00	156.35	490.35
3	Clr3	400.00	0.00	80.00	0.00	30.00	0.00	22.00	0.00	108.00	107.95	347.95
4	Clr4	400.00	0.00	80.00	0.00	30.00	0.00	22.00	0.00	108.00	121.71	361.71
5	Clr5	800.00	0.00	160.00	0.00	40.00	0.00	27.00	0.00	594.00	631.99	1452.99
Total (thousand Rp)		2800.00	0.00	560.00	0.00	160.00	0.00	115.00	0.00	1080.00	1190.39	3105.39
Total (US\$)		280.00	0.00	56.00	0.00	16.00	0.00	11.50	0.00	108.00	119.04	310.54













Appendix 23. Estimated implementation costs (price incentive, patrolling, and controlling costs) in each location

## Price incentive in Seribu Islands

No.	Common Name	Price (\$/ind)	Pr. Incentive (\$/ind)	Yield (individual)	Total incent. (\$)
1	Black damsel	0.50	0.01	1758	17.58
2	Black saddled toby	1.50	0.10	530	53.00
3	Black-spot goatfish	1.10	0.10	45	4.50
4	Blacktip reefshark	25.00	1.00	464	464.00
5	Blue green chromis	0.50	0.01	4688	46.88
6a	Blue ring angelfish S/M	6.00	0.10	204	20.40
6b	Blue ring angelfish L	13.50	0.10	179	17.90
7	Blue streak devil	0.90	0.01	212	2.12
8	Bluespot tamarin	2.10	0.10	72	7.20
9	Brown bird wrasse	1.20	0.10	166	16.60
10	Checkerboard wrasse	1.60	0.10	780	78.00
11	Clown anemone fish	0.80	0.01	24752	247.52
12	Clown sweetlips	4.50	0.10	870	87.00
13	Clown wrasse	1.50	0.10	173	17.30
14	Comet/marine betta	12.00	0.50	547	273.50
15	Damselsfish	2.50	0.10	459	45.90
16	Decorated butterflyfish	6.00	0.10	102	10.20
17	Dragon wrasse	2.00	0.10	2111	211.10
18	Dusky wrasse	1.50	0.10	678	67.80
19	Eclipse hogfish	2.70	0.10	108	10.80
20	Eight striped butterflyfish	2.00	0.10	1831	183.10
21	Emperor Angle	23.00	1.00	26	26.00
22	Emperor snapper	7.50	0.50	119	59.50
23	Filefish	1.00	0.10	1344	134.40
24	Golden dottyback	1.50	0.10	1853	185.30
25	Gold-spotted snake eel	6.60	0.10	90	9.00
26	Green wrasse	1.25	0.10	351	35.10
27	Grubfish	2.00	0.10	43	4.30
28	Half blue damsel	0.50	0.01	7994	79.94
29	Half-half thicklip	0.75	0.01	1010	10.10
30	Honey damselfish	0.50	0.01	595	5.95
31	Honey striped damsel	0.50	0.01	589	5.89
32	Humphead bannerfish	2.50	0.10	282	28.20
33	Janss' pipefish	2.40	0.10	26	2.60
34	Java eel	2.00	0.10	366	36.60
35	Java grubfish	2.00	0.10	15095	1509.50
36	Long horned cowfish	1.25	0.10	72	7.20
37	Longfinned batfish	3.50	0.10	103	10.30
38	Mediterranean rainbowfish	1.25	0.10	1328	132.80
39	Melon butterflyfish	2.50	0.10	546	54.60
40	Mirror butterflyfish	2.50	0.10	37	3.70
41	Molucca damsel	0.60	0.01	3581	35.81
42	Moorishidol	2.75	0.10	85	8.50
43	Oceanic seahorse	3.00	0.10	72	7.20
44	Orange band wrasse	0.90	0.01	702	7.02
45	Orange stripe angel	2.00	0.10	325	32.50
46	Orbiculate batfish	1.75	0.10	457	45.70
47	Painted sweetlips	3.87	0.10	18	1.80
48	Panda butterflyfish	3.00	0.10	3398	339.80
49a	Parrot fish L	4.00	0.10	347	34.70
49b	Parrot fish M	1.50	0.10	186	18.60
49c	Parrot fish S	1.50	0.10	258	25.80
50	Peacock lionfish	2.10	0.10	111	11.10
51	Pennant glyder	1.80	0.10	144	14.40
52	Pink and blue spotted goby	1.30	0.10	18	1.80
53	Polkadot boxfish	3.00	0.10	1664	166.40
54	Polkadot cardinal fish	0.75	0.01	5927	59.27
55	Powder black surgeon	3.00	0.10	81	8.10
56	Rabbitfish	1.20	0.10	117	11.70
57	Raffle butterfly	3.00	0.10	35	3.50
58	Saddle anemone	1.00	0.10	3517	351.70
59	Sebae anemones	1.25	0.10	2202	220.20
60	Sergeant major	0.50	0.01	1491	14.91
61	Shrimp fish	0.60	0.01	7116	71.16
62	Skunk striped anemonefish	0.80	0.01	6562	65.62
63	Slingjaw wrasse	2.50	0.10	27	2.70
64	Soldier fish	0.70	0.01	484	4.84
65	Spinecheek clown	0.80	0.01	10691	106.91
66	Spiny chromis	0.70	0.01	1567	15.67
67a	Spotfin lionfish	1.75	0.10	167	16.70
67b	Spottail gudgeon	1.30	0.10	252	25.20
68	Spottysail dottyback	0.80	0.01	57	0.57
69	Tailbar lionfish	4.00	0.10	512	51.20
70	Three spot damsel	0.50	0.01	1224	12.24
71	Triangle butterflyfish	2.50	0.10	864	86.40
72	Two coloured blenny	0.80	0.01	21	0.21
73	Vagabond's butterflyfish	2.50	0.10	28	2.80
74	White tailed damsel	0.50	0.01	117	1.17
75	Yellow goatfish	3.00	0.10	28	2.80
76	Yellow long nose butterflyfish	7.50	0.10	737	73.70
77	Yellow-lined sweetlips	4.50	0.10	570	57.00
78	Dusky brotulid	1.00	0.10	1789	178.90
T O T A L (US\$)					6419.68

## Price incentive in Menjangan Island

No.	Common name	Price (\$/ind)	Pr. Incentive (\$/ind)	Yield (individual)	Total incent. (\$)
1	Racoon butterfly fish	4.50	0.10	120	12.00
2	Teardrop butterflyfish	2.00	0.10	608	60.80
3	Vogabona's butterflyfish	2.50	0.10	592	59.20
4	Saddled butterflyfish	3.25	0.10	64	6.40
5a	Yellow long nose butterflyfish S	6.50	0.10	358	35.80
5b	Yellow long nose butterflyfish M	7.50	0.10	358	35.80
6	Sunset butterflyfish	3.00	0.10	121	12.10
7	Mirror butterflyfish	2.10	0.10	239	23.90
8	Meyer's butterflyfish	3.80	0.10	119	11.90
9	Klein's butterflyfish	2.00	0.10	358	35.80
10	Red tailed	2.00	0.10	118	11.80
11	Sergeant mayor	0.50	0.01	1198	11.98
12	Molucca damsel	0.50	0.01	1196	11.96
13	Sebae anemones	1.25	0.10	1801	180.10
14	Blue valvet damsel	1.00	0.10	1198	119.80
15	Bicolor chromis (Bali)	0.75	0.10	6018	601.80
16	Yellow bellied damsel	0.50	0.01	5995	59.95
17	Black tailed humbug	0.50	0.01	6001	60.01
18	Half blue damsel	0.50	0.01	1198	11.98
19	Honey striped damsel	0.50	0.01	1196	11.96
20	Skunk anemonefish	1.00	0.10	608	60.80
21	Skunk striped anemonefish	0.80	0.01	592	5.92
22	Reticulated damsel	0.40	0.01	1224	12.24
23	White tailed damsel	0.50	0.01	1181	11.81
24	Clown anemone fish	0.80	0.01	2399	23.99
Total (US\$)					1489.80

## Price incentive in Gili Islands

No.	Common Name	Price (\$/ind)	Pr. Incentive (\$/ind)	Yield (individual)	Total incent. (\$)
1	Asstid Lyretail Wrasse	1.10	0.10	338	33.80
1	Banner fish	3.00	0.10	535	53.50
2	Bicolor Angles	3.00	0.10	121	12.10
3	Blue Angle	2.60	0.10	315	31.50
4	Blue strak cleaner wrasse	0.80	0.01	1295	12.95
5	Butterflyfish	2.00	0.10	512	51.20
6	Clown Surgeon	1.50	0.10	334	33.40
7	Damselsfish	2.50	0.10	110	11.00
8	Dusky wrasse	1.50	0.10	415	41.50
9	False Blue Surgeon	6.50	0.10	261	26.10
10	Half blue damsel	0.50	0.01	460	4.60
11	Klein's butterflyfish	2.00	0.10	338	33.80
12	Mindnight Angle	2.60	0.10	119	11.90
13	Molucca damsel	0.60	0.01	60	0.60
14	Moorish Idol	2.00	0.10	823	82.30
15	Parrot fish	1.50	0.10	556	55.60
16	Pearl-Scale Angle	1.60	0.10	501	50.10
17	Powder-Blue Surgeon	10.00	0.10	443	44.30
18	Sergeant major	0.50	0.01	310	3.10
19	Soldier fish	0.70	0.01	417	4.17
20	Spot-Fin Lionfish	2.00	0.10	357	35.70
21	Two-lined snapper	1.00	0.10	239	23.90
22	Undulate trigger	2.40	0.10	387	38.70
23	White-rimmed trigger	1.30	0.10	416	41.60
24	Yellow damsel	0.50	0.01	521	5.21
Total (US\$)					742.63

## Patrolling cost

No.	Items	Seribu	Menjangan	Gili
1	Boat investment (\$)	7200.00	8400.00	3600.00
2	Engine investment (\$)	3000.00	3500.00	1500.00
3	Boat maintenance (\$/year)	900.00	1050.00	450.00
4	Engine maintenance (\$/year)	300.00	350.00	150.00
5	Fuel cost (\$/year)	49275.00	57487.50	24637.50
6	Labor cost (\$/year)	14400.00	16800.00	7200.00
Total (\$/year)		65895.00	76877.50	32947.50

## Total implementation cost

No.	Items	Seribu	Menjangan	Gili
1	Price incentive	6419.68	1489.80	742.63
2	Patrolling cost	65895.00	76877.50	32947.50
3	Controlling cost	7200.00	8400.00	3600.00
Total implementation cost		79514.68	86767.30	37290.13

Appendix 24. Input and output of stochastic model of economic analysis of actual coral reefs uses in selected sites

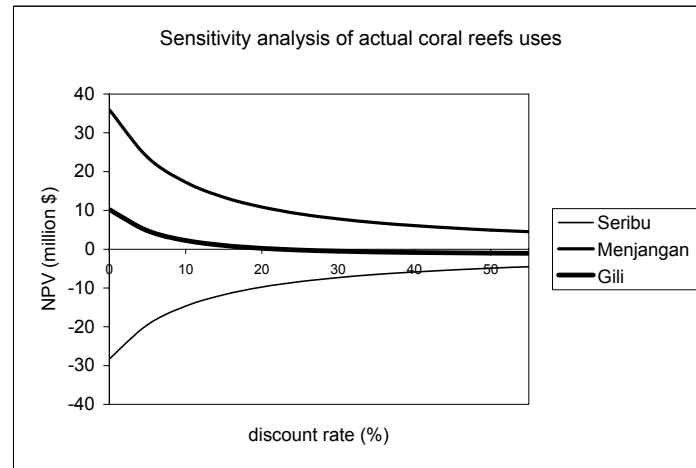
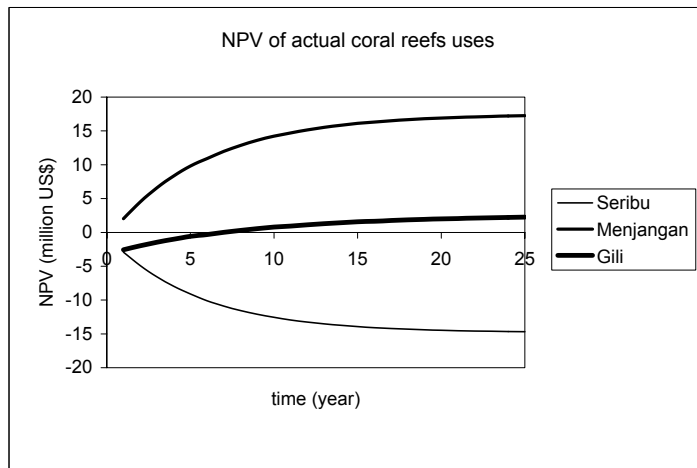
No.	Site	Natur.growth (%)	Actual Impact (%)		
			Tourism	Coral coll.	Cyan. Fishing
1	Seribu	22.213025	0.557339336	13.43258898	16.80620891
2	Menjangan	5.6784	3.834456564	1.778298351	7.372449625
3	Gili	3.6324	2.180727867	2.00683134	1.314860674
Impact change (%)					
No.	Site	Total (%)	Tourism	Coral coll.	Cyan. Fishing
1	Seribu	30.79613723	0.557339336	13.43258898	16.80620891
2	Menjangan	12.98520454	3.834456564	1.778298351	7.372449625
3	Gili	5.502419881	2.180727867	2.00683134	1.314860674
Intensity change (%)					
No.	Site	Net growth (%)	Tourism	Coral coll.	Cyan. Fishing
1	Seribu	-8.583112232	0.00	0.00	0.00
2	Menjangan	-7.306804539	0.00	0.00	0.00
3	Gili	-1.870019881	0.00	0.00	0.00

Net present value at discount rate (% 10)

No.	Site	PV Ben. (mill. \$)	PV Cost (mill. \$)	NPV (mill. \$)	Std.dev (mill.\$)	Coef. Var.
1	Seribu	8.866	23.544	-14.678	3.148	-0.2144417
2	Menjangan	38.082	20.833	17.249	2.103	0.1218928
3	Gili	31.411	29.154	2.257	0.532	0.2355499

Sensitivity analysis

No.	Site	NPV at discount rate (%)											
		0	5	10	15	20	25	30	35	40	45	50	55
1	Seribu	-28.292	-19.509	-14.678	-11.719	-9.748	-8.350	-7.308	-6.502	-5.860	-5.336	-4.900	-4.531
2	Menjangan	35.943	23.752	17.249	13.375	10.854	9.101	7.817	6.839	6.070	5.451	4.941	4.516
3	Gili	10.231	4.783	2.257	0.951	0.211	-0.238	-0.525	-0.716	-0.845	-0.934	-0.995	-1.037
		Standard deviation											
1	Seribu	4.657	3.701	3.148	2.777	2.506	2.297	2.127	1.987	1.868	1.765	1.675	1.596
2	Menjangan	3.275	2.517	2.103	1.835	1.644	1.497	1.381	1.285	1.205	1.136	1.075	1.022
3	Gili	0.992	0.670	0.532	0.456	0.408	0.372	0.345	0.323	0.304	0.288	0.274	0.262



Appendix 25. Parameters and coefficients of stochastic model of actual coral reefs uses

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
a1	-33.05907010827840000000	b1	10.50970487145080000000	Bfx	235160.31	22847588.77	Cefx	2506334.35	193505013891.24
a2	123.24713347779800000000	b2	0.0001557930399652110	Bfy	233452.45	28216846.72	Cefy	2488132.66	190704447667.18
a3	-3104.72446955074000000000	b3	949.30864002640600000000	Bfz	26451.70	1205949.38	Cefz	282001.36	2446977071.99
a4	-8.00355087502394000000	b4	8.32420188104385000000	Bcx	163430.00	763026209.70	Cecx	1382451.44	17368752684.37
a5	123.24713347779800000000	b5	0.0001557930399652110	Bcy	21991.00	1830542.19	Cecy	186121.10	314364813.02
a6	-861.23800061818600000000	b6	860.60246390250400000000	Bcz	17730.90	532475.36	Cecz	150087.99	204344396.30
a7	50.63404639099640000000	b7	0.02966482194145360000	Bdx	1265269.20	95365337702.56	Cedx	39533.39	2884998.06
a8	123.24713347779800000000	b8	0.0001557930399652110	Bdy	6427908.74	1746609458892.86	Cedy	200121.62	74695266.82
a9	14438.89513718590000000000	b9	9.24955748413818000000	Bdz	3912084.19	803207342689.14	Cedz	121864.79	27649344.33

Parameter	Coefficient	Parameter	Coefficient
a10	-0.0000961710359212435	b10	0.0001129493940234990
a11	-0.0000227469458987782	b11	0.0002229590142260300
a12	0.0005972822079426930	b12	0.0001896260402401770

Parameter	Coefficient	Parameter	Coefficient	Variance
Yfx	148795	Dfx	16.80620891	12.37
Yfy	65273	Dfy	7.37244963	2.38
Yfz	11642	Dfz	1.31486067	0.08
Ycx	60247	Dcx	13.43258898	3.73
Ycy	7976	Dcy	1.77829835	0.07
Ycz	9001	Dcz	2.00683134	0.08
Ydx	2936	Ddx	0.55733934	0.003
Ydy	20218	Ddy	3.83445656	0.147
Ydz	11497	Ddz	2.18072787	0.048

Parameter	Coefficient	Parameter	Coefficient	Variance
Ngx	22.2130250	Gnx	-8.583112232173430	16.103000
Ngz	3.6324000	Gnz	-1.870019881137510	0.208000
Ngz	3.6324000	Gny	-7.306804539364680	2.597000

Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
Cdfx1,6,..	40095.3760	123820.25	Cdfy1,6,..	38361.8150	478130.33	Cdfz1,6,..	4774.903	17610.33
Cdfx2-5,..	20185.3760	178551.28	Cdfy2-5,..	17081.8150	194796.45	Cdfz2-5,..	2209.903	8585.76
Cdcx1,6,..	18321.4440	256853.4	Cdcy1,6,..	3563.2740	47653.06	Cdcz1,6,..	534.539	8320
Cdcx2-5,..	10711.4440	1590381.28	Cdcy2-5,..	1703.2740	26199.51	Cdcz2-5,..	254.539	7821.4
Cddx1	897359.2900	483991627.1	Cddy1	1533631.3200	932078681.1	Cddz1	6217174.6400	4220892425
Cddx6,11,..	485103.7800	23693616.9	Cddy6,11,..	865399.3200	1266970089	Cddz6,11,..	2882118.640	29331095.89
Cddx2-10,..	340753.7800	314572359.5	Cddy2-10,..	568885.3200	405847689.4	Cddz2-10,..	2683736.640	4351625645





Appendix 28. Input and output of stochastic model of economic analysis of technical improved coral reefs uses in selected sites (with implementation cost)

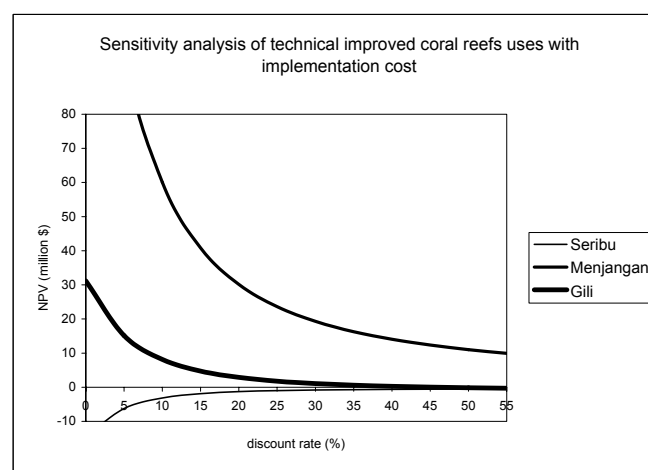
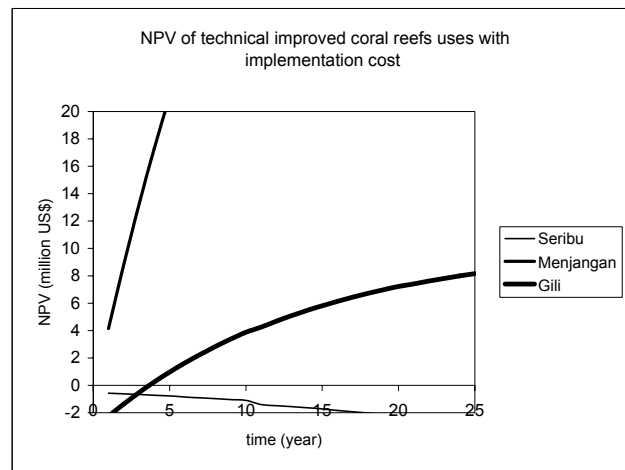
No.	Site	Natur.growth (%)	Actual Impact (%)		
			Tourism	Cyanide fishing	Coral coll.
1	Seribu	22.213025	0.204145396	7.161731131	13.43258898
2	Menjangan	5.6784	1.404582644	1.800330978	1.778298351
3	Gili	3.6324	0.798807083	0.522847978	2.00683134
Impact change (%)					
No.	Site	Total (%)	Tourism	Cyanide fishing	Coral coll.
1	Seribu	7.365876526	0.204145396	7.161731131	0.00
2	Menjangan	3.204913622	1.404582644	1.800330978	0.00
3	Gili	1.321655061	0.798807083	0.522847978	0.00
Intensity change (%)					
No.	Site	Net growth (%)	Tourism	Cyanide fishing	Coral coll.
1	Seribu	14.84714847	0.00	0.00	-100.00
2	Menjangan	2.473486378	0.00	0.00	-100.00
3	Gili	2.310744939	0.00	0.00	-100.00

Net present value at discount rate (%) = 10

No.	Site	PVB (mill. \$)	PVC (mill. \$)	NPV (mill. \$)	Std.dev.(mill.\$)	Coef. Var.
1	Seribu	58.560	61.731	-3.171	3.173	-1.000743
2	Menjangan	71.228	11.182	60.046	1.117	0.018594
3	Gili	42.772	34.610	8.163	0.425	0.052094

Sensitivity analysis

No.	Site	NPV at discount rate (%)											
		0	5	10	15	20	25	30	35	40	45	50	55
1	Seribu	-14.458	-6.252	-3.171	-1.889	-1.297	-0.992	-0.819	-0.710	-0.636	-0.582	-0.540	-0.507
2	Menjangan	186.877	98.742	60.046	40.821	30.143	23.619	19.311	16.286	14.058	12.352	11.006	9.919
3	Gili	31.155	15.143	8.163	4.741	2.881	1.777	1.075	0.603	0.273	0.034	-0.143	-0.276
1	Seribu	21.270	7.595	3.173	1.634	1.047	0.789	0.652	0.567	0.508	0.463	0.429	0.400
2	Menjangan	3.119	1.657	1.117	0.869	0.729	0.637	0.571	0.520	0.480	0.447	0.419	0.395
3	Gili	1.094	0.603	0.425	0.344	0.298	0.268	0.245	0.228	0.214	0.202	0.192	0.183



Appendix 29. Parameters and coefficients of stochastic model of technical improved coral reefs uses with implementation cost

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
a1	-14.42061309513840	b1	4.412197721856670	Bfx	198687.81	17020665	Cefx	889120.75	57395082514
a2	123.2471334777980	b2	0.0001557930399652110	Bfy	31160.75	351666	Cefy	139534.81	1411089574
a3	-1357.747312773120	b3	399.3721432517960	Bfz	19087.70	1086174	Cefz	85514.95	529300622.2
a4	0.0000000000000000	b4	0.0000000000000000	Bcx	0.00	0	Cecx	0.00	0
a5	0.0000000000000000	b5	0.0000000000000000	Bcy	0.00	0	Cecy	0.00	0
a6	0.0000000000000000	b6	0.0000000000000000	Bcz	0.00	0	Cecz	0.00	0
a7	16.64440444983650	b7	0.01125128637138130	Bdx	1265269.20	95365337703	Cedx	15064.90	4611128.949
a8	123.2471334777980	b2	0.0001557930399652110	Bdy	6427908.74	1746609458893	Cedy	75959.93	119340151.9
a9	4742.881741579970	b9	3.49208954531510	Bdz	3912084.19	803207342689	Cedz	46284.95	44180359.9

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance
a10	-0.00007562752139771270	b10	0.00005164677583495230	Yfx	138669	Dfx	7.16173113	3.172452863
a11	0.0000000000000000	b11	0.0000000000000000	Yfy	34860	Dfy	1.80033098	0.200431217
a12	0.0002058190245444010	b12	0.00006946170862740960	Yfz	10125	Dfz	0.52284798	0.016892381
				Ycx	0	Dcx	0.00000000	0
				Ycy	0	Dcy	0.00000000	0

Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Parameter	Coefficient	Variance
Ngx	22.2130250	Gnx	14.847148473709800	3.178236	Ycz	0	Dcz	0.00000000	0
Ngz	3.6324000	Gnz	2.310744939078630	0.105923	Ydx	2936	Ddx	0.20414540	0.005783531
					Ydy	20218	Ddy	1.40458264	0.275485254
					Ydz	11497	Ddz	0.79880708	0.089030856

Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
Cdfx1,6,..	40054.1260	123820.25	Cdfy1,6,..	38351.8650	478130.33	Cdfz1,6,..	4772.023	17610.33
Cdfx2-5,..	20144.1260	165560.8076	Cdfy2-5,..	17071.8650	190588.288	Cdfz2-5,..	2207.023	8478.15
Cdcx1,6,..	169104.1440	256853.4	Cdcy1,6,..	23052.8740	47653.06	Cdcz1,6,..	17905.939	8320
Cdcx2-5,..	169104.1440	763264834	Cdcy2-5,..	23052.8740	1837477.135	Cdcz2-5,..	17905.939	532868.628
Cddx1	423868.4600	483991627.1	Cddy1	658052.6200	932078681.1	Cddz1	2722826.7700	4220892425
Cddx6,11,..	568218.4600	23693616.89	Cddy6,11,..	954566.6200	1262053150	Cddz6,11,..	2921208.770	30796562.56
Cddx2-10,..	420268.4600	314572359.5	Cddy2-10,..	655652.6200	405847689.4	Cddz2-10,..	2721026.770	4351625645.04







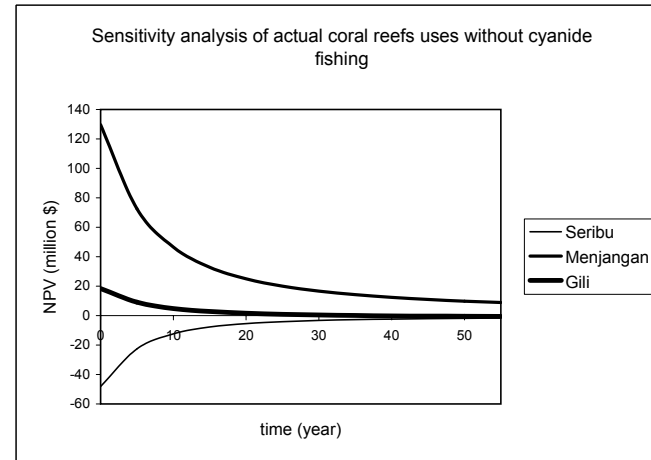
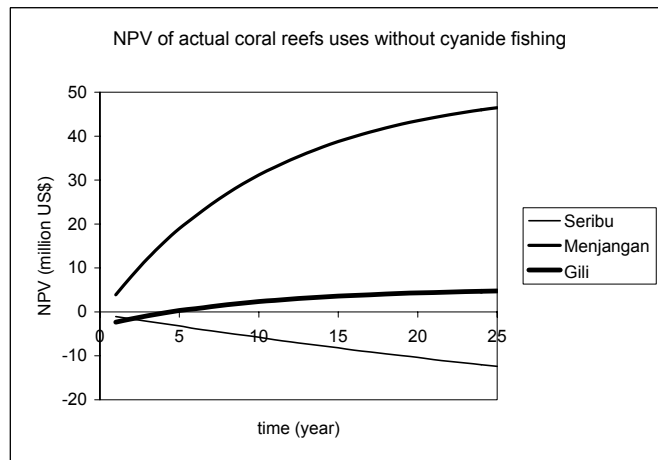
Appendix 32. Input and output of stochastic model of economic analysis of actual coral reefs uses in selected sites (without cyanide fishing activity)

No.	Site	Natur.growth (%)	Actual Impact (%)		
			Tourism	Coral coll.	Cyan. Fishing
1	Seribu	22.213025	0.557339336	13.432589	16.80620891
2	Menjangan	5.6784	3.834456564	1.77829835	7.372449625
3	Gili	3.6324	2.180727867	2.00683134	1.314860674
Impact change (%)					
No.	Site	Total (%)	Tourism	Coral coll.	Cyan. Fishing
1	Seribu	13.98992832	0.557339336	13.432589	0
2	Menjangan	5.612754914	3.834456564	1.77829835	0
3	Gili	4.187559207	2.180727867	2.00683134	0
Intensity change (%)					
No.	Site	Net growth (%)	Tourism	Coral coll.	Cyan. Fishing
1	Seribu	8.223096681	0.00	0.00	-100.00
2	Menjangan	0.065645086	0.00	0.00	-100.00
3	Gili	-0.555159207	0.00	0.00	-100.00

Net present value at discount rate (% 10)

No.	Site	PVB (mill. \$)	PVC (mill. \$)	NPV (mill. \$)	Std.dev.(mill.\$)	Coef. Var.
1	Seribu	26.891	39.278	-12.387	1.859	-0.150
2	Menjangan	58.834	12.362	46.472	0.671	0.014
3	Gili	34.242	29.466	4.776	0.420	0.088

No.	Site	NPV at discount rate (%)											
		0	5	10	15	20	25	30	35	40	45	50	55
1	Seribu	-48.193	-22.658	-12.387	-7.745	-5.397	-4.078	-3.268	-2.730	-2.351	-2.069	-1.853	-1.681
2	Menjangan	129.686	72.648	46.472	32.874	25.001	20.017	16.628	14.191	12.361	10.939	9.804	8.877
3	Gili	18.379	9.181	4.776	2.833	1.618	0.875	0.392	0.063	-0.169	-0.337	-0.461	-0.553



Appendix 33. Parameters and coefficients of stochastic model of actual coral reefs uses (without cyanide fishing activity)

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
a1	-33.05907010827840000000	b1	10.50970487145080000000	Bfx	235160.31	0.00	Cefx	0.00	0.00
a2	123.24713347779800000000	b2	0.0001557930399652110	Bfy	233452.45	0.00	Cefy	0.00	0.00
a3	-3104.72446955074000000000	b3	949.30864002640600000000	Bfz	26451.70	0.00	Cefz	0.00	0.00
a4	-8.00355087502394000000	b4	8.32420188104385000000	Bcx	163430.00	763026209.70	Cecx	1382451.44	17368752684.37
a5	123.24713347779800000000	b5	0.0001557930399652110	Bcy	21991.00	1830542.19	Cecy	186121.10	314364813.02
a6	-861.23800061818600000000	b6	860.60246390250400000000	Bcz	17730.90	532475.36	Cecz	150087.99	204344396.30
a7	50.63404639099640000000	b7	0.02966482194145360000	Bdx	1265269.20	95365337702.56	Cedx	39533.39	2884998.06
a8	123.24713347779800000000	b8	0.0001557930399652110	Bdy	6427908.74	1746609458892.86	Cedy	200121.62	74695266.82
a9	14438.89513718590000000000	b9	9.24955748413818000000	Bdz	3912084.19	803207342689.14	Cedz	121864.79	27649344.33

Parameter	Coefficient	Parameter	Coefficient
a10	-0.0000961710359212435	b10	0.0001129493940234990
a11	-0.0000227469458987782	b11	0.0002229590142260300
a12	0.0005972822079426930	b12	0.0001896260402401770

Parameter	Coefficient	Parameter	Coefficient	Variance
Yfx	0	Dfx	0.000	0
Yfy	0	Dfy	0.000	0
Yfz	0	Dfz	0.000	0
Ycx	60247	Dcx	13.4325890	3.73
Ycy	7976	Dcy	1.77829835	0.07
Ycz	9001	Dcz	2.00683134	0.08
Ydx	2936	Ddx	0.55733934	0.003
Ydy	20218	Ddy	3.83445656	0.147
Ydz	11497	Ddz	2.18072787	0.048

Parameter	Coefficient	Parameter	Coefficient	Variance
Ngx	22.2130250	Gnx	8.223192851553090	3.733000
Ngx	5.6784000	Gny	0.065741256731162	0.217000
Ngz	3.6324000	Gnz	-0.555063035915937	0.128000

Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
Cdfx1,6,..	262047.9860	123820.25	Cdfy1,6,..	260326.2650	478130.33	Cdfz1,6,..	29710.8025	17610.33
Cdfx2-5,..	262047.9860	178551.28	Cdfy2-5,..	260326.2650	194796.45	Cdfz2-5,..	29710.8025	8585.76
Cdcx1,6,..	18321.4440	256853.4	Cdcy1,6,..	3563.2740	47653.06	Cdcz1,6,..	534.539	8320
Cddx1	78505.7800	1590381.28	Cddy1	113263.3200	26199.51	Cddz1	241488.8800	7821.4
Cdcx2-5,..	10711.4440	483991627	Cdcy2-5,..	1703.2740	932078681.1	Cdcz2-5,..	254.539	4220892425
Cddx6,11,..	485103.7800	23693616.9	Cddy6,11,..	865399.3200	1266970089	Cddz6,11,..	2882118.640	29331095.9
Cddx2-10,..	340753.7800	314572359.5	Cddy2-10,..	568885.3200	405847689.4	Cddz2-10,..	2683736.640	4351625645





Appendix 36. Input and output of stochastic model of economic analysis of combination improved coral reefs uses in selected sites (with implementation cost)

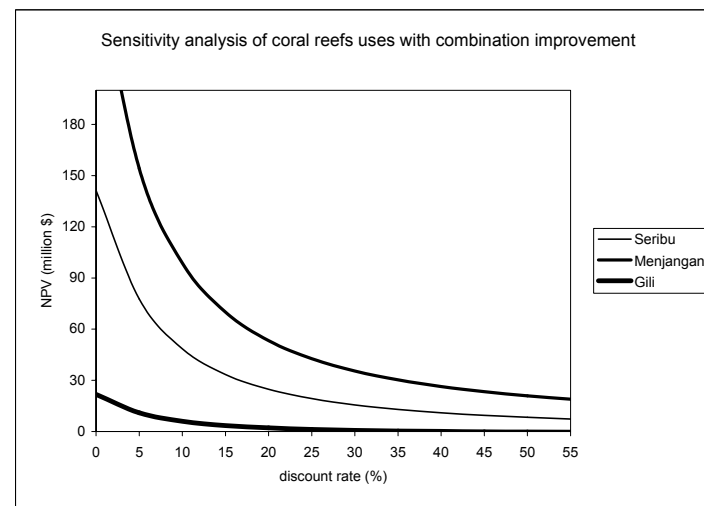
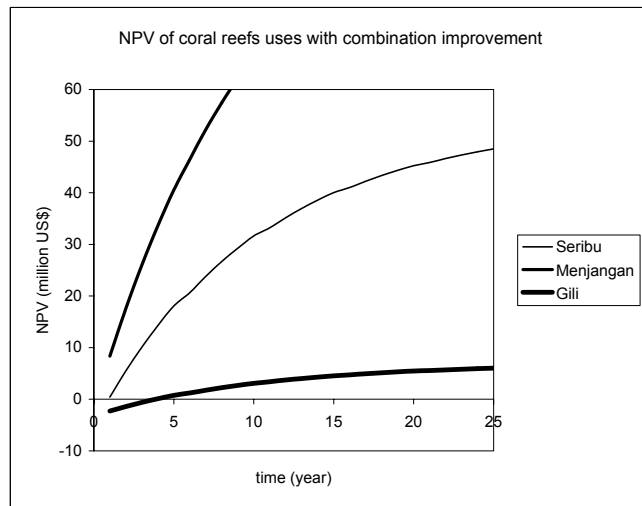
No.	Location	Natur.growth (%)	Actual Impact (%)		
			Tourism	Fishing	Coral coll.
1	Seribu	22.213025	0.204145396	7.161731131	13.43258898
2	Menjangan	5.6784	1.404582644	1.800330978	1.778298351
3	Gili	3.6324	0.798807083	0.522847978	2.00683134
Impact change (%)					
No.	Location	Total (%)	Tourism	Fishing	Coral coll.
1	Seribu	22.213025	2.041453956	20.17157104	0.00
2	Menjangan	5.6784	2.809165288	2.869234712	0.00
3	Gili	3.6324	0.798807083	2.833592917	0.00
Intensity change (%)					
No.	Location	Net growth (%)	Tourism	Fishing	Coral coll.
1	Seribu	0	900.00	181.66	-100.00
2	Menjangan	0	100.00	59.37	-100.00
3	Gili	0	0.00	441.95	-100.00

Net present value at discount rate (%) = 10

No.	Location	PVB (mill. \$)	PVC (mill. \$)	NPV (mill. \$)	Std.dev (mill.\$)	Coef. Var.
1	Seribu	119.929	71.429	48.499	20.992	0.4328263
2	Menjangan	117.144	18.358	98.79	2.656	0.0268915
3	Gili	35.683	29.666	6.017	0.503	0.0836142

Sensitivity analysis

No.	Location	NPV at discount rate (%)											
		0	5	10	15	20	25	30	35	40	45	50	55
1	Seribu	141.305	77.628	48.499	33.428	24.748	19.286	15.600	12.971	11.015	9.510	8.321	7.360
2	Menjangan	274.713	154.174	98.785	69.972	53.272	42.687	35.483	30.300	26.406	23.378	20.960	18.985
3	Gili	21.801	10.934	6.017	3.517	2.112	1.255	0.699	0.319	0.050	-0.146	-0.291	-0.401
1	Seribu	167.798	47.793	20.992	12.747	9.364	7.631	6.591	5.892	5.382	4.988	4.669	4.403
2	Menjangan	6.089	3.641	2.656	2.156	1.850	1.639	1.482	1.359	1.259	1.176	1.106	1.045
3	Gili	1.069	0.663	0.503	0.423	0.373	0.339	0.312	0.292	0.274	0.260	0.247	0.236



Appendix 37. Parameters and coefficients of stochastic model of combination improved coral reefs uses with implementation cost

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
a1	-14.42061309513840	b1	4.412197721856670	Bfx	198687.81	17020665	Cefx	889120.75	57395082513.50
a2	123.2471334777980	b2	0.0001557930399652110	Bfy	31160.75	351666	Cefy	139534.81	1411089573.72
a3	-1357.747312773120	b3	399.3721432517960	Bfz	19087.70	1086174	Cefz	85514.95	529300622.24
a4	0.0000000000000000	b4	0.0000000000000000	Bcx	163430.00	0	Cecx	0.00	0.00
a5	0.0000000000000000	b5	0.0000000000000000	Bcy	21991.00	0	Cecy	0.00	0.00
a6	0.0000000000000000	b6	0.0000000000000000	Bcz	17730.90	0	Cecz	0.00	0.00
a7	16.64440444983650	b7	0.01125128637138130	Bdx	1265269.20	95365337703	Cedx	15064.90	4611128.95
a8	123.2471334777980	b2	0.0001557930399652110	Bdy	6427908.74	1746609458893	Cedy	75959.93	119340151.92
a9	4742.881741579970	b9	3.49208954531510	Bdz	3912084.19	803207342689	Cedz	46284.95	44180359.90

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter
a10	-0.00007562752139771270	b10	0.00005164677583495230	Yfx	138669	Dfx	20.17170843	3.172452863	Dtx
a11	0.00000000000000000000	b11	0.00000000000000000000	Yfy	34860	Dfy	2.86927961	0.200431217	Dty
a12	0.0002058190245444010	b12	0.00006946170862740960	Yfz	10125	Dfz	2.83392716	0.016892381	Dtz

				Ycx	0	Dcx	0.00000000	0	
				Ycy	0	Dcy	0.00000000	0	
				Ycz	0	Dcz	0.00000000	0	
Parameter	Coefficient	Parameter	Coefficient	Ydx	2936	Ddx	2.03960158	0.005783531	
Ngx	22.2130250	Gnx	0.00	Ydy	20218	Ddy	2.80895947	0.275485254	
Ngz	3.6324000	Gnz	0.00	Ydz	11497	Ddz	0.79880708	0.089030856	

Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
Cdfx1,6,..	112815.5516	123820.25	Cdfy1,6,..	61122.3734	478130.33	Cdfz1,6,..	25862.1430	17610.33
Cdfx2-5,..	56737.4928	165560.8076	Cdfy2-5,..	27207.8791	190588.288	Cdfz2-5,..	11961.0357	8478.15
Cdcx1,6,..	175192.1440	256853.4	Cdcy1,6,..	24540.8740	47653.06	Cdcz1,6,..	18129.9394	8320
Cdcx2-5,..	175192.1440	483991627.1	Cdcy2-5,..	24540.8740	932078681.1	Cdcz2-5,..	18129.9394	4220892425
Cddx1	130398.0000	763264834	Cddy1	178734.0000	1837477.135	Cddz1	369169.0000	532868.628
Cddx6,11,..	5682184.6000	23693616.89	Cddy6,11,..	1909133.2400	1262053150	Cddz6,11,..	2921208.7700	30796562.56
Cddx2-10,..	4202684.6000	314572359.5	Cddy2-10,..	1311305.2400	405847689.4	Cddz2-10,..	2721026.7700	4351625645.04







Appendix 40. Input and output of stochastic model of economic analysis of combination improved tourism in selected sites (with implementation cost)

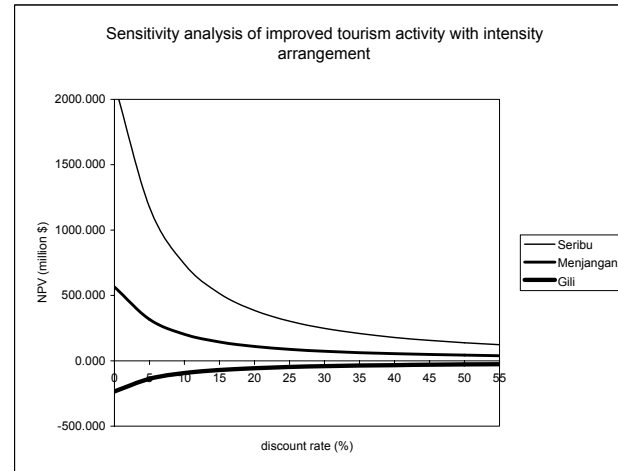
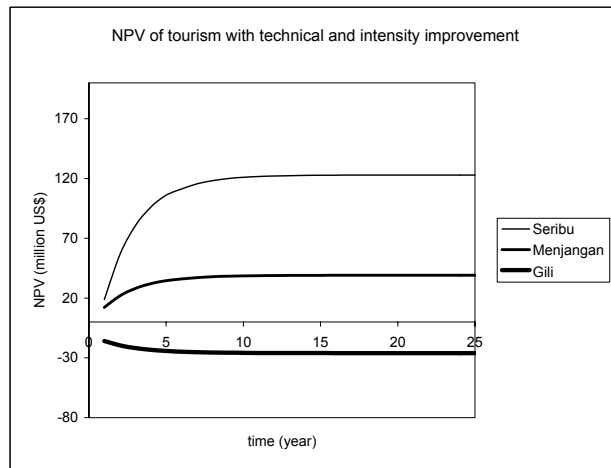
No.	Location	Natur.growth (%)	Actual Impact (%)	
			Tourism	Fishing
1	Seribu	22.213025	0.204145396	7.161731131
2	Menjangan	5.6784	1.404582644	1.800330978
3	Gili	3.6324	0.798807083	0.522847978
			Impact change (%)	
No.	Location	Total (%)	Tourism	Fishing
1	Seribu	22.213025	22.213025	0
2	Menjangan	5.6784	5.6784	0
3	Gili	3.6324	3.6324	0
			Intensity change (%)	
No.	Location	Net growth (%)	Tourism	Fishing
1	Seribu	0	10780.98	-100.00
2	Menjangan	0	304.28	-100.00
3	Gili	0	354.73	-100.00

Net present value at discount rate (%) = 55

No.	Location	PVB (mill. \$)	PVC (mill. \$)	NPV (mill. \$)	Std.dev (mill.\$)	Coef. Var.
1	Seribu	250.425	127.457	122.967	10.975	0.089250
2	Menjangan	47.247	8.148	39.100	2.370	0.060617
3	Gili	7.113	33.121	-26.009	1.267	-0.048709

Sensitivity analysis

No.	Location	NPV at discount rate (%)											
		0	5	10	15	20	25	30	35	40	45	50	55
1	Seribu	2122.815	1174.856	740.540	515.405	385.456	303.490	248.012	208.334	178.711	155.834	137.684	122.967
2	Menjangan	564.923	317.089	203.201	143.955	109.613	87.846	73.032	62.373	54.364	48.137	43.163	39.100
3	Gili	-233.717	-137.910	-93.468	-70.047	-56.244	-47.322	-41.116	-36.545	-33.026	-30.223	-27.929	-26.009
1	Seribu	58.705	35.478	26.201	21.503	18.630	16.644	15.162	13.996	13.045	12.249	11.567	10.975
2	Menjangan	13.836	8.271	6.034	4.896	4.200	3.720	3.363	3.084	2.857	2.669	2.509	2.370
3	Gili	4.510	2.949	2.350	2.046	1.854	1.716	1.608	1.519	1.444	1.378	1.319	1.267



Appendix 41. Parameters and coefficients of stochastic model of combination improved tourism with implementation cost

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter
a1	-14.42061309513840	b1	4.412197721856670	Bfx	198687.81	17020665	Cefx	889120.75	57395082513.50	dBfx
a2	123.2471334777980	b2	0.0001557930399652110	Bfy	31160.75	351666	Cefy	139534.81	1411089573.72	dBfy
a3	-1357.747312773120	b3	399.3721432517960	Bfz	19087.70	1086174	Cefz	85514.95	529300622.24	dBfz
a4	0.0000000000000000	b4	0.0000000000000000	Bcx	163430.00	0	Cecx	0.00	0.00	dBcx
a5	0.0000000000000000	b5	0.0000000000000000	Bcy	21991.00	0	Cecy	0.00	0.00	dBcy
a6	0.0000000000000000	b6	0.0000000000000000	Bcz	17730.90	0	Cecz	0.00	0.00	dBcz
a7	16.64440444983650	b7	0.01125128637138130	Bdx	1265269.20	95365337703	Cedx	15064.90	4611128.95	dBdx
a8	123.2471334777980	b2	0.0001557930399652110	Bdy	6427908.74	1746609458893	Cedy	75959.93	119340151.92	dBdy
a9	4742.881741579970	b9	3.49208954531510	Bdz	3912084.19	803207342689	Cedz	46284.95	44180359.90	dBdz

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient	Variance	Parameter	Coefficient
a10	-0.00007562752139771270	b10	0.00005164677583495230	Yfx	138669	Dfx	-0.00007563	0	Dtx	22.19076006
a11	0.0000000000000000	b11	0.0000000000000000	Yfy	34860	Dfy	-0.00007563	0	Dty	5.67769811
a12	0.0002058190245444010	b12	0.00006946170862740960	Yfz	10125	Dfz	-0.00007563	0	Dtz	3.63159427

Parameter	Coefficient	Parameter	Coefficient	Ycx	Ycy	Ycz	Dcx	Dcy	Dcz	0	0	0
Ngx	22.2130250	Gnx	0.022	Ydx	2936	Ddx	22.19083569	0.005783531				
Ngx	5.6784000	Gny	0.001	Ydy	20218	Ddy	5.67777374	0.275485254				
Ngz	3.6324000	Gnz	0.001	Ydz	11497	Ddz	3.63166990	0.089030856				

Parameter	Coefficient	Variance	Parameter	Coefficient	Variance	Parameter	Coefficient	Variance
Cdfx1,6,..	225575.4860	123820.25	Cdfy1,6,..	58034.5650	478130.33	Cdfz1,6,..	34419.8525	17610.33
Cdfx2-5,..	225575.4860	165560.8076	Cdfy2-5,..	58034.5650	190588.288	Cdfz2-5,..	34419.8525	8478.15
Cdcx1,6,..	175192.1440	256853.4	Cdcy1,6,..	24540.8740	47653.06	Cdcz1,6,..	18129.9394	8320
Cdcx2-5,..	175192.1440	483991627.1	Cdcy2-5,..	24540.8740	932078681.1	Cdcz2-5,..	18129.9394	4220892425
Cddx1	130398.0000	763264834	Cddy1	178734.0000	1837477.135	Cddz1	369169.0000	532868.628
Cddx6,11,..	61827751.8489	23693616.89	Cddy6,11,..	3859090.1845	1262053150	Cddz6,11,..	13283556.1432	30796562.56
Cddx2-10,..	45729338.0697	314572359.5	Cddy2-10,..	2650650.6065	405847689.4	Cddz2-10,..	12373272.4062	4351625645.04





Appendix 44. Condition and resource uses of Indonesian coral reefs

No.	location	n	Excell.	Good	Fair	Poor	Dominance species	Major actual resource uses
1	Semangka Bay	1	0	0	1	0	Acr. Por.	high poison, high coral
2	Belitung Island	1	0	0	1	0	Acr.	high poison, high coral, low tourism
3	Seribu Islands	16	0	2	7	6	Acr., Por. Mont.	high poison, high coral, low tourism
4	Natuna Islands	1	0	1	0	0	Acr.	high coral
5	Pangandaran Bay	1	0	0	0	1	Acr.	high poison, high coral, low tourism
6	Bali Island	14	0	0	0	14	Acr., Euph., Por.	mid poison, mid coral, mid tourism
7	Kangean Islands	7	0	4	3	0	Acr., Sin.	high poison, low tourism
8	Lampung Bay	1	0	0	1	0	Acr.	high poison, high coral
9	Jebara Bay	1	0	0	0	1	Acr.	high coral
10	Mentawai Islands	1	0	0	0	1	Acr., Por.	high poison, high coral, low tourism
11	Sunda Strait	1	0	0	0	1	Acr.	high poison, high coral, low tourism
12	North Madura Island	1	0	1	0	0	Acr.	high poison, high coral
13	Bangka Island	1	0	1	0	0	Acr.	high poison, high coral, low tourism
14	South Madura Island	1	0	0	1	0	Acr.	high poison, high coral
15	Weh Island	1	0	0	1	0	Mont., Acr.	high poison, high coral
16	Nias Island	1	0	0	1	0	Acr., Por.	high poison, high coral, low tourism
17	Belawan Bay	1	0	0	1	0	Acr., Mont.	high poison, high coral, low tourism
18	Riau Islands	1	0	0	0	1	Acr.	high poison, high coral, low tourism
19	Enggano Islands	1	0	0	0	1	Acr. Por.	high poison, high coral
20	Karimunjawa Island	1	0	0	0	1	Acr.	high poison, high coral
21	Padang Bay	1	0	0	0	1	Por.	high poison, high coral, low tourism
22	Lombok Islands	24	0	0	2	22	Acr., Por.	low poison, low coral, mid tourism
23	Sumbawa Islands	3	0	3	0	0	Mont., Por.	low poison, low coral, low tourism
24	Komodo Islands	6	2	2	1	1	Sin., Acr., Mont.	mid tourism
25	Rinca Islands	14	3	5	2	4	Sin., Acr., Por.	low tourism
26	Selayar Islands	5	0	2	3	0	Por., Acr.	high poison, high coral
27	Taka Bone Rate Islands	5	1	0	4	0	Acr., Gon.	low poison, low coral, high tourism
28	Tukang Besi Islands	5	0	0	3	2	Sin., Acr., Mont.	high poison, low tourism
29	Banggai Islands	17	1	8	6	2	Hel., Por., Mont.	high poison, high coral
30	Kumeke Islands	9	1	2	2	4	Acr., Por., Lob.	low poison, low coral
31	Dulupi Island (Gorontalo)	4	0	0	3	1	Por., Lob., Acr.	high coral
32	Derawan Islands	8	0	1	6	1	Acr., Sin., Por.	mid coral, mid tourism
33	Wetar Islands	8	0	1	5	2	Acr., Por.	low coral
34	Togian Island	8	0	4	4	0	Acr., Sin., Por.	mid tourism
35	Sangkalaki Island	6	0	3	3	0	Sin., Gon.	low coral
36	Kapoposang Islands	4	1	0	3	0	Acr., Por.	low coral
37	Bunaken Island	8	0	3	5	0	Gon., Mont., Acr.	high tourism
38	Tobelo Islands	14	0	4	2	8	Sin., Lob., Acr.	low poison, low coral
39	Morotai Islands	14	0	0	1	13	Acr., Por., Mont.	high poison, high coral
40	Ambon Bay	10	1	5	2	2	Lob., Sin., Acr.	high poison
41	West Seram	4	0	3	1	0	Por., Sin.	high coral, low tourism
42	Banda Islands	7	1	5	1	0	Acr., Sin., Por.	low coral, high tourism
43	Kai Islands	17	2	3	7	5	Acr., Sin., Por.	mid poison, mid coral, mid tourism
44	Padaido Islands	13	0	3	6	4	Acr., Por.	high poison, low tourism
45	Lucipara Islands	8	5	3	0	0	Acr., Sin., Lob.	low poison
46	Cendrawasih Bay	12	1	7	4	0	Por., Sin., Acr.	low poison, low coral
47	Biak Island	2	0	1	1	0	Mont., Por.	high poison, high coral, low tourism
48	Kupang Bay	8	0	1	4	3	Por.	high coral

Source:

Hopley and Suharsono, 2000  
Wallace, Richards, and Suharsono, 2001  
Country Status Overview, 2001  
Field Survey, 2001

Appendix 45. Distribution of common coral species in Indonesia

No.	Family	Genus	Number of species	Distribution	Special
1	Astrocoeniidae	Stylocoeniella	2	all over Indonesia	
2	Pocilloporidae	Pocillopora	1	all over Indonesia	
3		Madracis	1	east Indonesia	1
4		Seriopora	2	all over Indonesia	
5		Stylopora	1	all over Indonesia	
6		Palauastrea	1	all over Indonesia	
7	Acroporidae	Acropora	91	all over Indonesia	
8		Anacropora	4	east Indonesia	4
9		Montipora	45	all over Indonesia	
10		Astreopora	12	all over Indonesia	
11	Fungiidae	Cycloseris	7	Bali to east Ind.	7
12		Lithophyllon	1	all over Indonesia	
13		Herpolitha	2	all over Indonesia	
14		Polyphyllia	1	all over Indonesia	
15		Halomitra	1	all over Indonesia	
16		Sandalolitha	1	east Indonesia	
17		Fungia	14	all over Indonesia	
18		Heliofungia	1	all over Indonesia	
19		Diaseris	2	Lombok to east Ind.	2
20		Zoopilus	1	Sulawesi to east Ind.	1
21		Ctenactis	3	all over Indonesia	
22		Podabacia	1	all over Indonesia	
23	Agariciidae	Gardineroseris	1	all over Indonesia	
24		Pavona	12	all over Indonesia	
25		Leptoseris	14	all over Indonesia	
26		Coeloseris	1	all over Indonesia	
27		Pachyseris	2	all over Indonesia	
28	Siderastreaeidae	Pseudisiderastrea	1	all over Indonesia	
29		Coscinaraea	8	all over Indonesia	
30		Psammocora	8	all over Indonesia	
31	Poritidae	Porites	25	all over Indonesia	
32		Alveopora	16	all over Indonesia	
33		Goniopora	20	all over Indonesia	
34	Faviidae	Caulastrea	4	all over Indonesia	
35		Plesiastrea	1	all over Indonesia	
36		Favia	20	all over Indonesia	
37		Favites	11	all over Indonesia	
38		Oulophyllia	1	all over Indonesia	
39		Goniastrea	10	all over Indonesia	
40		Platygyra	7	all over Indonesia	
41		Leptoria	1	all over Indonesia	
42		Montastrea	7	all over Indonesia	
43		Diploastrea	1	all over Indonesia	
44		Leptastrea	8	all over Indonesia	
45		Cyphastrea	8	all over Indonesia	
46		Oulastrea	1	all over Indonesia	
47		Echinophora	7	all over Indonesia	
48	Trachyphylliidae	Trachyphyllia	1	all over Indonesia	
49		Wellsophyllia	1	all over Indonesia	
50	Oculinidae	Archelia	1	all over Indonesia	
51		Galaxea	2	all over Indonesia	
52	Merulinidae	Hydnophora	5	all over Indonesia	
53		Merulina	2	all over Indonesia	
54		Scapophyllia	1	all over Indonesia	
55	Mussidae	Acanthastrea	6	all over Indonesia	
56		Symphyllia	6	all over Indonesia	
57		Lobophyllia	5	all over Indonesia	
58		Scolymia	2	all over Indonesia	
59		Cynarina	1	all over Indonesia	
60		Blastomusa	2	all over Indonesia	
61	Pectiniidae	Pectinia	7	all over Indonesia	
62		Echinophyllia	5	all over Indonesia	
63		Oxypora	2	all over Indonesia	
64		Mycedium	2	all over Indonesia	
65	Caryophylliidae	Euphyllia	5	all over Indonesia	
66		Catalaphyllia	1	all over Indonesia	
67		Plerogyra	1	all over Indonesia	
68		Physogyra	1	all over Indonesia	
69	Dendrophylliidae	Turbinaria	15	all over Indonesia	
70		Tubastrea	5	all over Indonesia	
71		Dendrophyllia	5	all over Indonesia	
Total			474		15

Note:

Number of genera which are distributed all over Ind. = 65 or 91.55%

Number of species which are distributed all over Ind. = 518 or 96.84%

Source: Suharsono, 1996 and Wallace et al, 2001.

Appendix 46. Export quota of Indonesian live corals (2000-2003)

200			2001			2002			2003		
No.	Species	Pieces	No.	Species	Pieces	No.	Species	Pieces	No.	Species	Pieces
1	<i>Acropora formosa</i>	10800	1	<i>Acropora formosa</i>	12000	1	<i>Acropora formosa</i>	9500	1	<i>Acanthastrea echinata</i>	1000
2	<i>Acropora humilis</i>	9000	2	<i>Acropora humilis</i>	10000	2	<i>Acropora humilis</i>	7000	2	<i>Acropora formosa</i>	10700
3	<i>Acropora hyacinthus</i>	14400	3	<i>Acropora hyacinthus</i>	16000	3	<i>Acropora hyacinthus</i>	12500	3	<i>Acropora humilis</i>	9300
4	<i>Acropora spp.</i>	6300	4	<i>Acropora spp.</i>	7000	4	<i>Acropora spp.</i>	5500	4	<i>Acropora hyacinthus</i>	13750
5	<i>Blastomussa wellsii</i>	7200	5	<i>Blastomussa wellsii</i>	6000	5	<i>Blastomussa wellsii</i>	2500	5	<i>Acropora spp.</i>	24500
6	<i>Caulastreaa echinulata</i>	9000	6	<i>Caulastreaa echinulata</i>	10000	6	<i>Caulastreaa echinulata</i>	8000	6	<i>Alveopora spongiosa</i>	1050
7	<i>Caulastreaa tumida</i>	12600	7	<i>Caulastreaa tumida</i>	14000	7	<i>Caulastreaa tumida</i>	11500	7	<i>Blastomussa wellsii</i>	3800
8	<i>Catalaphyllia jardinei</i>	58500	8	<i>Catalaphyllia jardinei</i>	56000	8	<i>Catalaphyllia jardinei</i>	24000	8	<i>Caulastreaa echinulata</i>	9500
9	<i>Cynarina lacrymalis</i>	9000	9	<i>Cynarina lacrymalis</i>	10000	9	<i>Cynarina lacrymalis</i>	4500	9	<i>Caulastreaa tumida</i>	12350
10	<i>Cyphastrea serailia</i>	450	10	<i>Cyphastrea serailia</i>	500	10	<i>Cyphastrea serailia</i>	400	10	<i>Catalaphyllia jardinei</i>	28500
11	<i>Diploastrea heliopora</i>	450	11	<i>Diploastrea heliopora</i>	500	11	<i>Dendrophyllia fistula</i>	20000	11	<i>Cynarina lacrymalis</i>	9000
12	<i>Distichopora spp.</i>	900	12	<i>Distichopora spp.</i>	1000	12	<i>Diploastrea heliopora</i>	500	12	<i>Cyphastrea serailia</i>	450
13	<i>Eguchipsammia fistula</i>	22500	13	<i>Dendrophyllia fistula</i>	25000	13	<i>Distichopora spp.</i>	800	13	<i>Dendrophyllia fistula</i>	19500
14	<i>Euphyllia ancora</i>	36000	14	<i>Euphyllia ancora</i>	40000	14	<i>Euphyllia ancora</i>	25000	14	<i>Diploastrea heliopora</i>	450
15	<i>Euphyllia cristata</i>	54000	15	<i>Euphyllia cristata</i>	55000	15	<i>Euphyllia cristata</i>	32000	15	<i>Distichopora spp.</i>	1400
16	<i>Euphyllia glabrescens</i>	36000	16	<i>Euphyllia glabrescens</i>	40000	16	<i>Euphyllia glabrescens</i>	14000	16	<i>Echinopora lamellosa</i>	450
17	<i>Favia pallida</i>	5850	17	<i>Favia pallida</i>	6000	17	<i>Favia pallida</i>	5000	17	<i>Euphyllia ancora</i>	27550
18	<i>Favia spp.</i>	9900	18	<i>Favia spp.</i>	11000	18	<i>Favia spp.</i>	8500	18	<i>Euphyllia cristata</i>	30100
19	<i>Favites abdita</i>	5400	19	<i>Favites abdita</i>	6000	19	<i>Favites abdita</i>	3500	19	<i>Euphyllia glabrescens</i>	28000
20	<i>Favites spp.</i>	7200	20	<i>Favites spp.</i>	8000	20	<i>Favites spp.</i>	6000	20	<i>Favia pallida</i>	4750
21	<i>Fungia fungites</i>	8550	21	<i>Fungia fungites</i>	9500	21	<i>Fungia fungites</i>	6500	21	<i>Favites abdita</i>	5200
22	<i>Fungia moluccensis</i>	6300	22	<i>Fungia moluccensis</i>	7000	22	<i>Fungia moluccensis</i>	6000	22	<i>Favites chinensis</i>	7100
23	<i>Fungia paumotensis</i>	6750	23	<i>Fungia paumotensis</i>	7500	23	<i>Fungia paumotensis</i>	6500	23	<i>Fungia fungites</i>	9300
24	<i>Fungia spp.</i>	2700	24	<i>Fungia spp.</i>	3000	24	<i>Fungia spp.</i>	2550	24	<i>Fungia moluccensis</i>	7500
25	<i>Galaxea astreata</i>	5400	25	<i>Galaxea astreata</i>	6000	25	<i>Galaxea astreata</i>	5500	25	<i>Fungia paumotensis</i>	7500
26	<i>Galaxea fascicularis</i>	16650	26	<i>Galaxea fascicularis</i>	18500	26	<i>Galaxea fascicularis</i>	13500	26	<i>Galaxea astreata</i>	4650
27	<i>Goniastrea pectinata</i>	450	27	<i>Goniastrea pectinata</i>	500	27	<i>Goniastrea pectinata</i>	400	27	<i>Galaxea fascicularis</i>	17550
28	<i>Goniastrea retiformis</i>	450	28	<i>Goniastrea retiformis</i>	500	28	<i>Goniastrea retiformis</i>	500	28	<i>Goniastrea pectinata</i>	1800
29	<i>Goniopora lobata</i>	45000	29	<i>Goniopora lobata</i>	47000	29	<i>Goniopora lobata</i>	38000	29	<i>Goniastrea retiformis</i>	950
30	<i>Goniopora minor</i>	45000	30	<i>Goniopora minor</i>	48000	30	<i>Goniopora minor</i>	39500	30	<i>Goniopora lobata</i>	43700
31	<i>Goniopora stokesi</i>	45000	31	<i>Goniopora stokesi</i>	48000	31	<i>Goniopora stokesi</i>	38000	31	<i>Goniopora minor</i>	47000
32	<i>Heliofungia actiniformis</i>	54000	32	<i>Heliofungia actiniformis</i>	60000	32	<i>Heliofungia actiniformis</i>	49000	32	<i>Goniopora stokesi</i>	47000
33	<i>Heliopora coerulea</i>	1350	33	<i>Heliopora coerulea</i>	1500	33	<i>Heliopora coerulea</i>	1500	33	<i>Heliofungia actiniformis</i>	49500
34	<i>Herpolitha limax</i>	2250	34	<i>Herpolitha limax</i>	2500	34	<i>Herpolitha limax</i>	2200	34	<i>Heliopora coerulea</i>	950
35	<i>Hydnophora exesa</i>	11250	35	<i>Hydnophora exesa</i>	12000	35	<i>Hydnophora exesa</i>	9000	35	<i>Herpolitha limax</i>	2000
36	<i>Hydnophora microconos</i>	4500	36	<i>Hydnophora microconos</i>	5000	36	<i>Hydnophora microconos</i>	1500	36	<i>Hydnophora exesa</i>	10900
37	<i>Hydnophora rigida</i>	4500	37	<i>Hydnophora rigida</i>	5000	37	<i>Hydnophora rigida</i>	3900	37	<i>Hydnophora microconos</i>	4750
38	<i>Lobophyllia corymbosa</i>	12600	38	<i>Lobophyllia corymbosa</i>	14000	38	<i>Lobophyllia corymbosa</i>	12000	38	<i>Hydnophora rigida</i>	4750
39	<i>Lobophyllia hemprichii</i>	15300	39	<i>Lobophyllia hemprichii</i>	17000	39	<i>Lobophyllia hemprichii</i>	13000	39	<i>Lobophyllia corymbosa</i>	12800
40	<i>Merulina ampliata</i>	4050	40	<i>Merulina ampliata</i>	4500	40	<i>Merulina ampliata</i>	4500	40	<i>Lobophyllia hemprichii</i>	12900
41	<i>Millepora spp.</i>	1800	41	<i>Millepora spp.</i>	2000	41	<i>Millepora spp.</i>	1300	41	<i>Merulina ampliata</i>	4750
42	<i>Montastreaa annuligera</i>	2700	42	<i>Montastreaa annuligera</i>	3000	42	<i>Montastreaa annuligera</i>	2800	42	<i>Millepora spp.</i>	1700
43	<i>Montastreaa valenciennesii</i>	3600	43	<i>Montastreaa valenciennesii</i>	4000	43	<i>Montastreaa valenciennesii</i>	3300	43	<i>Montastreaa annuligera</i>	2800
44	<i>Montastreaa spp.</i>	360	44	<i>Montastreaa spp.</i>	400	44	<i>Montastreaa spp.</i>	300	44	<i>Montastreaa valenciennesii</i>	3600
45	<i>Montipora foliosa</i>	2250	45	<i>Montipora foliosa</i>	2500	45	<i>Montipora foliosa</i>	2300	45	<i>Montastreaa spp.</i>	450
46	<i>Montipora verrucosa</i>	1800	46	<i>Montipora verrucosa</i>	2000	46	<i>Montipora verrucosa</i>	1800	46	<i>Montipora foliosa</i>	2550
47	<i>Montipora spp.</i>	1800	47	<i>Montipora spp.</i>	2000	47	<i>Montipora spp.</i>	600	47	<i>Montipora verrucosa</i>	1700
48	<i>Pectinia lactuca</i>	900	48	<i>Pectinia lactuca</i>	1000	48	<i>Nemenezophyllia turbida</i>	11500	48	<i>Montipora spp.</i>	12150
49	<i>Physogyra lichtensteini</i>	9000	49	<i>Physogyra lichtensteini</i>	10000	49	<i>Pectinia lactuca</i>	800	49	<i>Nemenezophyllia turbida</i>	15000
50	<i>Plerogyra sinuosa</i>	31500	50	<i>Plerogyra sinuosa</i>	3600	50	<i>Physogyra lichtensteini</i>	8500	50	<i>Pectinia lactuca</i>	2350
51	<i>Plerogyra turbida</i>	16200	51	<i>Plerogyra turbida</i>	15000	51	<i>Plerogyra sinuosa</i>	24000	51	<i>Physogyra lichtensteini</i>	10500
52	<i>Pocillopora damicornis</i>	4950	52	<i>Pocillopora damicornis</i>	5500	52	<i>Pocillopora damicornis</i>	4500	52	<i>Plerogyra sinuosa</i>	29500
53	<i>Pocillopora verrucosa</i>	3150	53	<i>Pocillopora verrucosa</i>	3500	53	<i>Pocillopora verrucosa</i>	3500	53	<i>Pocillopora damicornis</i>	7100
54	<i>Polyphyllia talpina</i>	9000	54	<i>Polyphyllia talpina</i>	10000	54	<i>Polyphyllia talpina</i>	8500	54	<i>Pocillopora verrucosa</i>	5600
55	<i>Porites cylindrica</i>	15300	55	<i>Porites cylindrica</i>	17000	55	<i>Porites cylindrica</i>	13500	55	<i>Polyphyllia talpina</i>	9800
56	<i>Porites lichen</i>	7650	56	<i>Porites lichen</i>	8500	56	<i>Porites lichen</i>	5500	56	<i>Porites cylindrical</i>	28950
57	<i>Porites lobata</i>	1800	57	<i>Porites lobata</i>	3000	57	<i>Porites lobata</i>	1500	57	<i>Porites lichen</i>	5200
58	<i>Porites lutea</i>	1800	58	<i>Porites lutea</i>	2000	58	<i>Porites lutea</i>	1500	58	<i>Porites lobata</i>	2850
59	<i>Porites nigrescens</i>	9000	59	<i>Porites nigrescens</i>	10000	59	<i>Porites nigrescens</i>	7000	59	<i>Porites lutea</i>	1600
60	<i>Scolymia vitiensis</i>	3600	60	<i>Scolymia vitiensis</i>	4000	60	<i>Scolymia vitiensis</i>	2500	60	<i>Porites nigrescens</i>	9000
61	<i>Seriatopora hystrix</i>	1800	61	<i>Seriatopora hystrix</i>	2000	61	<i>Seriatopora hystrix</i>	1000	61	<i>Scolymia vitiensis</i>	4500
62	<i>Stylophora pistillata</i>	1350	62	<i>Stylophora pistillata</i>	1500	62	<i>Stylophora pistillata</i>	1300	62	<i>Seriatopora hystrix</i>	3200
63	<i>Symphylia agaricia</i>	1350	63	<i>Symphylia agaricia</i>	1500	63	<i>Symphylia agaricia</i>	1200	63	<i>Stylophora pistillata</i>	2250
64	<i>Symphylia spp.</i>	900	64	<i>Symphylia spp.</i>	1000	64	<i>Symphylia spp.</i>	700	64	<i>Symphylia agaricia</i>	1400
65	<i>Trachyphyllia geoffroyi</i>	76500	65	<i>Wellisophyllia radiata</i>	85000	65	<i>Trachyphyllia geoffroyi</i>	36000	65	<i>Symphylia spp.</i>	1100
66	<i>Tubipora musica</i>	9000	66	<i>Tubipora musica</i>	9000	66	<i>Tubipora musica</i>	8500	66	<i>Trachyphyllia geoffroyi</i>	52000
67	<i>Turbinaria mesenterina</i>	17100	67	<i>Turbinaria mesenterina</i>	19000	67	<i>Turbinaria mesenterina</i>	15000	67	<i>Tubastrea aurea</i>	6650
68	<i>Turbinaria peltata</i>	15300	68	<i>Turbinaria peltata</i>	17000	68	<i>Turbinaria peltata</i>	13000	68	<i>Tubipora musica</i>	7600
	TOTAL LIVE CORAL	858960		TOTAL LIVE CORAL	896000		<i>Wellisophyllia radiata</i>	1500	69	<i>Turbinaria mesenterina</i>	17550
	Base rocks (kg)	135000		Substrate	950000		TOTAL LIVE CORAL	637650	70	<i>Turbinaria peltata</i>	15650
	Substrate	675000		Live rock (kg)	450000		Substrate	950000	71	<i>Wellisophyllia radiata</i>	11000
							Live rock (kg)	450000		TOTAL LIVE CORAL	813950
										Substrate	900000
										Live rock (kg)	450000

Source: CITES (2003).

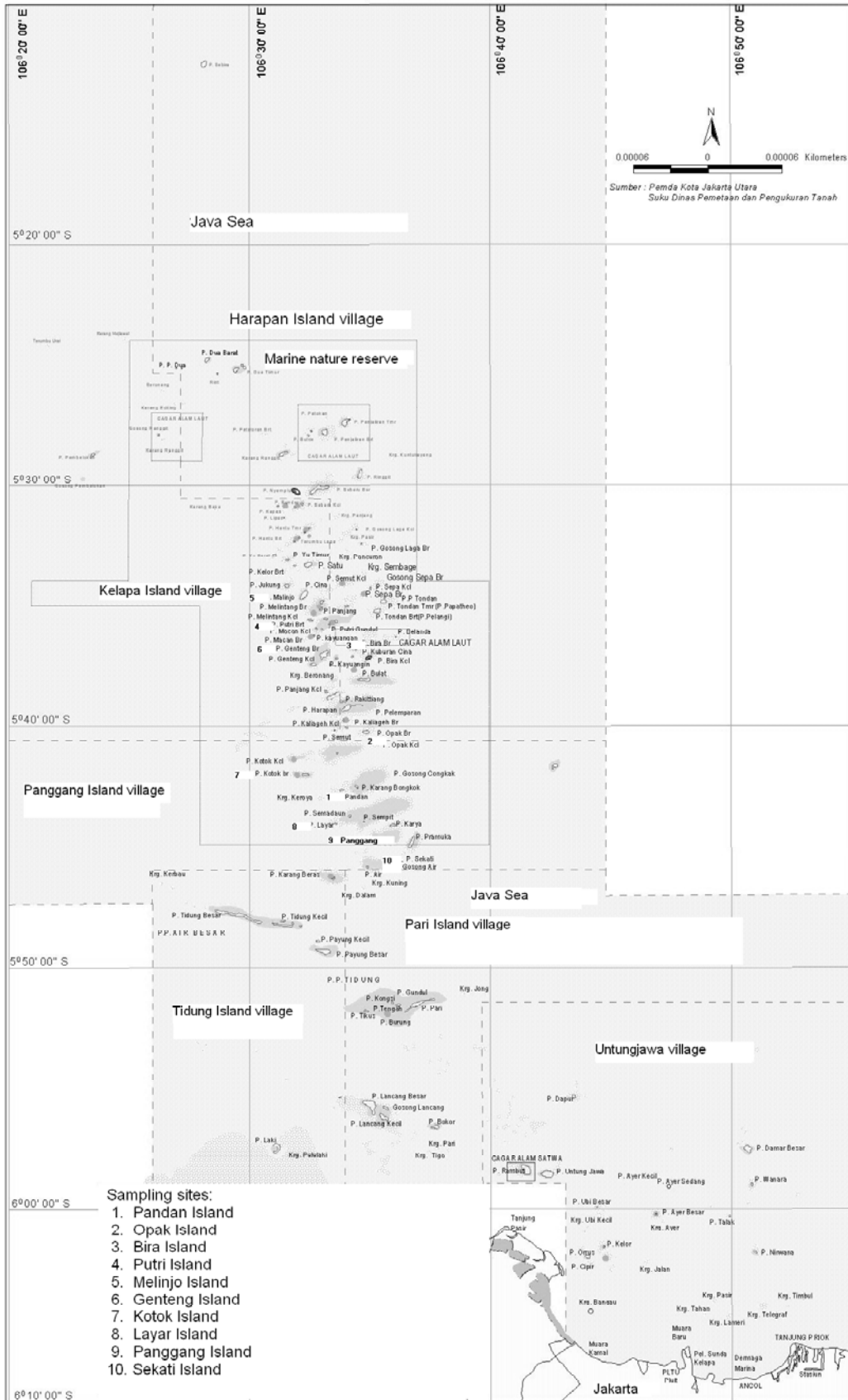


Appendix 47. Tourism data in Indonesia (2001)

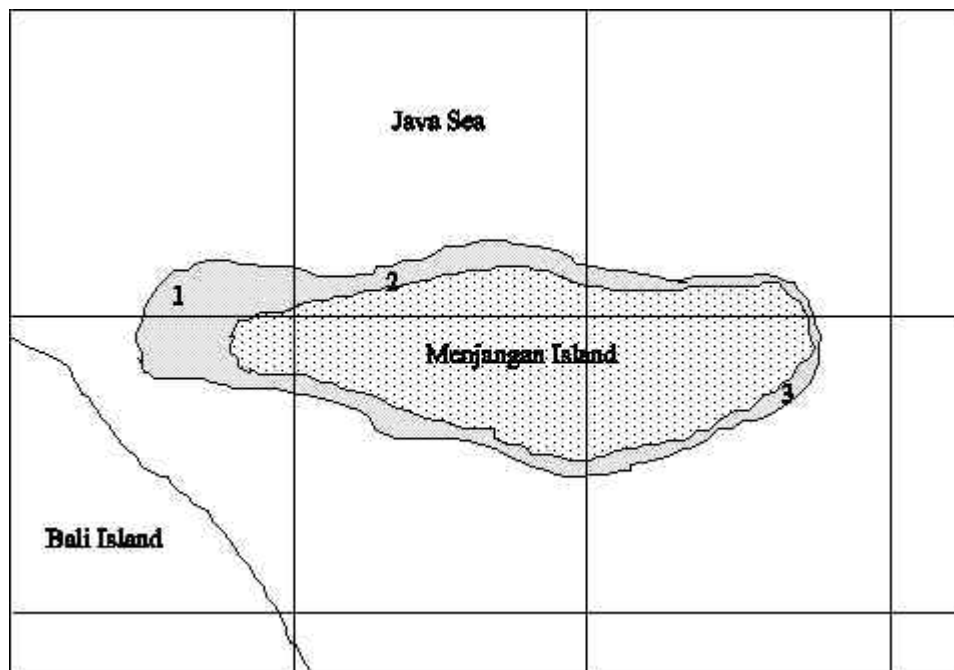
No.	Province	Number Of			Average Labour per		Guests Per Day		
		Facility	Room	Bed	Facility	Room	Domestic	Foreign	Total
1	Nanggroe Aceh Darussalam	146	2,671	5,236	8.6	0.5	666	3	669
2	North Sumatera	641	15,105	24,394	14.4	0.6	5,599	409	6,008
3	West Sumatera	219	4,260	8,088	11.3	0.6	1,351	81	1,432
4	R i a u	405	15,183	22,355	31	0.8	3,565	2,351	5,916
5	J a m b i	118	2,496	4,089	10.8	0.5	785	4	789
6	South Sumatera	247	4,956	8,224	13.5	0.7	1,342	15	1,357
7	Bengkulu	84	1,365	2,444	7.4	0.5	235	-	235
8	Lampung	138	3,022	5,188	12.9	0.6	1,495	12	1,507
9	DKI Jakarta	297	31,627	48,077	123.2	1.2	12,850	3,861	16,711
10	West Java	1,267	37,250	62,894	23.8	0.8	19,337	772	20,109
11	Central Java	989	20,632	34,562	12.8	0.6	9,613	282	9,895
12	DI Yogyakarta	970	13,357	22,429	8.4	0.6	4,077	325	4,402
13	East Java	1,154	25,541	42,063	16.9	0.8	11,765	577	12,342
14	B a l i	1,340	36,537	57,111	33.9	1.2	3,860	11,335	15,195
15	West Nusa Tenggara	297	5,092	8,634	14.6	0.9	596	636	1,232
16	East Nusa Tenggara	219	3,162	6,357	7.2	0.5	334	36	370
17	West Kalimantan	167	4,076	7,144	11.5	0.5	1,678	68	1,746
18	Central Kalimantan	207	3,817	6,030	6	0.3	819	3	822
19	South Kalimantan	157	3,544	5,674	11.8	0.5	1,306	21	1,327
20	East Kalimantan	285	6,661	10,609	17.3	0.7	2,186	125	2,311
21	North Sulawesi	110	3,124	4,780	21.4	0.8	795	133	928
22	Central Sulawesi	166	2,104	3,894	6	0.5	265	12	277
23	South Sulawesi	406	7,888	13,085	14	0.7	2,215	163	2,378
24	South East Sulawesi	124	1,266	2,223	5.3	0.5	306	3	309
25	M a l u k u	119	2,040	3,497	8.6	0.5	195	22	217
26	Irian Jaya	103	2,674	4,441	18.7	0.7	488	32	520
	Indonesia	10,375	259,450	423,519	20.6	0.8	87,723	21,281	109,004

Source: Central Bureau of Statistic, 2003

Appendix 48. Sampling sites in Seribu Islands

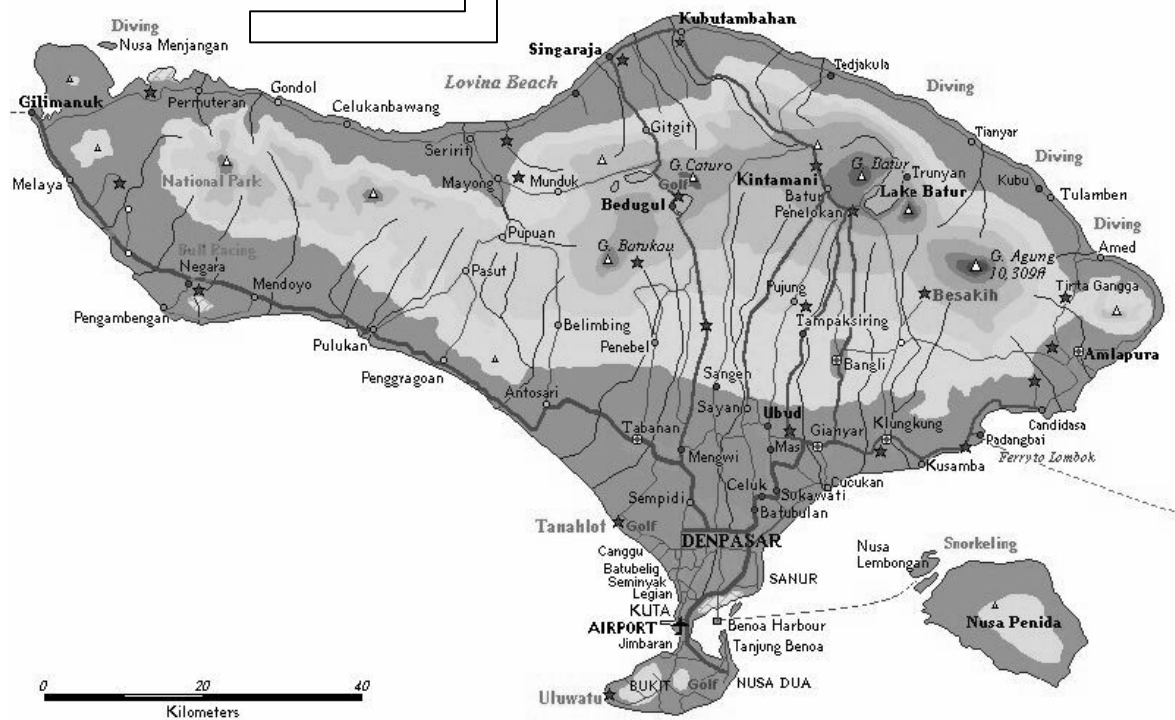


Appendix 49. Sampling sites in Menjangan Island

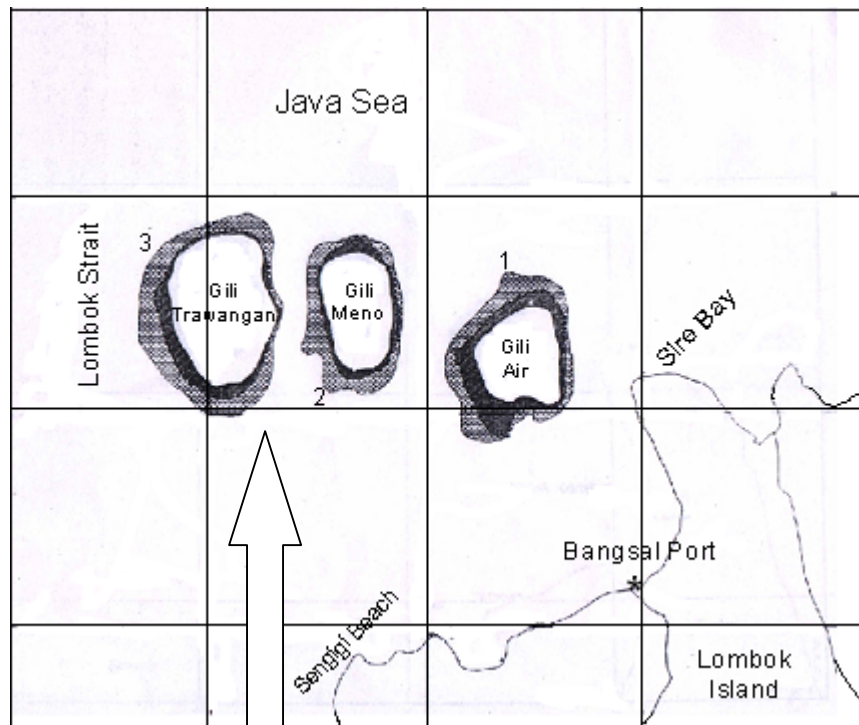


Sampling sites:

1. Garden Eel
2. Wreck
3. Posdua



## Appendix 50. Sampling sites in Gili Islands



- Sampling sites:
1. Gili Air
  2. Gili Meno
  3. Gili Trawangan

Appendix 51. Photos of Seribu Islands

Nature reserve zone in Seribu Islands



Tourism zone in Seribu Islands



Inhabitant zone in Seribu Islands



Source: Marine Nature Reserve Authority of Seribu Islands

## Appendix 52. Photos of Menjangan Island and Gili Islands

Menjangan Island



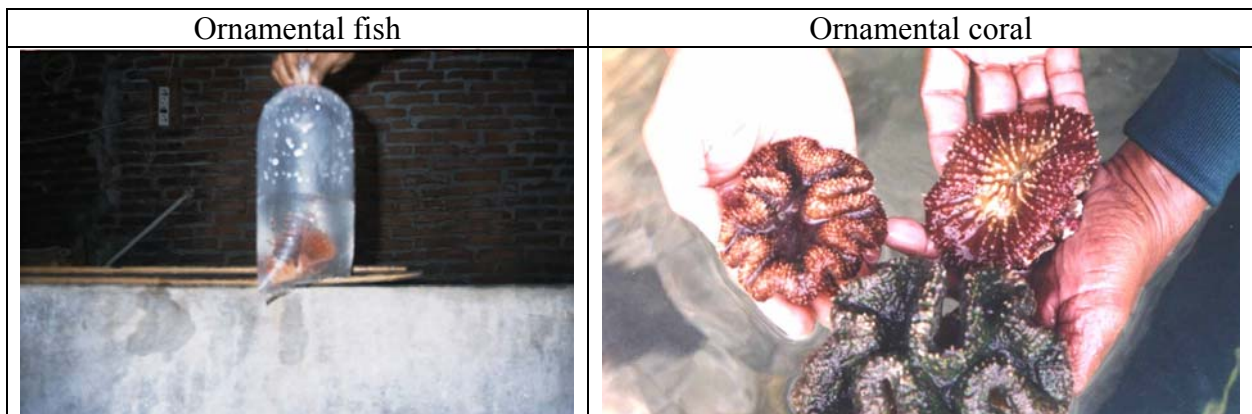
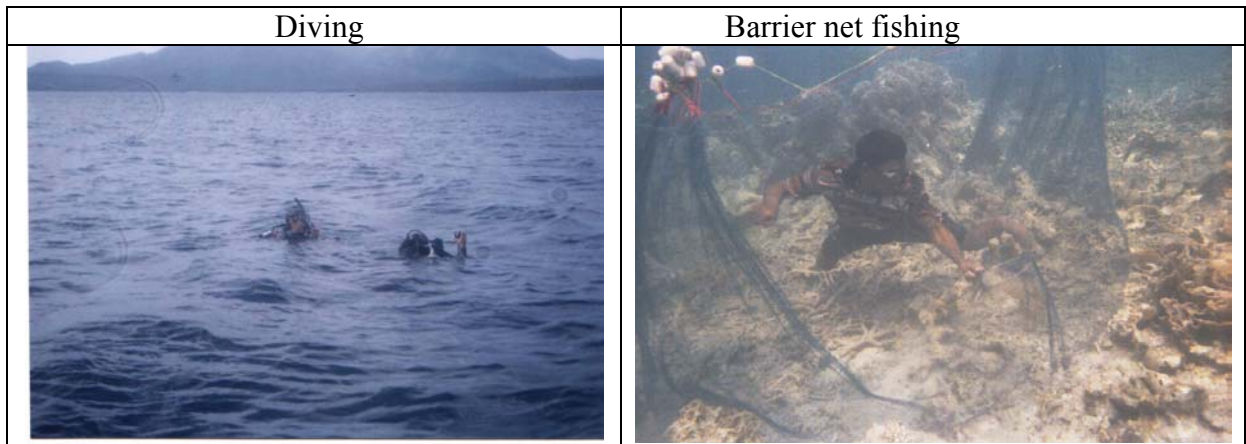
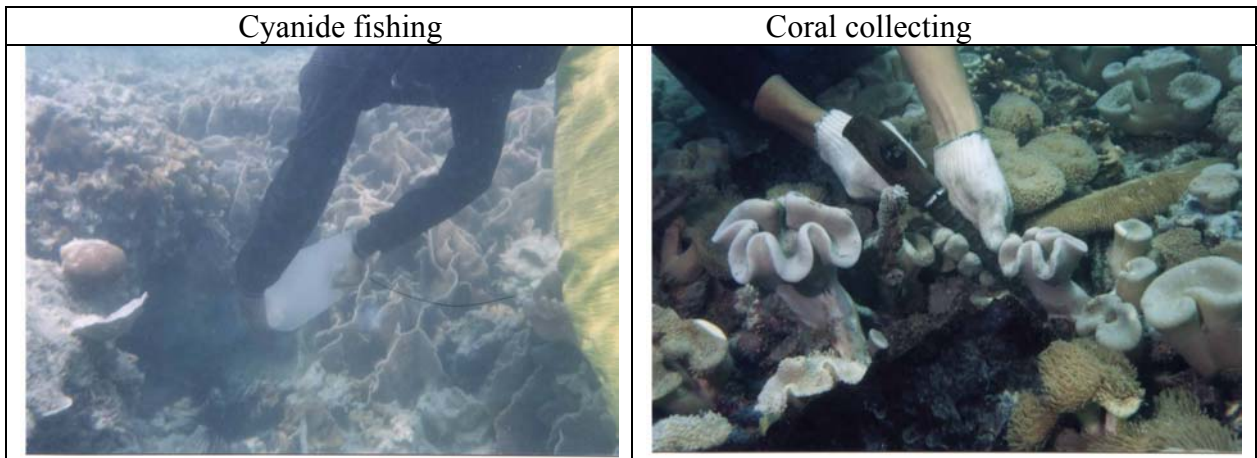
Gili Air Island



Gili Meno Island



Appendix 53. Photos of coral reefs uses



## **Eidesstattliche Erklärung**

Hiermit erkläre ich an Eides statt, dass ich die vorgelegte Dissertation mit dem Titel

" Extended Cost Benefit Analysis of Present and Future Use of Indonesian Coral Reefs - An Empirical Approach to Sustainable Management of Tropical Marine Resource"

selbstständig und ohne unerlaubte Hilfe angefertigt habe und dass ich die Arbeit noch keinem anderen Fachbereich bzw. noch keiner anderen Fakultät vorgelegt habe.

Kiel, den 6. November 2003

Achmad Fahrudin



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Kiel, den 06.11.2003

Achmad Fahrudin