An Overview of the Exploitation, Trade and Management of Corals in Indonesia

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Coral extraction is one of several factors threatening to undermine the viability of coral reefs in Indonesia. In recent years, this country has become the world's primary supplier of ornamental corals; in 1990 alone, it exported in the vicinity of one million pieces. The USA and Japan accounted for 85% of this trade between 1985 and 1995, mainly of live and dead specimens for the aquarium market. Use of coral in construction has a long tradition in Indonesia. Small-scale collection for use as building blocks is widespread but its effects are not well known. In contrast, large-scale mining of corals for lime production occurs at only a few locations but has resulted in clearly observable impacts on reefs. Although several laws regulate the mining of corals in Indonesia, it is apparent that these are not well enforced. Corals are also sought for making jewellery and anecdotal reports suggest that in many parts of Indonesia the slow-growing, long lived species that are in demand for such items are increasingly rare.

Although sedimentation and destructive fishing methods may pose more risk to Indonesian coral reef ecosystems as a whole, the commercial extraction of corals cannot be overlooked. Proper assessment, monitoring and enforcement of protective measures are necessary to ensure prevention of over-exploitation.

INTRODUCTION

Coral reefs are one of Indonesia's most important natural resources. Spanning an area of between 50 000 km^2 to 100 000 km^2, they are one of the most extensive of any country in the world. Coral reef ecosystems provide a source of food and income to thousands of coastal communities, in addition to offering coastal protection and revenue from tourism. Unfortunately, several factors threaten the viability of coral reefs in Indonesia. One of these is the extraction of the hard corals that form the backbone of the reef.

The group commonly known as hard corals consists of animal polyps that secrete external skeletons of calcium carbonate as they grow. These corals comprise a large number of morphologically diverse families. Some species, like the mushroom corals, consist of a single polyp, whereas others have colonies made up of thousands of small polyps. This study focuses on hard corals in the Orders Coenothecalia (blue coral), Milleporina (fire corals), Scleractinia (stony corals), Stylasterina (lace corals) and Stolonifera (organ pipe corals); also considered is the exploitation of semi- precious Antipatharia (black coral) species, which are easily distinguishable from hard corals, having a flexible, internal skeleton made of a horny, non-calcareous material. All these species are listed in CITES Appendix II and include all the coral species known to be harvested in Indonesia. There is no evidence that the large group commonly known as soft corals (subclass Alcyonaria) are exploited in significant quantities in Indonesia and this group is not considered further here.

In Indonesia, hard corals are collected for a wide variety of purposes, ranging from hotel construction to traditional medicine. However, three main types of exploitation have been identified: collection for aquarium and ornamental specimens, for construction purposes and for use in jewellery. This report examines the collection and trade associated with each of the three uses of corals, providing an overview of harvest locations, preferred species and dynamics of the trade, as well as the relative impacts on corals and coral reefs. TRAFFIC Southeast Asia is to produce a report which will focus in more depth on the trade in aquarium and ornamental coral pieces.

METHODS

Research on the exploitation and trade of corals in Indonesia was carried out between June and October 1997. Information was obtained during interviews with coral collectors and traders, researchers and non-governmental organizations. In addition, two data sources were used to assess the extent and dynamics of Indonesia's international trade in corals: the *CITES Trade Database* and Indonesia's reports of *International Trade of Fisheries Commodities.* The *CITES Trade Database* contains trade records that Parties to the Convention are obliged to compile annually. The database is managed by the World Conservation Monitoring Centre, Cambridge, UK, on behalf of the CITES Secretariat (WCMC, 1996). Records pertaining to the trade in corals from Indonesia were extracted for the period 1985 to 1995 and are referred to in this report as the CITES annual report data. Indonesian export records for 1995 had not been included in the *CITES Trade Database* at the time data for this report were analysed (March 1998).

The reports of *International Trade of Fisheries Commodities*, published annually by Indonesia's Directorate General of Fisheries, contain data from the Central Bureau of Statistics on the trade in fisheries commodities, including the category "Coral and similar substances". These are available for the years 1989 to 1995 and are referred to herein as DGF data.

During the latter part of 1997, the value of the Indonesian rupiah fluctuated significantly. The exchange rate used in this article is US$1 = Rp3000, the approximate exchange rate at the time of this research.

CORAL EXPLOITATION AND ITS USES

Aquarium and Ornamental Pieces

Nature of Use

Recent advances in technology have allowed hobbyists to keep corals alive in home aquaria. This has resulted in an increase in demand for live coral specimens, particularly for species with large colourful polyps such as *Catalaphyllia* and *Trachyphyllia* (O'Brien Shoup and Gaski, 1995). The largest market for these corals is the USA (see *International Trade*) where large pieces fetch up to US$200. Other species are prized for their ornate skeletons and dead specimens are popular as ornaments, both for aquaria and other purposes.

In addition to coral pieces, there is a significant trade in 'live rock'. This is usually fragments of dead coral which are naturally encrusted in live corraline algae (*Lithothamnion* spp. and *Neogoniolithon* spp.) and other marine organisms. Varieties of live rock advertised recently by aquaria suppliers in the USA have names which reflect their Indonesian origin – "Premium Red Algae Jakarta Rock" and "Fancy Bali Red Live Rock", for example.

Background

Prior to the early 1980s, the Philippines was the world's major supplier of ornamental corals to international markets. However, Presidential decrees in 1977 and 1980, which banned coral exports, resulted in a dramatic reduction of trade from that country. By the late 1980s only about half of the trade originated from the Philippines (Mulliken and Nash, 1993) and by 1993 fewer than 500 pieces of coral were reported as exported from that country each year (O'Brien Shoup and Gaski, 1995; Mulliken and Nash, 1993). Concurrent with the reduction in trade from the Philippines, exports from Indonesia rose and by the early 1990s that country was supplying as much as 95% of the corals reported in international trade (O'Brien Shoup and Gaski, 1995).

In response to concerns of over-exploitation, all 150 species of black coral (Order Antipatharia) were listed in CITES Appendix II in 1981 followed, in 1985, by the 17 coral genera most commonly exported from the Philippines (O'Brien Shoup and Gaski, 1995). However, problems

with enforcement were encountered owing to difficulties in distinguishing these latter 17 genera from other hard corals. Therefore, in 1989, all members of the Orders Scleractinia and Coenothecalia and the Family Tubiporidae (of the Order Stolonifera) were included in Appendix II. Currently, there are five hard coral Orders listed, which include over 250 genera (O'Brien Shoup and Gaski, 1995).

Collection and Domestic Trade

Although Indonesia has extensive areas of coral reef, 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: both Jakarta and Bali are served by international airports, which offer the primary means of export for coral pieces.

Collection is carried out by local fishers diving from boats using 'hookah' – diving apparatus that uses air supplied through a line from a surface compressor - or by free diving using only a mask. Fishers may cover large areas of reef in their search for desired species, often using a basket to hold the coral. Some species that are sought occur on reef flats and can be collected on foot at low tide.

Collectors often sell their catch to village-based dealers who, in turn, sell to exporting companies. For example, on a small island off Ujung Pandang there are four dealers, each with onshore tanks or small, submersed offshore cages for keeping corals alive. Each operator sends about two shipments per week to Ujung Pandang, receiving between Rp300 (US$0.10) and Rp3000 (US$1) per specimen depending on the species. One operator interviewed had about 500 pieces of live coral awaiting shipment.

Coral exporting companies based in Jakarta mostly buy corals from collectors operating in the Seribu Islands, Belitung Island and the Lampung area. In the main, those 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 a 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.

Reporting on the International Coral Trade

CITES annual report data

CITES annual reports record the country of origin, export/re-export and importing country, quantity, units (e.g. kilogrammes or pieces), description (e.g. live, raw, carvings), purpose (e.g. commercial trade, personal) and source (e.g. wild, bred in captivity). The reports provide a useful tool for assessing trade volumes. However, owing to a number of factors, accurate assessment of trade volumes is hindered. For example, different units may be used to describe the same coral shipments (e.g. pieces or kilogrammes); because some countries, including Indonesia, report on the basis of the number of specimens included on all permits issued rather than on the actual number of items traded; export permits may be issued in one year but not used until the next, with the result that the trade is reported in separate years by the exporting and importing country; or, trade is reported at a different taxonomic level. The situation is complicated even further in the case of Indonesia's annual reports, which contain numerous records of new permits issued to be used in lieu of permits, or parts of permits issued previously, all of which are included in the CITES annual report data compiled by WCMC (J. Caldwell pers. comm. to T. Mulliken, April 1998). As a result many shipments may be recorded more than once.

Virtually all coral reported as exported from Indonesia was reported as originating in that country. The vast majority of reported trade is recorded in terms of number of pieces, with very little recorded by weight: only 545 t of coral were reported as imported from Indonesia and 115 t

were recorded as exported by Indonesia during 1985 to 1994, which is estimated to be less than 10% of the volume traded during this period. Of these, 76 t were recorded as "grapel" (presumably gravel) and 36 t as "coral sands" in 1993. In addition, Indonesia's annual reports showed the export in that year of 1100 bags of "coral sand". These records have been excluded from the following summaries of CITES data. Based on an analysis of US import data for the 1980s, the average weight of a "piece" of coral has been estimated at just under one kilogramme (Anon., 1989). This conversion factor has been used to convert all raw coral "pieces" reported in trade by weight to numbers of "pieces".

Indonesia's CITES annual reports for the period studied do not record the source of specimens in trade or the purpose of transactions. This information was reported by many importing countries, however, as is shown below. Indonesia began providing this information in 1996 (J. Caldwell pers. comm. to T. Mulliken, April 1998).

DGF data

The DGF data category relevant to coral is "Coral and similar substances" (Code 050800100). While this classification suggests that other reef animals could be included, separate categories exist for the other main commercial taxa in trade, namely, 'mother of pearl shell', 'trochus' and 'other shells and sponges'. Therefore, if other reef animals are included, the weight is likely to be small. The data summarize export weight (kg) and value (US$) by month, by destination and by port of export.

Analysis of CITES trade

A comparison of CITES import and export data reveals that Indonesia generally reports a higher quantity of exports than is recorded by importing countries. This is not surprising, however, given the characteristics of Indonesia's CITES annual report data noted above, e.g. that trade records show all specimens on permits issued. From 1985 to 1994, CITES annual report data for Indonesia show the export of a total of 8.5 million pieces, whereas reported imports totalled 5.1 million. The discrepancy is most marked during 1993, when the difference between recorded exports and imports was approximately 1.6 million pieces. Indonesia's CITES annual report records nearly 2.7 million pieces exported by Indonesia during 1993. But, a summary provided in the annual report indicates that approximately 1.7 million pieces were exported during 1993 (Anon., 1993). This latter figure may more closely reflect the actual trade as it is likely to exclude cancelled permits. In other years, Indonesia's reported exports are either higher or are very close to reported imports (Figure 1). Only four minor importing countries - Australia, Belgium, Spain, and the Republic of Korea - reported imports greater than reported exports. In all these cases the discrepancy in reported trade was fewer than 15 000 pieces in any one year.

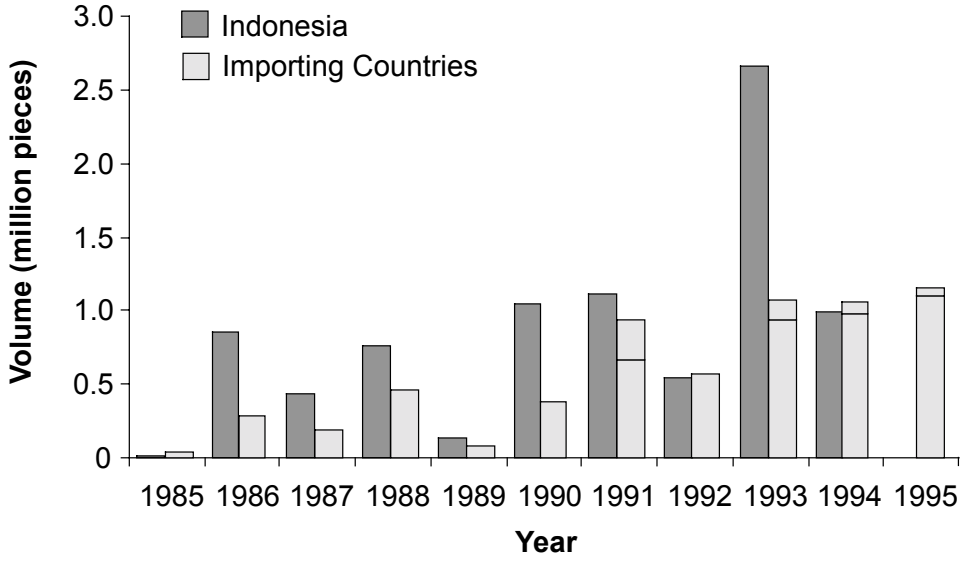


Figure 1. Comparison of the number of coral pieces recorded as exported from Indonesia, by Indonesia and importing countries, 1985 - 1995. *Source: CITES Trade Database.*

CITES gross trade by country

CITES gross trade quantities have been estimated for this study by comparing annual import records for each importing country, with corresponding export records from Indonesia. According to these estimates, the USA and Japan accounted for 85% of the reported imports of corals from Indonesia between 1985 and 1995 (Table 1). Apart from a peak in 1993, exports to the USA have fluctuated at around 700 000 pieces annually, and show no obvious trend. Exports to Japan and Europe, while still minor compared to the USA, have increased significantly since 1990 (Figure 2).

Table 1. Average annual CITES trade in Indonesian corals for the top 15 importing countries, 1985-1995. *Source: CITES Trade Database*

Importer	**Pieces**
USA	676 531
Japan	114 219
Germany (F.R.)	38 986
Spain	21 493
Italy	20 540
France	17 275
Netherlands	11 030
UK	10 253
Canada	5 730
Singapore	2 809
Austria	1 821
Hong Kong	1 671
Malaysia	1 258
New Zealand	1051
Korea (Rep. of)	978
Other countries	3 802

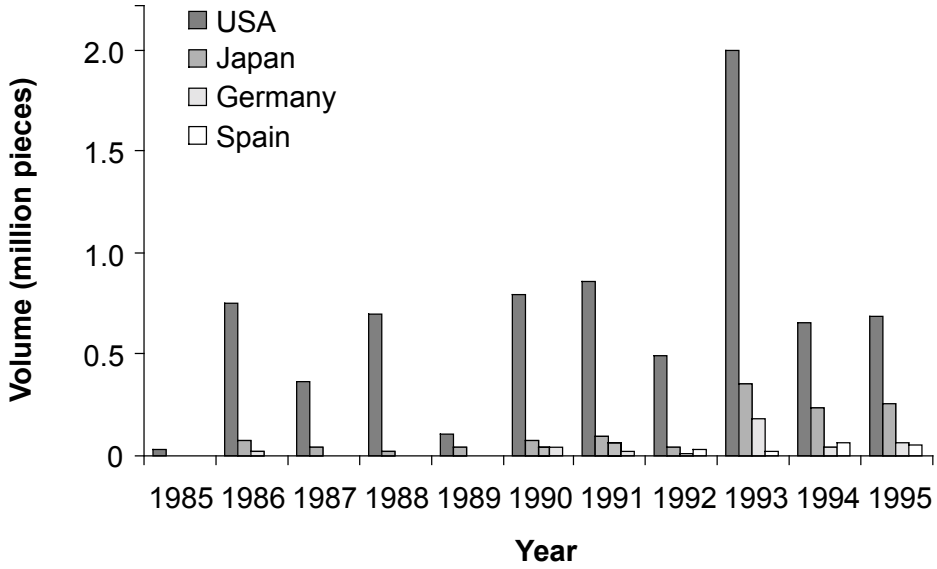


Figure 2. Reported imports of Indonesian corals for the top importing countries, 1985 - 1995. *Source: CITES Trade Database*.

CITES trade by term, purpose and source

As noted above, Indonesian CITES data did not specify a purpose or source for exports during the period studied. Furthermore, they do not discriminate between live and dead coral pieces. Trade data from importing countries show that trade is commercial in nature and involves wild-caught specimens, and that "Live" corals represent close to half the trade (Table 2). An indication of live coral trade is provided in Indonesia's 1993 annual report which gives "live rock" as the common name for numerous shipments of *Acropora* spp. Analysis of CITES annual report data provided by countries importing from Indonesia (Table 3) shows trends in the relative proportions of various genera of coral in trade.

There has been a gradual increase in the proportion of live corals imported by the USA (Figure 3). "Raw coral" made up 83% of imports by Japan, the remainder being "carvings", and 97% of coral imports by Germany were of "raw" material.

Table 2. The percentage of coral exports by purpose, source and term, as reported by importing countries. *Source: CITES Trade Database*

Purpose	**Importing Countries**
Commercial trade	97.17
Unspecified	2.74
Scientific	0.05
Circuses and travelling exhibitions	0.03
Zoos	0.01
Personal	<0.01
Source	
Wild	44.87
Unknown	34.83
Unspecified	19.31
Confiscated/seized	0.73
Pre-CITES	0.26
Captive-bred	0.02

Description	
Raw corals	54.53
Live	42.69
Carvings	2.61
Unspecified	0.08
Bodies	0.08
Shells	0.01
Scientific specimens	<0.01

Table 3. Number of pieces and percentage of "Raw" and "Live" coral imports reported as imported from Indonesia, by genera, 1985-1995. ***Source: CITES Trade Database***

Raw	Pieces	%	Live	Pieces	%
Pocillopora	561 654	16.6	*Euphyllia*	274 720	10.3
Acropora	428 256	12.6	*Goniopora*	199 407	7.5
Heliopora	297 917	8.8	*Catalaphyllia*	163 186	6.1
Fungia	242 889	7.2	*Trachyphyllia*	113 200	4.3
Tubipora	134 562	4.0	*Plerogyra*	112 667	4.2
Porites	124 782	3.7	*Heliofungia*	79 069	3..0
Seriatopora	91 204	2.7	*Acropora*	77 079	2.9
Stylophora	61 129	1.8	*Porites*	62 014	2.3
Euphyllia	55 029	1.6	*Pocillipora*	51 989	2.0
Other genera	407 616	12.0	Other genera	356 754	13.4
Unidentified Scleractinia	986 695	29.1	Unidentified Scleractinia	1165491	43.9
Scleractinia	986 695	29.1	*Scleractinia*	1 165 491	43.9

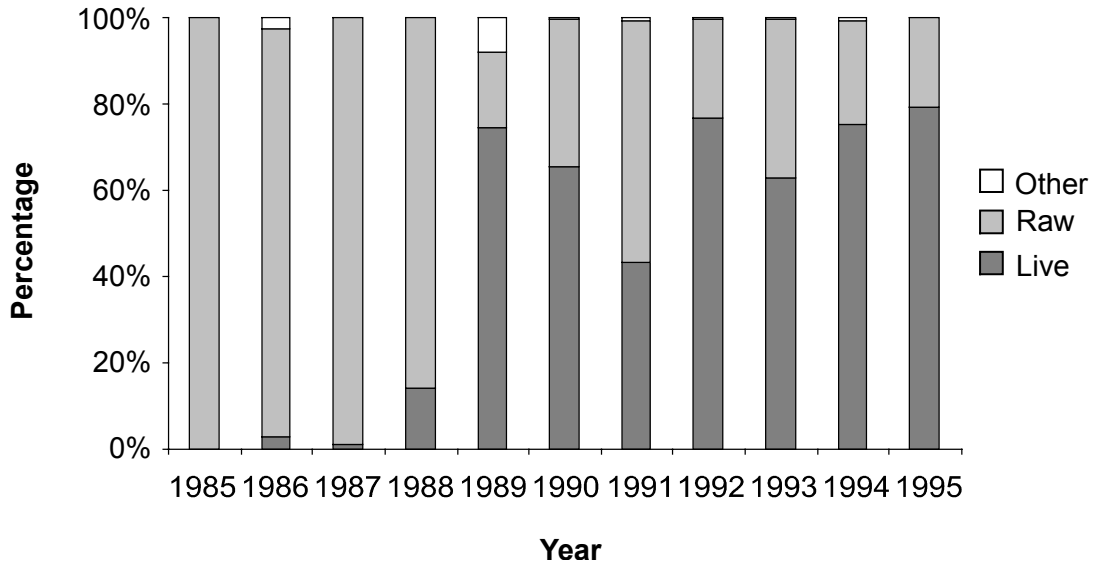


Figure 3. The proportion of coral reported by the USA as imported from Indonesia, by description, 1985 - 1995. ***Source: CITES Trade Database .***

CITES by species

The taxonomic description of coral in trade is similar between importing countries and Indonesia, which identified 127 and 131 different taxa respectively. Ranks of taxon abundance are also similar between import and export records. However, as Indonesia's trade data do not generally distinguish between live and dead coral, import records must be consulted to assess the relative volumes of different genera traded as live and dead specimens.

As would be expected, raw coral exports, in demand for ornamental purposes, are dominated by genera with ornate skeletal structures including *Pocillopora* spp., *Acropora* spp. and *Fungia* spp. In addition, unusual species such as the blue coral *Heliopora* spp., and the colourful organ pipe coral *Tubipora* spp., are among the most commonly exported raw corals.

Live coral exports are largely composed of corals that are popular for keeping live in aquaria. Specimens of *Euphyllia, Gonopora, Catalaphyllia, Plerogyra, Trachyphyllia* and *Heliofungia*, which have large live polyps, often with spectacular lobes, are particularly common.

DGF data

Since DGF data are recorded in kilogrammes it is difficult to compare these with CITES trade data. In most years total export quantities recorded by the DGF data are below 200 t. However, in 1992 a total of 1200 t were exported, of which over 1000 t were exported to Japan (Table 4). Over 95% of coral exports reported by DGF were sent to Japan, USA and Taiwan. There is no consistent trend in DGF exports to any of these countries, either in weight or value, or in the relationship between these.

According to the DGF data the major export points were the seaports of Belawan, north Sumatra; Tanjung Priok, Jakarta; Tanjung Emas, central Java and Tanjung Perak, east Java. Smaller amounts of coral were reported as being exported from Ngurai Airport, Bali and Hassanudin Airport, Ujung Pandang. The preponderance of seaports in the DGF data set suggests that it mostly records dead coral exports as live coral would be unlikely to survive long ocean journeys. It also suggests that the DGF data underreport coral exports because the significant quantities that are known to leave from airports are not recorded. Export quotas are set by the Indonesian authorities for "shingles from corals and similar substances" (see **MANAGEMENT/ REGULATIONS**). This quota is set in terms of kilogrammes and the DGF data may be recording only this commodity under the classification "coral and similar substances".

Table 4. DGF exports from Indonesia, 1985-1995. *Source: CITES Trade Database and Directorate General of Fisheries, Indonesia.*

Year	DGF exports (kg)
1989	104 160
1990	76 240
1991	199 691
1992	1 199 919
1993	135 818
1994	155.098
1995	73.569

Construction Material

Throughout coastal Indonesia, corals are used for construction, either crushed and fired to produce lime (an important constituent of cement), or as pieces for use as building blocks for walls and foundations. Their use in construction is reported from Java, Kalimantan, Bali,

Lombok, Sulawesi, and Maluku (Polunin, 1983; Cesar, 1996) and consists mainly of genera with dense calcium carbonate skeletons such as *Platygyra*, *Porites* and *Favia* (Table 5).

Table 5. Taxonomic composition of corals collected for lime production at a location in Bali. *Source: Sarjana Putra, 1992*

Genus	%
Platygyra	26
Porites	25
Favia	20
Acropora	15
Favites	10
Pocillopora	4

Since the 1800s, coral limestone - the skeleton of dead corals - has been mined from Jakarta Bay for use in the construction of jetties. Annual coral extraction from the Jakarta area in the late 1920s and early 30s has been estimated at between 10 000 m^3 and 25 000 m^3 (Polunin, 1983). In 1970, the mining of coral, sand and stone in the seas off Jakarta was banned (Lang, 1992). However, some of these activities have continued. Six small islands in the Thousand Islands Archipelago have recently disappeared, reportedly owing to sand mining for the construction of the Soekarno-Hatta International Airport and land reclamation in north Jakarta (Anon., 1997a). There are also reports of coral limestone being used for the construction of a new airport runway in Lombok.

Corals are also used for small-scale construction throughout coastal Indonesia. For example on an island off Ujung Pandang, south Sulawesi, coral heads are used for small breakwalls as protection against shifting sands close to houses. At Majene, south Sulawesi, coral rocks are used to line shrimp ponds.

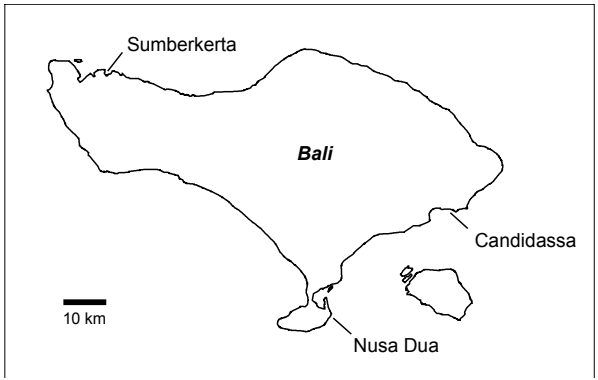
Reports of coral burning for the production of lime date to 1854 (Polunin, 1983). Corals are collected in shallow water, broken into smaller pieces and then burned in a kiln or open fire until only lime remains. A relatively low conversion ratio of about 1.8:1, corals to lime by weight, is obtained after burning the coral skeletons (Box 1). Although the practice of small-scale coral burning appears to be widespread in Indonesia, it is perhaps best known from Lombok island, and in Bali where the damage caused by these practices has led to significant and expensive erosion problems (Box 2). At one mined site on Bali, coral cover is now less than 5%, with a virtual absence of the species that were preferred for lime production. Subsequent monitoring has shown very little recovery of mined sites throughout Bali (Sarjana Putra, 1992). Coral mining in Bali has now largely ended.

Box 1. Predicting conversion rates: the chemistry of making lime from corals

Coral skeletons consist mainly of calcium carbonate which, in the presence of heat, decomposes to produce calcium oxide (lime) and carbon dioxide $CaCO_3 > CaO + CO_2$. Using this equation and the atomic weights of the elements it contains, the conversion ratio between corals and lime can be estimated. For every 100 kg of calcium carbonate that is burned, 56 kg of lime and 44 kg of carbon dioxide are produced. In other words, every kilogramme of lime that is produced requires at least 1.8 kg of coral.

Box 2. Using corals for hotel construction in Bali: costly consequences

During the late 1970s, the rapid tourist boom in Bali brought with it the construction of new hotels along the coast. A cost-effective way of producing lime for cement was to mine corals on the reefs adjacent to the hotel sites. By the 1980s there were more than 400 coral



burning kilns on the eastern and southern coasts of the island. Most were concentrated in Candidassa (125 kilns) and Nusa Dua (134 kilns). Corals were manually removed from shallow reefs to depths of up to two metres, and broken into pieces ready for firing in kilns (Sarjana Putra, 1992).

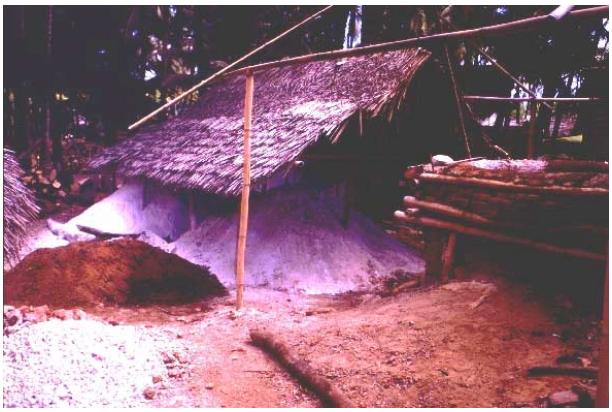
The volume of coral mined from the south coast of Bali has been estimated at up to 150 000 m^3. The resulting erosion of the beachfront has been significant and millions of dollars have subsequently been spent on protective measures, such as seawalls and breakwaters: some hotels are reported to be spending over US$100 000 each year (Cesar, 1996). Today at Candidassa, the beach has virtually disappeared and waves crash at the base of hotel retaining walls.

In 1985, the Balinese government outlawed coral mining. Initially, the response to this regulation was slow, but by 1990 mining had stopped in most areas. The exception is Sumberkerta, a small town on the north coast, where small amounts of dead coral are still used for lime production. This reduction in mining can partly be attributed to the end in the hotel building boom, and a general increase in the standard of living that gave miners alternative job opportunities.

In Lombok, coral mining for lime production still occurs at Teluk Dalam (Box 3) and to a lesser extent at Pelangan on the southwestern peninsula. Although there are no definitive estimates of the total lime production from corals in Indonesia, the operations at Teluk Dalam are probably the largest in the country. The cost of explosives is probably too great to warrant its use for the production of lime and there are no reports of large-scale coral mining in Indonesia using large ships or dredges.

Box 3. Lime Production at Teluk Dalam, Lombok

Coral has been mined at Teluk Dalam, on the northwest coast of Lombok, since the late 1940s. The mine is probably the largest in Indonesia, and operations here reflect the general methods used to mine coral for lime in other, smaller, occasional, operations that may be scattered throughout the country. Men travel out in small canoes and dive in shallow water to collect coral heads of species such as those of *Porites* and *Favia*. Nowadays, they need to travel up to one kilometre because areas closer by have already been depleted. Depending upon sea conditions, collectors make up to five



trips a day, each time collecting 1 m^3 to 1.5 m^3 (about 200 kg) of coral.

On shore, women and men split the coral into smaller pieces ready for firing. There are about twenty kilns fired with wood from nearby forests. After four days in the kiln, the coral is reduced to a fine lime and shovelled from the base of the kiln into piles to await packaging in sacks, ready for shipment. Each sack weighs between 20 kg and 25 kg and is sold for about Rp2500 (US$0.80). Each kiln, which measures about 3 m^3 to 4 m^3, takes three loads a month, producing a total of about 175 sacks of lime. Production is divided between two companies employing a total of some 125 people. Most of the lime produced in Teluk Dalam is used locally in the private and government sectors for building construction (Cesar, 1996).

Each week, two 10 t lorry loads of sacks are taken away to be sold, which suggests an annual lime production of about 1000 t. This would require the collection of about 1800 t of raw coral. Information on collecting activities supports this value. It is suggested that, on average, 20 boats make two to three trips a day, 300 days a year, each time collecting 150 kg. This is equivalent to an annual coral harvest in the vicinity of 2000 t.

Jewellery

Of the 200 species of black coral, about ten, mostly of the genus *Antipathes*, are commercially exploited for use in jewellery (Grigg, 1984; Fitzgerald, 1989). A large number occur in Indonesia and have been collected since at least the eighteenth century (Yogev, 1978). Almost all occur at depths accessible by diving and are generally collected by small-scale fishers using compressors. In the Spermonde Archipelago the delicate black skeletons are cut into one-metre lengths and sold for Rp5000/kg (US$1.67) (Erdmann, 1995). Souvenir and jewellery shops in nearby Ujung Pandang sell black coral bracelets for between Rp4000 and Rp7000 (US$1.33 and US$2.33) each. Here, half metre lengths of dried black coral sell for Rp50 000 to Rp70 000 (US$16 to US$23) each, although they are only long enough to make four or five bracelets. The price discrepancy is caused by the presence or absence of the organism's holdfast – a structure that attaches the coral to the substrate - which is used in this region as a medicine for treating sore joints and infertility. Collection of black coral appears to be getting rarer and anecdotal reports throughout Indonesia suggest that it is now hard to find.

MANAGEMENT/REGULATIONS

Export of aquarium and ornamental coral, and jewellery

The Directorate General of Forest Protection and Nature Conservation (PHPA) in the Ministry of Forestry is the authority responsible for issuing CITES permits. Based on advice from the National Institute of Sciences (LIPI), it sets export quotas for various taxa in the trade. These quotas are assigned to the Indonesian Coral Shell and Fish Association (AKKII) whose members are the only people in Indonesia permitted to export corals. It is not known how or if the quotas are divided among member companies of AKKII.

It is not clear to what extent export quotas have been enforced: AKKII claim to be within their quotas, but there are reports that non-member companies based in Ujung Pandang and Menado are exporting corals without permits. In 1995, total quota levels were set at 1 075 000 pieces (O'Brien Shoup and Gaski, 1995). Gross trade reported by importing countries in the same year totalled 1 154 979 pieces, 7% over the quota level. Quotas for 1997 were set at 765 000 pieces of "live stony corals" (broken into 39 categories), 90 000 pieces of "base rock" (assumed to mean pieces of dead coral skeleton encrusted with algae, sponges and other invertebrates), and 45 000

kg of "shingles from corals and similar substances" (assumed to mean pieces of broken coral suitable for use as aquarium substrate gravel) (Anon., 1997b). Indonesia's trade records for this year are not yet available.

Coral mining

Coral mining falls under the jurisdiction of the regional government (Lang, 1992). In 1970, *Decree No. 15/12/43/70* banned the mining of coral, sand and stone in the seas off Jakarta (Lang, 1992), and in 1985 Bali outlawed coral mining (*Law PP No. 10/1983*).

Several national regulations also pertain to coral mining. The *Wildlife Protection Ordinance of 1931* restricted the exploitation of live corals and required permits for collection. *The Conservation of Living Resources and their Ecosystems Law No. 5, 1990* has repealed this law although the management of coral exploitation is covered by this legislation. Despite their applicability to coral mining, however, neither of these laws has been well-enforced (Lang, 1992; O'Brien Shoup and Gaski, 1995). Furthermore, national *Government Assessment/Analysis of Environmental Impacts Regulation No. 29, 1986* does not appear to have been applied to coral mining which, as an activity which exploits natural resources, should be covered by this regulation (Lang, 1992).

Despite the problems caused by coral mining, members of LIPI and the Department of Trade, meeting in 1984, recognized that corals represent an important construction material for small island communities (Sarjana Putra, pers. comm., July 1997). Owing to the expense of purchasing alternative construction materials, it was decided to allow the collection of dead corals only. It is not clear whether a law has been passed based upon these recommendations. However, such a law would be hard to enforce as identifying live from dead coral can be difficult, particularly when specimens have been split and dried for lime production.

Domestic trade in ornamental corals

There are no known restrictions on the collection or domestic sale of precious corals in Indonesia, including ornamental and aquarium pieces.

CONCLUSIONS AND DISCUSSION

Although coral exploitation in Indonesia is widespread, it is also varied. Different types of exploitation target quite different species and operate over different spatial scales. This makes a comparison of their overall impact on coral reefs difficult. However, some general conclusions can be drawn.

Coral mining is a highly localized activity that can cause significant impacts on coral reefs. Furthermore, experience has shown that these effects on the habitat can have major implications for coastal protection, potentially resulting in great cost: a recent analysis (Cesar, 1996) estimated that one square kilometre of reef mined for lime production in Indonesia yielded benefits of US$121 000 to the miner over 25 years, but caused losses to society of US$93 600 in fisheries value, US$12 000-US$260 000 in coastal protection value, US$2900-US$481 900 in tourism value and US$67 000 in forest damage caused by the collection of firewood for lime kilns. The total net losses to society are estimated to be 7.5 times higher than the net individual benefits (Cesar, 1996).

Recolonization of reefs after mining may take a long time. Catastrophic storms in Hawaii resulted in reductions in living coral cover from 46% to 10%: 12 years later coral cover had only increased to 15%. Extrapolation of these results suggests recovery to pre-storm conditions in 40 to 70 years (Dollar and Tribble, 1993). Preliminary research in Indonesia suggests that recovery rates after mining may also be very slow (Sarjana Putra, 1992).

The amount of coral utilized for construction purposes is probably greater than coral exploited for other purposes. Large-scale mining operations at Teluk Dalam alone have been estimated at around 1800 t annually. Combined with the widespread, small-scale collection of coral that

occurs elsewhere, the annual volume of coral mined for construction purposes countrywide could amount to over 5000 t a year. In contrast, even assuming each piece of coral that was exported weighs one kilogramme, exports of coral have probably never been more than 3000 t a year. However, comparison of the relative impacts of these types of exploitation based on weights alone could be misleading.

Although coral mining causes the localized destruction of coral habitats, collection for ornaments, aquaria and jewellery focuses on a small number of species that are often rare and slow-growing. While this is unlikely to result in damage to the reef ecosystem, it could result in severe localized depletion of some species. Such impacts have been documented on reefs exposed to collection activities in the Philippines (Ross, 1984).

Export quotas are almost certainly the most effective means of limiting the exploitation rates of corals collected for aquaria and ornamental purposes and destined for overseas markets. The huge expanses of coral reef in Indonesia preclude the usefulness of on-the-ground enforcement under the current budgetary constraints of the relevant enforcement agencies. However, to prevent the localized depletion of sought-after species, in areas close to transport centres for example, it may be appropriate to combine export quotas with local regulations. For instance, the rotational harvesting of areas of a reef could provide a relatively easily enforceable means of preventing the localized depletion of coral populations. Such local-based regulations are more likely to be successful if designed and implemented by Government together with coral collectors.

In addition to local level regulations, an effective management system will need to set export quotas appropriately. Ideally these would be based on information on the area of coral reefs, colony densities, individual colony growth, mortality and the annual recruitment of new colonies, its variability and relationship to the number of adult colonies. Given the difficulty of obtaining such information, a more feasible short-term alternative is to base quotas on monitoring of current population levels. Trends in the size and density of colonies of each species could be used to assess the sustainability of export quota levels. Although defining meaningful base levels for these indicators might be difficult, significant declines in either would suggest the need for reductions in the size of export quotas.

In the absence of such research or monitoring, the most appropriate approach is a precautionary one. In particular, quota levels should be related to what is currently known about population dynamics and abundance of the species, with those species that are least abundant and the slowest growing having the lowest quotas assigned to them. This does not appear to be the case at present. For example, *Acropora* and *Pocillopora*, both common and fast-growing genera, were assigned quotas of 30 600 and 2700 pieces, respectively, in 1997. In contrast, the less abundant genera *Euphyllia*, *Plerogyra* and *Trachyphyllia* were assigned quotas of 110 250, 51 300 and 70 650 pieces, respectively (Anon., 1997b). This appears to be contrary to the relative distribution of harvest levels that we would expect based on current knowledge about abundance and growth rates of these species (Table 6).

Table 6. Abundance[1] and growth rates of the coral genera most commonly exploited in Indonesia.

Source: [1]Based on descriptions in Veron, 1986. Abundance will vary with location, habitat and among species within the genus. Here it refers to density within distribution. Almost all the genera involved in the trade occur throughout Indonesia, so it is abundance within their range, which is of most concern.
[2]Linear growth rates in the Philippines, Gomez et al., *1985.*

Use	[1]Abundance	Growth Rate (cm/yr)[2]
Live export		
Euphyllia	uncommon	4.6 - 7.9
Goniopora	common	1.8
Catalaphyllia	uncommon	-
Trachyphyllia	common	-
Plerogyra	uncommon	1.4

Raw export		
Pocillopora	common	0.8 - 5.2
Acropora	common	3.0 - 18.1
Heliopora	common	-
Fungia	common	0.8 - 2.8
Tubipora	common	-
Mining		
Platygyra	common	1.3 - 1.3
Porites	common	2.8
Favia	common	1.4 - 2.3
Acropora	common	3.0 - 18.1
Favites	common	-

Although basing quota levels on published estimates of growth and abundance can provide guidelines in the absence of other information, it should be noted that these factors can vary considerably. Growth rates have been shown to vary within species, depending on aspects such as depth, sedimentation, location and morphological variants (Buddemeier and Kinzie, 1976; Van Veghel and Bosscher, 1995). Furthermore, there may be variation in abundance within a genus. For example, *Goniopora columna* is common and often forms large stands whereas other members of the genus, such as *G. stokesi*, are small and uncommon. This illustrates the need for management decisions to be based at the species rather than at genus level, and for more accurate collection of trade data.

As well as considering the state of coral stocks, a precautionary approach to quota setting may also be beneficial to the coral exporting industry in Indonesia. In particular, consideration of the worldwide supply and demand of corals may be worthwhile in determining quota levels. The prices that aquaria enthusiasts are willing to pay for coral specimens are often related to the species' relative rarity; prices in consuming countries can vary from week to week depending on their availability (O'Brien Shoup and Gaski, 1995). Because a reduction in the number of coral pieces available may increase their unit price, coral exporters may not necessarily suffer a reduction in total revenue if export quotas were reduced.

In this context, Indonesia could take advantage of its place at the centre of coral species diversity (Veron, 1993). Although species such as *Euphyllia* are widespread in the Indo–Pacific, others like *Catalaphyllia* are restricted to central Asia (Veron, 1993), and large-scale commercial collection of this species only occurs in Indonesia (O'Brien Shoup and Gaski, 1995). Indonesia is also home to endemic species (e.g. *Indophyllia macassarensis*). The increasing popularity of corals for aquaria means that collectors are seeking rare forms. But while this type of demand could be used positively to promote an export industry based on low volumes of valuable species, care must be taken that export quotas are adhered to and that smuggling of rarer species does not occur. According to anecdotal reports, black coral has already been severely overexploited in Indonesia and is in urgent need of attention. Generally, these species are slow growing and long lived, making them vulnerable to overexploitation. Grigg (1984) estimated a maximum sustainable yield of around six tonnes per year (equivalent to only about 3.5% of the biomass) from a bed of about 84 000 colonies of *Antipathes dichotoma* in Hawaii. In contrast to aquarium and ornamental pieces, a significant proportion of black coral collected in Indonesia appears to be consumed domestically. This may make exploitation levels more difficult to regulate.

Other impacts on coral reefs also need to be considered when assessing the potential effect of coral exploitation. Increased sedimentation caused by logging, soil erosion and dredging has been shown to have harmful effects on corals (Bak, 1978; Babcock and Davies, 1991). Nutrient enrichment caused by the increased use of fertilizers and land clearance may have similar effects (Tomascik and Sander, 1985, 1987a, 1987b; Hunte and Wittenberg, 1992). Activities related to expanding tourism can also have significant impacts on coral reefs (Rinkevich, 1995 and

references therein) as can destructive fishing techniques using dynamite and cyanide (Johannes and Riepen, 1995; Erdmann and Pet-Soede, 1996).

Where it occurs, coral mining probably has ecosystem impacts comparable to any of these other threats. In contrast, coral collection activities for the export of aquarium and ornamental pieces and for the making of jewellery, may be a relatively minor risk to the overall health of coral reef ecosystems. However, the impact of such activities on the abundance of certain species cannot be ignored. Effective setting and enforcement of exploitation levels will be required to ensure that these species can continue to contribute to the benefits that Indonesia derives from its coral reefs.

RECOMMENDATIONS

- In recognition of the environmental and economic impacts that can be attributed to coral mining activities, (a) Indonesian national and provincial governments should move towards banning large scale coral mining activities for the production of lime and seek to provide alternative forms of incomes for the communities involved; and, (b) the Indonesian Government should study the feasibility of providing alternative materials to replace smaller-scale exploitation for construction.

- The PHPA, in association with the AKKII and local government authorities, should consider the use of area-based limits on collection activities. This would augment the effectiveness of the current export quota system and prevent the concentration of coral collection activities in specific areas which can lead to localized depletion of aquarium and ornamental species.

- Appropriate research and monitoring by Indonesia's CITES Scientific Authority, LIPI, should be carried out on the stocks of coral species in trade in order that appropriate export quota levels are set.

- In order to ensure that the Indonesian coral export industry can be maintained into the future, a precautionary approach must be taken in the setting of export quotas: existing information on the abundance and population dynamics of coral species should be utilized in this regard and it should be recognized that even short term export earnings may not be adversely affected by setting quotas conservatively.

- In recognition of the vulnerability of black corals *Antipathes* spp. to overexploitation, regulations should be considered governing the collection and domestic sale of these species.

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