environmental guidelines for

coral harvesting operations

by
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Reef Coral Harvesting Operations

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Published in **April 1994**,
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Contents

Introduction

Healthy coral reefs play a major role in the economies of coastal and island countries, providing fish and other food for local people and visitors and recreation for tourists and SCUBA divers. Coral reefs form natural breakwaters that protect the shore from erosion by waves and storms.

Through the breakdown of the calcareous skeletons of plants, corals, molluscs and other animals that make up reefs, they provide sand which makes and replenishes white sand beaches. Reefs will therefore have an increasingly important role in protecting low-lying islands from sea level rise if the predicted effects of global warming take place.

Threats to the health of reefs are many. Even without the impact of humans, these ecosystems suffer many stresses, such as cyclones and storms, outbreaks of coral predators like the Crown-of-Thorns starfish, and disease.

In the past, reefs were able to recover from such impacts, but nearby human habitation and other impacts now intervene to slow or halt the recovery process. Siltation, sewage pollution, badly planned coastal development and tourism, damaging fishing methods and over-exploitation of fish and other reef resources all have degraded coral reefs.

Coral harvesting, unless carried out in a sustainable manner, can exert an additional pressure. It will always damage the coral reef habitat, and inappropriate removal of corals is likely to substantially degrade reefs.

So before starting a coral harvesting programme, the benefits of reefs must be fully considered and weighed against the projected benefits of a coral harvesting operation. If coral harvesting is to occur, it should not jeopardise other vital functions of a reef or increase the risk of damaging reef health. The income from ornamental corals for the curio trade or for marine aquaria may be **insignificant** compared to the value of reefs lost to fisheries, the tourist industry and protection of coasts and low-lying islands.

Corals are harvested for many purposes. These guidelines do not cover the harvesting or mining of coral sand for construction and for use in aquaria, or the harvesting of precious and semi-precious (black) corals. They also do not cover the many forms of coral and coral reef extraction that occur on a larger, more industrial scale. These include mining and dredging coral reefs and the removal of live coral heads or reef rock for building materials and aggregates. These extractive activities are enormously destructive to coral communities and coral reefs.

If such activities must be undertaken, guidelines on how to minimise damage are provided in the SPREP environmental impact assessment manual: *How to Assess Environmental Impacts on Tropical Islands and Coastal Areas* (Carpenter and Maragos, 1989), which is available from the East-West Center and the Asian Development Bank. *Guidelines to Environmental Impact Assessment in the South Pacific*, is also available from SPREP. A recent review of coastal construction impacts and guidelines on coral reefs is found in Maragos (1993).

These *Guidelines* address operations, or proposals for operations, which involve the direct removal of individual coral colonies for marine curios, aquaria, medicinal uses, traditional lime production and research. The *Guidelines* have been mainly written for Pacific island countries, but could also be of use in other developing countries where many of the same issues arise.

Good scientific knowledge on growth and reproductive rates is still lacking for most coral species, so scientifically based management plans cannot yet be prepared. The *Guidelines* therefore emphasise the precautionary approach. Management must be conservative and capable of immediate modification if problems start to arise, an approach called *adaptive management*.

If it is decided that regulated harvesting may take place, the *Guidelines* explain how harvesting can be carried out in a sustainable manner with the least environmental damage. The *Guidelines* do not provide all the information needed for every potential coral harvesting situation, but aim to advise government departments of the important considerations if coral harvesting is allowed.

Part 1 of these *Guidelines* gives **background information** on coral harvesting, biology and the management options now available. **Part 2** has **specific guidelines** for considering proposals for and (possibly) implementing programmes to sustainably harvest corals.

part 1:

Background information on coral harvesting, management and legislation

1. Uses of Corals

1.1. Marine Curios

A wide variety of reef corals are collected, dried and sold locally or exported as marine curios; others are exported dead to decorate marine aquaria. The most popular genera include *Acropora*, *Fungia*, *Pocillopora*, *Heliopora*, *Tubipora*, *Stylophora*, *Seriatopora*, *Pectinia* and *Pavona*.

In the Philippines, over 30 species are collected for curios. In Fiji, 56 species are collected, but 70% of the corals taken are in the genus *Acropora*; 90% of the species taken are fast-growing branching forms. In contrast, in Australia, few species are harvested and 70% of the harvest (for local sale) is *Pocillopora damicornis*.

World trade in corals for marine curios increased rapidly in the 1970s and 1980s, and has fluctuated wildly since then. An estimated 1.2-1.5 million pieces and an additional 500 tonnes of coral were involved in the ornamental coral trade in 1990, and illegal exports from the Philippines could make these figures higher.

USA is the main consumer, accounting for 70 to 90% of imports. Other significant coral importers are European countries and Japan. US imports in 1988 were a record 1456 tonnes (a small proportion of which is probably coral sand), having risen from an annual average of about 200 tonnes in the 1960s.

The Philippines was one of the main suppliers, despite legislation since 1977 banning collection and export (apart from brief periods in 1986 and 1992 when the ban was temporarily lifted). Much recent Filipino trade

has been carried out using forged permits (Mulliken and Nash, 1993). In 1988, USA illegally imported about 600 tonnes from Philippines (illegal under Philippine law and under the US Lacey Act - *see section 4 - Legislation*).

The other major supplier is Indonesia. US imports from this country rose from negligible amounts in the early 1980s to nearly 480 tonnes in 1988 (Wood and Wells, 1988; Wells and Wood, 1989). By 1990 over one million pieces of coral were exported.

Fiji is the only regular supplier of coral from the Pacific. The majority of Fiji's exports are destined for USA for decorating aquaria. US imports from Fiji increased from 54 tonnes in 1985 to 133 tonnes in 1988. In 1991, 70,895 pieces were imported into USA from Fiji.

New Caledonia was a major supplier in the late 1980s, exporting brain corals (Faviidae) that had been shaped on a lathe as art objects or lamp bases. However, exports of corals as marine curios dropped from 120 tonnes in 1989 to zero in 1991, largely because the only exporter left the country.

Several other countries in the Pacific have temporarily exported coral for this market. Commercial harvesting started in Western Samoa in the late 1980s (about eight tonnes were exported to the US in 1989) but this has now ceased. Vanuatu exported corals in 1991 and 1992 through a New Zealand company, but this operation has also ceased. A small amount of blue coral, *Heliopora*, was exported from Kiribati to the US by a Fiji exporter, as this species is not found in Fiji. Statistics show that Kiribati exported over 12,000 pieces of coral in 1990. The Marshall Islands exported 18 tonnes in 1990, and the Solomon Islands exported about six tonnes to the US in 1991. There have also been some exports from Pohnpei Island, Federated States of Micronesia, and Tonga.

Small-scale harvesting probably takes place in most Pacific island countries to supply local tourist demand. On some islands, corals are imported for sale to tourists. For example, most coral on sale in Hawaii and Fiji comes from the Philippines and Indonesia.

1.2 *Live corals and live rock for marine aquaria*

Dead corals have been used for many years to decorate private and public aquaria. Recently, however, there has been a dramatic increase in the use of live corals for this purpose. This is because of new, simple technology to maintain tropical organisms or "mini-reefs" in tanks. The main corals used are *Catalaphyllia*, *Euphyllia*, *Goniopora* and *Favites* (Carlson, 1987; Adey and Loveland, 1991).

The main suppliers of live coral are Indonesia, followed by Haiti, the Philippines, Singapore, Sri Lanka and Taiwan. Fiji exported over 12 thousand pieces of live coral in 1991, Tonga exported nearly 6 tonnes that year, and Kiribati exported just over 2,000 pieces of live coral in 1990. Other Pacific island countries have been approached by prospective importers.

USA and European countries are the major importers, USA importing over 345,000 pieces of live coral in 1991, compared with only 40,000 pieces in 1988. By 1991, live coral was one third of the total US coral imports (Mulliken and Nash, 1993).

Trade in "*live rock*" has also grown dramatically in recent years. Live rock is loose coral rubble or chiselled-off pieces of coral limestone with marine organisms attached. This material provides a more natural environment for reef animals, is decorative, and has an important role in mini-reef tanks as a natural filtering system (Carlson, 1987; Wheaton, 1989). It is collected in large quantities in Florida, where nearly 390 tonnes was harvested in 1992, but USA is also reported to import live rock from other countries.

It should be noted that despite the enthusiasm of aquarium hobbyists for keeping live corals and live rock, there is now a wide variety of artificial corals, made from a range of materials, available to decorate tanks.

1.3 *Medicinal uses*

Reef corals are used in bone graft operations to replace sections of damaged bone. In time, new bone grows over the template provided by the coral. The advantage of coral implants over bone implants, which is the technique usually used, is that the human immune system does not seem to recognise coral as foreign material and so does not reject the implant.

This technique has been used in Europe and Asia since 1982. Thousands of people have had such operations for severe bone fractures, cancer of the bone and other problems (Hodgson, 1989).

Several biomedical companies import corals for this purpose, notably from New Caledonia and, in 1988, from Tonga. The most useful genera are *Goniopora* and *Alveopora*, and species which form massive rounded heads from which blocks can be cut. New Caledonia exports *Acropora*, *Porites* and *Lobophyllia* for this purpose. Only small quantities of coral are required - New Caledonia exported less than one tonne in 1992.

Many reef animals may contain substances of potential biomedical interest. A growing number of research institutions and pharmaceutical companies are looking at appropriate species. Most potential lies with sea fans, soft corals and sea whips, with lesser interest in stony corals. However, work carried out in Australia on the pigments in coral tissues that protect the animals from intense UV radiation suggests that these could have applications in sun creams for humans.

1.4. Lime production for traditional uses

In Pacific island countries such as Papua New Guinea, Palau and the Federated States of Micronesia, stony corals are harvested and burnt to make lime for chewing with betel nut. Whole coral skeletons, often of *Acropora*, are burnt in kilns or ovens. For example, on Yap, up to one pound (half a kilo) of lime is used by an average betel nut consumer each week. The total demand in the state has been calculated at 130 tons a year (Maragos, 1990).

1.5. Research

Many coral reef scientists need to remove specimens of live coral for further studies in laboratories and universities. The amounts of harvested coral are usually small, and the removal should always be conducted using required procedures. The results of the research may bring long-term benefits to all those dependent on reefs; a better understanding of the biology of corals will enable better management strategies for the reef.

Box 1

Types of Coral

The word "coral" is loosely applied to a range of different animals in the phyllum or group of animal called Coelenterata (or sometimes Cnidaria).

Hard or stony corals are the main reef-builders. These form the basic framework of a coral reef. They have hard external skeletons of calcium carbonate, which are formed by the many tiny coral animals, or *polyps*, that form a coral colony. Reef building, or *hermatypic*, corals have symbiotic algae, or *zooxanthellae*, in their bodies which allow them to grow faster than other stony corals living in reefs.

There are about 700 species of reef-associated corals. They are grouped under these scientific names:

Order **Scleractinia** - stony corals.

Order **Coenothecalia** - blue coral, e.g. *Heliopora coerulea.*

Order **Athecata**

Family Milleporidae - fire corals, e.g. *Millepora spp.*

Family Stylasteridae - lace corals, e.g. *Stylaster spp* and *Distichopora* spp.

Order **Stolonifera**

Family Tubiporidae - organpipe coral, *Tubipora musica.*

The order **Scleractinia** contains most of the reef-building corals. The orders Coenothecalia and Stolonifera each contain only one reef-building species, blue coral and organpipe coral respectively.

The order **Athecata** has many coral species, but most of these do not have the appearance of stony corals, and so are not traded. Exceptions are the fire corals *Millepora*, which are true reef-builders, and the lace corals *Stylaster* and *Distichopora.*

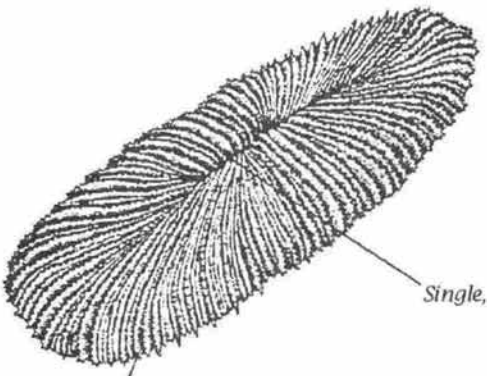
Two types of coral are used extensively for jewellery, but they are not discussed as they do not form a structural part of the reef. Black corals (order Antipatharia) grow in tropical waters, often on reefs. They have a flexible, internal skeleton made of a horny non-calcareous material which can be polished to look like a fine gemstone. The beautiful pink and red "precious" corals are in the order **Gorgonacea**. They are not found on reefs but occur in cooler, mostly deeper waters, in large beds on the sea bottom or attached to rocks.

Many other animals that live on coral reefs go by the name of corals, such as the soft corals and false corals, but these are rarely collected and are not discussed here.

Order Scleractinia
Family Fungiidae

Fungia spp.

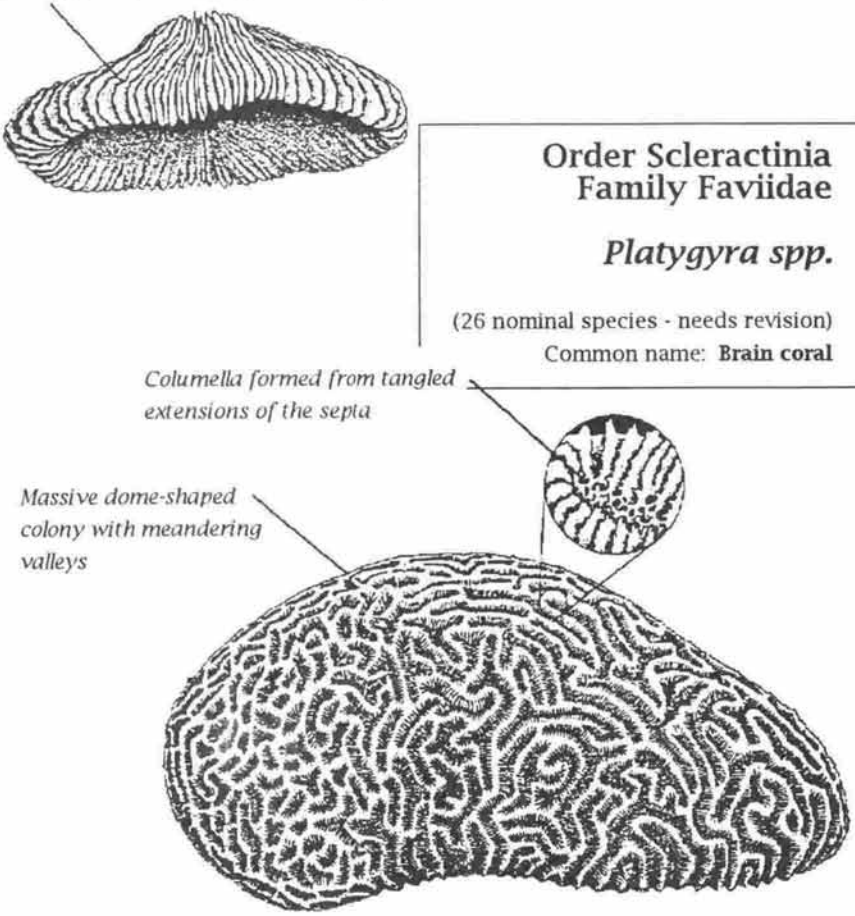
(approx. 22 species)
Common name: **Mushroom coral**



Order Scleractinia
Family Faviidae

Platygyra spp.

(26 nominal species - needs revision)
Common name: **Brain coral**



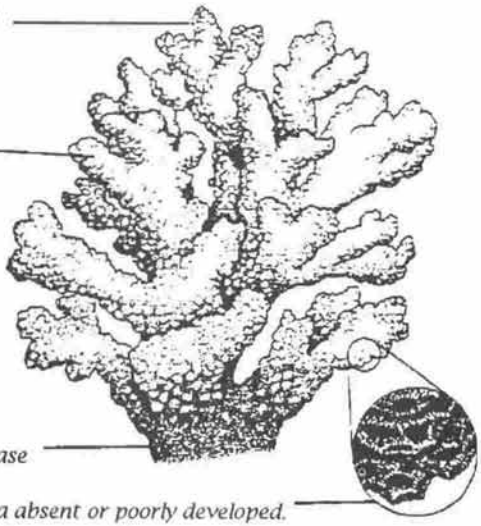
Branching produces 2 or more equal branches with no clear central axis.

Branches covered in small bumps.

Order Scleratinia
Familly Pocilloporidae

Pocillopora spp.

(7-10 species)
Common name: **Brown Stem coral**



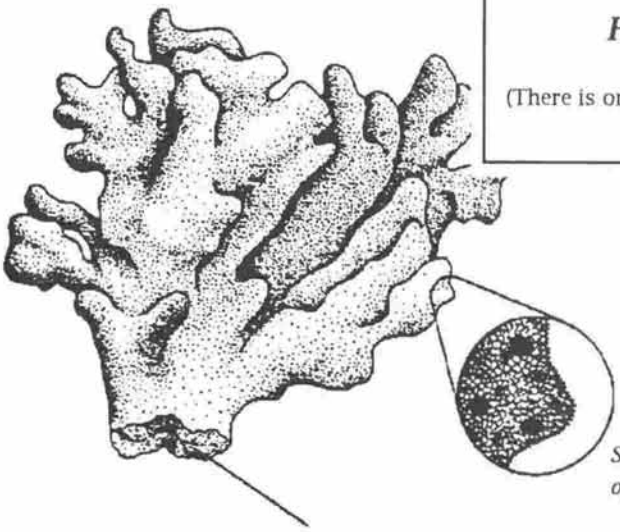
Deep chocolate brown colour near base of branches.

Septa absent or poorly developed. Corallites resemble empty pits.

Order Helioporacea
Family Helioporidae

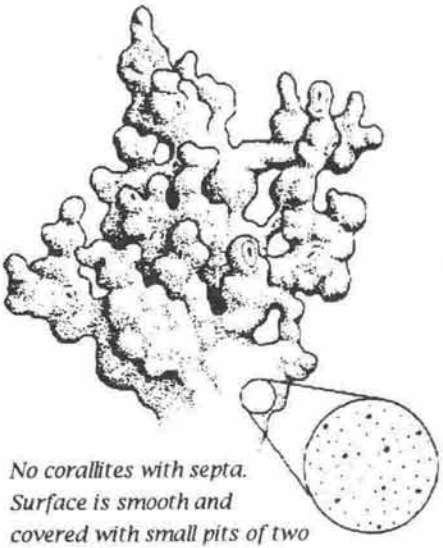
Heliopora coerulea

(There is only one species of *Heliopora)*
Common name: **Blue coral**

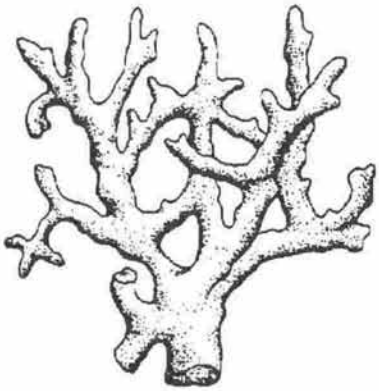


Surface covered in small pits of different sizes.

Broken surface is blue.



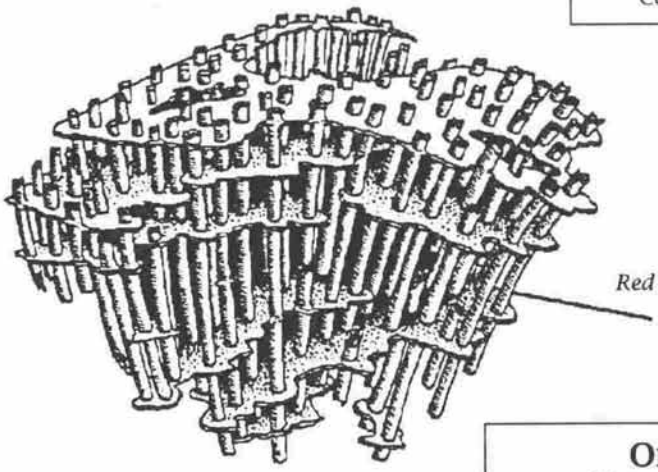
No corallites with septa. Surface is smooth and covered with small pits of two different sizes.



Order Milleporina
Family Milleporidae

Millepora spp.

(about 10 species)
Common name: **Fire coral**



Red skeleton composed of vertical tubes and horizontal sheets.

Order Stolonifera
Family Tubiporidae

Tubipora musica

(There is only one species in *Tubipora*.)
Common name: **Organ Pipe coral**

2. Damage caused by coral harvesting

2.1 Damage to reef framework

Stony corals are the main reef-builders and form the basic structural framework of a coral reef. Coral harvesting, therefore, removes the living animals responsible for forming the reef, and reduces the reef's ability to recover from cyclones, pollution, ship groundings, tourist pressure, and coastal development. Damage to a reef that forms a natural breakwater may lead to more coastal erosion, and deterioration of the aesthetic qualities of the reef may affect its value to the tourist industry.

Reduction in coral abundance and live rock, which is essentially the basis of the reef, also reduces the habitat available for fish and other reef animals, many of which are important for local or commercial fisheries. Carpenter et al. (1981) found that, in the Philippines, there were more fish where there was a greater cover of live stony coral.

Unless great care is taken while harvesting corals, other non-target coral and other organisms may be damaged. Standing on and touching corals can harm the live tissue of a colony. This further weakens the animals and may encourage the spread of disease and attract coral predators such as the Crown-of-Thorns starfish. Careless use of crowbars and other pieces of equipment can also break or kill non-target animals.

2.2. Over-exploitation of coral populations

Corals usually grow very slowly, although there are distinct differences between species. In general, corals that form branching colonies grow more quickly than those forming massive rounded colonies. Species of branching *Acropora* may grow at 10 to 20 cm per year, while massive corals such as *Montastrea* and *Platygyra* may grow only 0.4 to 2.0 cm per year (Buddemeier and Kinzie, 1986).

Corals also take several years to decades to colonise and re-establish new adult colonies and mature communities (Grigg and Maragos, 1974; Pearson, 1981). Any long range management schemes for the harvesting of corals from specific reef sites must account for the normally slow rate of colonisation and recovery of coral colonies.

These factors, combined with their immobile nature and their restriction to shallow waters, means that corals are vulnerable to over-collection. On a Philippine reef subject to coral collection, colonies of species that were harvested were less abundant and smaller than on an adjacent reef where there was no collection (Ross, 1984). Six more commonly-collected species declined in abundance (in

colony density and % reef cover) by over 70%. Long-term collection of immature colonies may have explained the near absence of one genus (*Seriatopora*) and the low abundance of another (*Fungia*).

In New Caledonia, harvesting massive corals (Faviidae) in the late 1980s was estimated to be twelve times the sustainable yield. It was found that an exploited area of reef did not start to recover for five years (Joannot, 1990; Joannot and Bour, 1988). Massive species such as brain corals are particularly vulnerable to collection because of their slow growth or colonisation rates.

Coral harvesting is, however, unlikely to easily cause many species extinctions. Corals often have a wide distribution and may be found on reefs over large areas of the Indian and Pacific Oceans. Nevertheless, some species have quite restricted distributions, or occur in very small scattered populations. Some coral species are endemic to reefs around particular islands (e.g. Hawaii); others are found in a restricted area such as some eastern Pacific species.

Collection of species with small ranges obviously poses a greater risk; the coral trade in Costa Rica could be a threat to some of the eastern Pacific species (Guzman, 1991). Since the full distribution of many species is unknown, particular care is needed when collecting species that appear to be rare.

2.3 *Mortality of live corals in aquaria*

Live corals can be very difficult to keep in captivity, and there have been strong recommendations that they should not be harvested for the home aquarium trade because of wastage. It is thought that 50% of the corals collected may die between collection and reaching retail shops (Wood, 1992; Vallejo, pers. comm.).

Unfortunately, comparatively little research has been carried out on the species involved in the aquarium trade and the results that have been obtained to date often appear confusing. A study of 30 aquaria ranging in size from 33 to 180 gallons (125 to 680 litres) showed that most corals, particularly stony corals, survived for only a few days, to a maximum of six months (Bacquero, 1991). However, marine biologists and experienced private and public aquarists have maintained corals in tanks over longer periods, provided appropriate conditions, particularly water quality and light intensity, are maintained (Carlson, 1987; Adey and Loveland, 1991).

The species that appear to be best adapted to aquaria are those collected from back-reef areas, lagoons or deep fore-reef environments well below the effects of surf, i.e. from calm waters that most closely match the artificial conditions of an aquarium. In some instances, corals taken from disturbed nearshore A

reefs, where the environmental conditions are already stressed, seem to grow best.

Corals with large polyps - e.g. *Goniopora*, *Plerogyra*, *Heliofungia*, and *Catalaphyllia* - survive better than those with small polyps, as do free living species such as *Fungia* and the "polyp balls" produced by *Goniopora* (Carlson, 1987; Yates and Carlson, in press). Some aquarists have found that some species of *Acropora* survive well, perhaps because they break up easily (Yates and Carlson, in press), but others have found that it is difficult to maintain in tanks, particularly if Caribbean species are used (Jaap *in litt.*, 1993).

3. Management approaches

3.1. No harvesting

Little detailed information on factors such as coral growth and colonisation rates, species distributions, and aquarium survival rates is available. This is needed to develop sustainable coral harvesting programmes. without this information, a precautionary approach is essential.

Until sustainable methods for exploitation - methods that give both a sustainable yields and also do not damage the habitat - can be demonstrated, a ban on coral exploitation should be considered, particularly on coral harvesting for certain purposes.

The ornamental curio trade services a purely luxury market, unlike many other forms of reef exploitation. Many people buy corals as cheap souvenirs - bought on a whim and discarded as rapidly - or as expensive *objets d'art*, and are unaware of the animal origins of corals.

As mentioned above, good artificial corals, replicating actual species, are now available for aquarium hobbyists which should replace some demand for live corals. However, for those keeping mini-reefs, a major goal is to maintain live corals as part of the reef ecosystem.

number of countries have now legislated to ban the collection and export of corals (see *section 4 - Legislation*).

3.2 Sustainable yields

It is possible to estimate sustainable yields for corals (Grigg, 1984), if certain basic data are available. Both maximum sustainable yields and optimum yields have been calculated for the precious corals and black corals in Hawaii, and for precious corals in other areas. These studies could provide valuable models for stony corals, as they have similar life histories to precious corals, being slow-growing, long-lived and having low rates of recruitment and mortality.

Grigg used the Beverton and Holt Fishery Model (Beverton and Holt, 1957). For any species, this model needs information on distribution and abundance, growth rate, and rates of mortality and recruitment; age at reproductive maturity is also useful. Unfortunately, this information is available for very few stony corals in very few areas.

Grigg (1984) showed that the model could be used to predict levels of maximum sustained yield for the stony coral *Pocillopora verrucosa* in the Philippines. The minimum size of a colony for harvest was calculated to be 18 cm height - about six years old. This is the generally

preferred size for Philippine collectors. Generally, colonies of 12 to 50 cm (5 to 20 inches) diameter are preferred in the marine curio trade.

There may be other ecological reasons for implementing size limits. Some species, such as blue coral and several brain corals, develop large colonies. If they develop in shallow water, these are sometimes called *micro-atolls*, as they form rings of living coral. These may play a very important structural role on the reef. A maximum size limit on collection for these species may ensure that the largest colonies are left in place.

Other species may benefit from minimum size limits. Colonies of *Pocillopora*, *Fungia*, and some species of *Acropora* may never grow very large, and would benefit from restrictions on the collection of smaller colonies. However, further work is needed to develop firm guidelines.

The amount of coral that could be taken sustainably from reefs on the Great Barrier Reef has been estimated, using information obtained in the Galapagos for the branching coral *Pocillopora damicornis* (Glynn *et al.*, 1979). It was assumed that natural coral cover on the Great Barrier Reef is 10%, which led to the estimation that eight tonnes of coral could be taken annually from an area of reef 4000 sq m - just under 0.5 hectare (Oliver and McGinnity, 1985). This figure is very similar to the actual amounts taken by Australian collectors, and no further management action has been taken on the Great Barrier Reef.

In New Caledonia, a maximum sustainable yield of 15.5 tonnes a year has been calculated for faviid species on a reef covering 1,300 ha. This is markedly lower than the yield calculated for the fast-growing branching species in Australia (one tonne per c. 800,000 sq m, compared with one tonne per 500 sq m), This clearly shows how important it is to carry out specific site and species studies.

Coral harvesting in New Caledonia is limited to a section of the back area of only one reef, and is operated under a permit system and monitored by the Aquarium of Noumea. However, actual harvest rates in the late 1980s were calculated to be twelve times greater than the sustainable yield (Joannot and Bour, 1988).

Better information is needed for several basic aspects of coral biology - such as larval and adult recruitment, settlement, growth and natural mortality - before management strategies based on sustainable yields can be developed for most reefs. However, where there is enough funding and technical expertise is available, this is clearly the prefered approach if coral is to be harvested.

3.3 *Regulated harvesting*

With little information on sustainable yields, the best approach may be to establish conservative guidelines that exert maximum control. The system in Fiji is a good example of this, where harvesting is carried out under a set of voluntary guidelines approved by the Cabinet, although exports need CITES permits. Annual field monitoring has shown that less than 5% of live coral cover is removed by harvesting operations.

It is recommended that if live coral cover is reduced by more than 5%, harvesting should be reduced (Lewis, 1985; Viala, 1988). The guidelines in Part 2 of this document draw heavily on this system.

Management needs for particular collecting areas in Fiji are determined through discussions between the collector and the Fisheries Division. Baseline surveys are carried out before any new area is harvested. The exporter trains villagers to recognise the desired species. Coral colonies are removed using a steel bar about 2 cm in diameter and 0.75 m long, sharpened to a chisel point at one end.

After drying, the corals are selected by species, measured, recorded and packed, using old newspapers, into wooden crates (50 x 50 x 75 cm). Exporters - currently there is only one - must have a permit. There is a maximum annual quota of 100,000 pieces a year, which is not reached at present. Exporters must supply a full list of the species exported.

Collectors in Fiji are required to use outer fringing reefs and inner lagoon reefs rather than inshore reefs which are more affected by run-off and are likely to regenerate more slowly. Collecting is spread out and does not focus on one site, and exporters are encouraged to shift areas as often as possible.

The concept of rotating fishing and harvesting areas fore non-coral species, to allow exploited populations to recover, has been a customary practice in some parts of the Pacific for many years, and is a standard procedure in the management of the precious coral fishery (Grigg, 1984).

However, on the Great Barrier Reef, collecting reef resources is permitted on only a few reefs. This philosophy is based on collectors having an incentive to maintain the health of the reef as they have the rights to exploit the reef and so will be less likely to damage or over-harvest the resources.

In Fiji, the use of SCUBA gear is forbidden by collectors. This is largely to ensure that collectors from villages over a wide area can participate, and who can probably only afford to invest in a mask and snorkel. Commercial divers could easily out-compete villagers and the

industry would rapidly become large-scale.

Under some circumstances, SCUBA gear may be better as it may limit damage to target and non-target specimens. However, it could also increase damage to non-target organisms through careless use of equipment and collection of other resources, especially species in deeper water that were previously inaccessible.

3.4 Reducing wastage and maximising economic returns

One important factor in sound management of coral harvesting is to minimise damage to non-target corals and other reef organisms during collection, and to minimise breakage and damage of specimens during collection, transportation and export. The guidelines in Part 2 advise on how it is possible to minimise this damage.

It is also important to maximise economic returns to the local people, who need the additional income. In Fiji, traditional custodians of the reef are involved to the maximum extent practicable. For example, the exporting company must use villagers to do all collecting. By moving the collecting area regularly and thus using different fishing rights areas, different village collectors can benefit. Corals should be processed locally, focusing on local production to increase the coral's value. Sales should first be local so that profits go directly to the community.

Exported corals with minimum 'working' have the lowest value. If corals are harvested, it may be more profitable to develop a handicraft industry based around these and other sustainably harvested products.

3.5 Farming corals and restoring reefs

Corals reproduce sexually by

- *spawning* - the release of eggs and sperm into the ocean where fertilisation takes place - or *brooding*; and,
- asexually by *budding* and *fragmentation* - the formation of a new colony from the old one.

Although some public aquaria have induced coral spawning in tanks, this is still difficult to achieve in private aquaria. Fragmentation is easier, but the slow growth of most species means that farming corals for the marine curio trade is unlikely ever to be feasible.

However, research in public aquaria suggests that it might eventually be feasible to supply the live coral trade with cultured corals, particularly soft corals such as *Sarcophyton* and *Xenia*, and fast-growing *Acropora*.

Colonies would have to be grown on easily recognisable artificial substrates or within designated plots to prove that they had not been collected in the wild.

If successful, this could lead to the phasing out of wild-harvested specimens for aquaria, and research into this should therefore be encouraged. Several other reef species popular for aquaria, such as the 'false' corals *Rhodactis* and *Actinodiscus*, reproduce well in captivity and would be suitable for culture. Trials are also underway in Florida to culture live rock, using fossil coral or cement substrate on to which benthic fauna and flora settles.

It is possible, however, to speed up the regeneration of an exploited reef and improve maintenance of coral populations by planting small pieces or "cuttings" of corals. Depending on species and location, transplanting small pieces of stony coral can give 50-100% success rates (Maragos, 1992; Harriott and Fisk, 1988; Yap and Gomez, 1988; Guzman, 1991; Yap et al., 1992). Transplantation is perhaps potentially most useful in aiding reef recovery from local impacts such as ship groundings, but it may be of some value in harvesting corals. Since results are highly variable with different species, more studies are needed.

3.6. Marine protected areas

Many countries have marine protected areas where collecting any living organisms, including corals, is banned. These areas protect breeding populations of corals and other organisms which can replenish areas that are depleted by harvesting. Establishing marine protected areas is important for any marine resource management programme. Guidelines and information on their establishment and management are given in Salm and Clark (1984), Kenchington and Hudson (1988), Carpenter and Maragos (1989), Roberts and Polunin (1991) and Kelleher and Kenchington (1991).

4. Legislation

4.1. International legislation

All stony corals (Orders Scleractinia and Coenothecalia, families Milleporidae, Stylasteridae and Tubiporidae) are listed in Appendix II of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

Although many of the listed species are very abundant and widespread, all reef corals are listed because individual species are extremely difficult to identify. This would present customs officers with major problems in idenfying individual species.

Appendix II listing does not ban trade. Rather, it means that countries that are party to CITES may only accept imported reef corals if they are accompanied by a valid export permit from the country of origin, or a re-export certificate if not coming from the country of origin.

These regulations allow the monitoring of the international trade through a permit system, and oblige importing countries to honour national legislation such as export bans in exporting countries. CITES export permits for corals should not be issued in countries where coral collection and export is prohibited.

Import and export permits are issued by the CITES Management Authority of the country concerned. CITES regulations apply to scientific as well as commercial specimens, unless the scientists or scientific organisations have been registered for non-commercial exchange of specimens by the CITES Management Authority of their own country. Permits are also required for the export of souvenirs by tourists, if purchased in the country of origin. Some countries, such as all European Union member states, have stricter measures and require an import permit as well as an export permit before an import can take place.

At the time of publication, Papua New Guinea, Vanuatu and some of the overseas territories of USA and European countries are the only parties to CITES in the Pacific islands region. Nevertheless, countries that are not party to CITES may still be required to issue appropriate permits. For more information on CITES and its role in controlling trade in marine species, consult Wells and Barzdo (1991) and MCS (1992).

4.2 National legislation

Collecting and exporting reef corals is now prohibited or restricted in some 30 countries worldwide. A few Pacific countries have legislation which specifically mentions corals:

Australia

Collection in the Great Barrier Reef Marine Park is regulated by both Commonwealth and State legislation; it is restricted to licensed areas of the reef front (about 400 m long). Additional permits are required from the Great Barrier Reef Marine Park Authority if the licensed areas fall within zoned sections of the Park; commercial collecting is only allowed in zones designated for general use.

Federated States of Micronesia

In Kosrae State, draft regulations have been drawn up and should soon be approved. They state that live coral may not be collected without written authorisation from the Director of the Department of Conservation and Development.

Guam

Live coral may not be removed from depths of less than 10 fathoms, and corals may be collected only with an appropriate permit.

Hawaii

Harvesting of live corals in the order Madreporaria and any rock with marine life attached is prohibited under state law, unless a scientific permit is issued.

New Caledonia

Commercial coral collection is authorised on Tetembia reef only. Fourteen genera and the family Faviidae may be collected under permit. Exploiting other corals here, and in other areas is prohibited. There is an annual quota of 30 tonnes for the family Faviidae, and for these corals, colonies of less than 25 cm diameter may not be taken.

Coral harvesting of all species is prohibited between 1st October and 31st December. Non-commercial coral harvesting is permitted for the genera *Acropora* and *Fungia* only; fragments of *Acropora* must not exceed 300 gm in weight.

Philippines

Collection and export has been banned since 1977. This prohibition has been periodically lifted for a few months at a time.

USA

(This is in addition to specific information for the US Pacific areas listed separately)

Corals are listed on the Lacey Act, a Federal Law prohibiting the import of listed wildlife illegally collected or exported from its country of origin. State laws cover the harvesting of marine resources within state waters, usually up to 3 nautical miles from the coast.

Vanuatu

Coral trade is regulated by the Fisheries Act 1982 and subsequent Fisheries Regulations order No. 49 1983. No person shall take more than three pieces of living coral in any period of 24 hours, except with the permission of the Director of Fisheries. No coral may be exported without the written permission of the Minister of Fisheries.

Part 2 of these *Guidelines* includes outlines for the ***contents of appropriate legislation*** that could be drafted to regulate coral harvesting.

part 2:

Guidelines for evaluating and managing coral harvesting

These *Guidelines* provide steps for evaluating proposals, and possibly implementing programmes, to harvest corals. Overall, ***it is strongly recommended that coral harvesting not be allowed.*** Coral harvesting must be considered in the context of the general management of tropical marine resources. General marine resource management guidelines are found in Kenchington and Hudson (1989), Carpenter and Maragos (1989) and Salm and Clark (1984).

The specific ecological and socio-economic conditions of the country and island for coral harvesting should also be considered.

These *Guidelines* cannot provide all the information and answers needed for every potential situation, but they aim to advise government departments on the important issues to be considered when proposals to harvest corals are made.

The *Guidelines* consist of:

Section 1: Describes how to evaluate whether a proposal should go ahead.

Section 2: Outlines issues to be covered when policy and legislation is developed and drawn up to prohibit or regulate coral harvesting.

Sections 3,4,5: Describe how coral harvesting can be regulated.

Section 6: Describes collecting and handling methods that are appropriate and cause minimal environmental damage.

Section 7: Describes the points to be considered in setting up a permitting system.

Section 8: Outlines monitoring methods that should be used to follow any changes on reefs that could be due to coral harvesting.

1. Evaluating coral harvesting proposals

1.1 Evaluate the purpose of the proposed coral harvest

1.1.1 Do **NOT** allow *live* coral harvesting for:

- construction materials; and,
- production of lime for commercial uses.

1.1.2 Limited, regulated and sustainable harvesting of live coral and live rock may be considered for:

- local processing, sale and export as marine curios,
- local processing and export for medicinal purposes,
- export of live corals and live rock for aquaria, and
- production of lime for traditional uses (e.g. for chewing with betel nut).

1.2 Assess the value and viability of the proposed coral harvest, accounting for environmental, economic and social costs and benefits to the local community.

1.2.1 Environmental costs and benefits. For example, will coral harvesting:

- reduce the ability of the reef structure to withstand storms, respond to sea level rise and produce sediments which create beaches?

1.2.2 Economic costs and benefits. For example, will coral harvesting:

- provide jobs for a wide range of local people (collectors, packers, village-level handicraft processors) and increase their income? or,
- provide income to only a few individuals, or to middlemen and firms based outside the local area or abroad?
- generate local tax revenue?
- interfere with fishing activities or reduce catches of commercial or subsistence fish, shellfish and other reef resources by degrading the habitat?
- reduce tourist income by making the reefs less attractive?
- require capital investment in expensive equipment such as special holding tanks and packing facilities for the live coral trade?

1.2.3 Social costs and benefits. For example, will coral harvesting:

- conflict with other conservation measures that the government is trying to introduce?
- give a bad image, for example, to tourists?
- result in social unrest due to uneven distribution of the proceeds if some villages have access to reefs that are better collecting grounds?

2. Developing coral harvesting policy and legislation

*2.1 **Hold public meetings with local communities and resource users to explain the issues and the areas proposed for coral harvesting, and ask for input and comments from those affected.***

*2.2 **Incorporate public comments and suggestions, holding further public meetings as necessary.***

*2.3 **Seek scientific advice; help can be obtained from a number of institutions in the region including the South Pacific Regional Environment Programme (Western Samoa), University of the South Pacific (Fiji), East-West Center (Hawaii), the University of Guam, and Universite Francaise du Pacifique (Tahiti).***

*2.4 **If coral harvesting and/or export is to be prohibited:***

2.4.1 Consider whether there should be exceptions to a harvesting ban, e.g. for traditional purposes, medicinal use or research.

2.4.2 Consider whether there should be exceptions to an export ban, e.g. for medicinal use, research or live corals for public aquaria.

2.4.3 Ensure that any exceptions will not provide loopholes for unregulated harvesting.

2.4.4 Inform the CITES Secretariat of any bans. Parties to CITES will then be notified that the country has enacted stricter controls than those

required under CITES and parties will be requested to take account of this when authorising imports.

2.5 If limited, regulated coral harvesting is to be allowed:

2.5.1 Identify the lead agency responsible for managing the programme, and any other agencies involved, clearly establishing their roles in issuing permits, monitoring, and so on.

2.5.2 Set up a joint venture agreement between the prospective coral harvester or exporter and local owners, companies and the government, to ensure that economic benefits accrue locally.

2.5.3 Establish a budget through for training, developing necessary infrastructure, enforcement, etc.

2.5.4 Seek scientific advice for developing the programme, carrying out the Environmental Impact Assessment (EIA), and monitoring harvesting.

2.5.5 Decide how harvesting will be regulated. Controls may be imposed by restriction of one or more of these:

- total area or number of areas where corals may be harvested (Section 3);
- species and sizes of colonies to be harvested (Section 4);
- amount - i.e. numbers or weight of colonies - to be harvested, by a quota system (Section 5); and,
- number of collectors and exporters, limiting entry into the local market (Section 7.2).

2.6 Once the decision has been made on whether to ban or allow regulated coral harvesting, appropriate legislation must be drafted. Where limited, regulated harvesting is to be permitted, legislation must:

- specify the responsible agencies;
- require an EIA to be carried out before harvesting is approved;
- require joint venture or local ownership, and account for customary tenure of reefs;
- require a permit for harvesting and export, and establish fines and penalties for violation;
- identify the areas or types of areas where harvesting is permanently banned;

- specify the species, sizes, weight and numbers of colonies to be harvested;
- specify the harvesting methods to be used; and,
- require regular monitoring.

3. *Areas for coral harvesting*

3.1 ***Undertake a preliminary field survey of proposed harvest areas, and obtain detailed information on their characteristics, especially coral abundance and the size class distribution of colonies (i.e. the numbers of colonies in different size groups for each species).***

3.2 ***Undertake a survey of marine resource use in proposed harvest areas and obtain information on existing and potential uses, e.g. fisheries and tourism.***

3.3 ***Carry out public and community reviews of proposed harvest areas, including any alternative sites suggested during the evaluation.***

3.4 ***Do NOT permit harvesting in these areas:***

- existing or proposed marine protected areas;
- unique or critical coral reef habitats (e.g. reef fish spawning areas, and turtle nesting or feeding areas);
- reefs with unusually low coral cover for the area;
- existing or proposed sites for tourist use (e.g. for diving, snorkelling, or glass-bottom boat tours);
- traditional fishing areas if the owners object to coral harvesting;
- areas associated with myths, legends or traditions;
- reef areas already subject to human and natural stress (e.g. nearshore fringing reefs near ports, sources of run-off and outfalls); and,
- outer ocean slopes during periods of potentially dangerous wave action.

3.5 *Areas to be considered for harvesting include:*

- reef areas that, following an EIA, are to be legally dredged, reclaimed or otherwise altered or destroyed;
- areas with a high cover of live hard coral;
- reefs where larval recruitment is expected to be good (e.g. down-current from a protected coral reef);
- outer fringing reef, lagoon patch reefs and lagoon slope barrier reefs; and,
- outer ocean reef slopes without potentially dangerous wave action.

3.6 ***If harvesting must be regulated by limiting the number of permitted areas, identify these and designate the boundaries - harvesting areas should be of a size to enable them to be surveyed and monitored using local resources.***

3.7 ***Consider establishing a marine protected area where coral harvesting is specifically prohibited up-current of any proposed coral harvesting area to encourage coral recruitment.***

3.8 ***If information is available on the spawning time of the corals to be harvested, prohibit exploitation during this period.***

(e.g. In New Caledonia, the reproductive period is at the beginning of the austral summer, and so harvesting is prohibited from 1 October to 31 December).

4. Types and sizes of corals to be harvested

4.1 ***Seek scientific advice on species that are particularly rare in the country, and prohibit their harvest.***

4.2 ***Restrict harvesting to species which are abundant***

- in the general area; and,
- in the specified harvesting site.

4.3 ***Restrict harvest to the species, genera, growth forms and sizes preferred by the companies proposing coral harvesting, accounting for restrictions in 4.1 and 4.2 above:***

4.3.1 For marine curios, robust species are required - fast growing species with rapid recruitment are prefered, as their populations will recover more quickly.

4.3.2 For live aquarium coral, species that can survive transport and aquarium life are required - these may include free-living species (e.g. mushroom corals *Fungia*) and species with unattached colonies (e.g. *Goniopora* polyp balls), large polyps (e.g. *Plerogyra*) or which fragment easily (e.g. Indo-Pacific species of *Acropora*).

4.3.3 For other uses of harvested coral (e.g. medicinal and traditional) there will be specific requirements which should be identified.

4.3.4 Encourage harvesting of diseased or recently killed corals (e.g. due to bleaching or predation by Crown-of-Thorns) if these are acceptable to the company and purpose concerned.

4.3.5 Depending on the species, do not allow harvesting of undersize or very large mature corals. Scientific advice will be required to specify the size classes to be collected for different species, as size at reproductive maturity depends on the species, and colonies of particular sizes may have important ecological roles on the reef.

The trade in live corals generally prefers colonies of 5 to 10 cm diameter or length, as these survive handling and transport better: 3 cm diameter is the minimum size that should be taken. Colonies of 12 to 50 cm diameter are preferred in the curio trade.

4.4 Draw up a list of the corals that are preferred for harvesting and that are ecologically suitable for harvest, giving common local/ vernacular, English names and scientific names.

5. Determining the amount of coral to be harvested

5.1. Determine the amount of coral required by the companies involved.

5.2. If harvesting is to be regulated by a quota and if sufficient data are available, the quota should be set on the basis of:

- target species and growth forms;
- reef habitat types;
- percentage coral cover; and,
- relative abundance of target corals.

5.3. ***If harvesting is to be regulated through a quota on either number or weight of coral, but scientific data are not available, use guidelines that have been prepared for similar situations***

(e.g. Fiji has a quota of 100,000 pieces of coral a year; on the Great Barrier Reef, sustainable yield for branching corals is estimated at one tonne / 500 square meters / year; in New Caledonia, sustainable yield has been estimated for massive corals at one tonne / 800,000 square meters / year.)

6. Methods for minimising coral damage during collecting, handling and packing

6.1 Train collectors in appropriate methods (and ensure that these are specified on permits), as follows:

6.1.1 Non-target species, sizes or growth forms of corals should never be removed from the reef;

6.1.2 Corals should be removed with a hammer and chisel or pointed instrument (e.g. steel bar sharpened to a chisel edge or point) by sharp blows to the base of the coral colony; take already broken fragments where possible.

6.1.3 Corals should NOT be removed if they are so close to other corals and organisms that these will be damaged during collection.

6.1.4 Collectors must avoid brushing against and disturbing non-target corals and other marine life, unduly stirring up reef sediments and standing or walking on corals.

6.1.5 Collecting should NOT take place under wave and surge conditions which prevent the collector from being in complete control at all times.

6.1.6 Collectors must carefully handle all corals collected to minimise breakage and waste of harvested colonies.

6.1.7 Collectors should minimise touching the living tissue of corals collected for live export. Colonies should be placed in plastic bags while still underwater, and the bags then placed in a plastic container to ensure minimal damage as they are passed into the boat.

6.1.8 SCUBA equipment should only be used if both of the requirements below are met:

- harvesting is to be carried out by professional divers or by local people where it is already in widespread use; and,
- divers can be rigorously monitored to check that other organisms are not being taken illegally.

6.2 Provide collectors with:

- photographs, drawings, and samples of the coral species and sizes to be harvested;
- a list of identification guides (given in the bibliography); and,
- copies of Dollinger (1984 / 86) and Coffey (1991) to provide identification information on corals involved in trade.

6.3 Establish suitable transport and handling procedures:

6.3.1 Boats transporting corals should return to shore with minimal delay and should move carefully, especially through rough waters, to minimise unnecessary coral breakage.

6.3.2 The water around live corals must be changed frequently (once an hour if possible), and their containers must not be placed in full sunlight.

6.3.3 Corals for the marine curio trade should be laid carefully on the bottom of the boat or in containers but not stacked on each other.

They should be kept moist because if they dry before all the tissue has been removed, they will have unsightly blotches and unpleasant odours which will reduce their value.

6.4 Establish suitable processing and packing procedures:

6.4.1 Corals for the marine curio trade should be fully immersed for one day in containers on land in a mixture of half strength bleach and freshwater. On each of the next two days they should be immersed in containers of freshwater to rinse them. A moderate pressure hose can be used if available, taking care on the more delicate portions of the corals. The used bleach and freshwater rinsings should be disposed of at a suitable site on-land; they should never be discharged onto the reef or into the sea.

Repeated rinsings with freshwater can achieve the same effect and is cheaper than using bleach, but it does require more time and effort to obtain a commercially acceptable result. Colonies should be laid out to dry in the open air on racks or mats for 1-2 days. Clean dried corals should be wrapped in paper or other packaging and packed in well-labelled wooden crates; care must be taken if newspaper is to be used as this may blacken the corals. Water with bleach should be disposed of properly.

6.4.2 Live corals should be held in oxygenated holding tanks on shore, in the shade, until shipping. The containers should then be wrapped in plastic strips and placed in individual containers. The containers should be filled with seawater to immerse the corals and then drained leaving a few millimeters of water. They should then be filled with oxygen, sealed with a tightly fitting lid and packed in a well-labelled styrofoam container.

7. *Permits for harvesting and export*

7.1 Collecting permits must specify:

- the harvest area (a map should be included);
- kinds, sizes and amount (numbers or weights) of coral that may be taken;
- collection, handling, transport, processing and packaging methods to be used; and,
- actions to be taken to avoid or mitigate other environmental damage from harvesting, and to comply with local customs.

7.2 Export permits must conform with CITES requirements and require exporters to notify authorities of:

- amount of coral to be exported - either numbers or weight of corals;
- types of coral to be exported;
- value of coral to be exported; and,
- planned dates of export.

Exporters should be required to assist in verification and inspection of shipments.

7.3 If coral harvesting is to be regulated through limited entry, establish the maximum number of collectors and exporters to be issued with permits.

7.4 Charge fees for collecting and for the export permits to help cover costs of management, enforcement and monitoring of the programme.

7.5 Coral harvesting and exporting must stop immediately if permit conditions are violated, and a fine or other penalties should be imposed.

7.6 Customs and fisheries officers must be trained to inspect permits and to recognise the corals that are harvested and exported. Customs officers should be provided with the coral section of the CITES Identification Manual No. 4 (Dollinger 1984/86); Coffey (1991) is another useful guide.

8. Monitoring

8.1 Obtain scientific advice on appropriate survey methods (see bibliography) and train officers in the relevant agency in these methods.

8.2 Install permanent monitoring stations, using reef markers, at the collecting sites and at reference or control sites.

8.3 Document reef conditions before harvesting starts, and then at regular intervals (at least twice a year) after harvesting is underway.

8.4 Keep records of the amount of coral harvested and carry out spot checks to ensure that harvesters are providing the correct information and using the correct collecting methods.

8.5. Halt harvesting immediately if monitoring reveals serious reef degradation, from over-collecting or other factors.

9. Coral transplantation

9.1. If coral transplantation is to be attempted:

- seek scientific advice before starting; and,
- carry out a pilot study to determine the value of the project.

References

1. Coral identification guides

Coffey, M. 1991. *Guide to Indian and Pacific Corals Common in the Wildlife Trade.* US Fish and Wildlife Service.

Dollinger, P. (Ed.) 1984/86. *CITES Identification Manual* Vol. 4. Parts and Derivatives 1. CITES Secretariat, Switzerland.

Veron, J.E.N. 1986. *Corals of Australia and the Indo-Pacific.* Angus and Robertson Publishers, Australia.

Wood, E.M. 1983. *Corals of the World.* TFH Publications Inc., Ltd., USA.

(If these guidelines are being applied in the Caribbean, a good coral guide is: Humann, P. 1993. *Reef Coral Identification: Florida, Caribbean, Bahamas.* New World Publications Inc.)

2. General management of coral reefs

Carpenter, R.A. and Maragos, J.E. 1989. *How to Assess Environmental Impacts on Tropical Islands and Coastal Areas.* SPREP Training Manual, East-West Center, Honolulu, Hawaii.

Kelleher, G. and Kenchington, R. 1991. *Guidelines for Establishing Marine Protected Areas.* A Marine Conservation and Development Report. IUCN, Gland, Switzerland. 79 pp.

Kenchington, R.A. and Hudson, B.E.T. 1988. *Coral Reef Management Handbook.* UNESCO Regional Office of Science and Technology for South-east Asia, Jakarta. 2nd Edition. 321 pp.

Roberts, C.M. and Polunin, N.V.C. 1991. Are marine reserves effective in management of reef fisheries? *Rev. Fish. Biol. and Fisheries* 1: 65-91.

Salm, R.V. and Clark, J.R. 1984. *Marine and Coastal Protected Areas: a Guide for Planners and Managers.* IUCN, Gland, Switzerland.

SPREP. 1993. *A Guide to Environmental Impact Assessment in the South Pacific.* South Pacific Regional Environment Programme, Apia, Western Samoa.

3. Coral biology and harvesting

Adey, W.H. and Loveland, K. 1991. *Dynamic Aquaria: Building Living Ecosystems.* Academic Press Inc., 643 pp.

Bacquero, J. 1991. Scleractinians or stony corals and the aquarium trade. Part 1. *Sea Wind* 5(2).

Beverton, R.J.H. and Holt, S.V. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agric. Fish. Food (G.B.)* Ser. II, 19: 1-553.

Buddemeier, R.W. and Kinzie, R.A. 1976. Coral growth. *Oceanogr. Mar. Biol. Ann. Rev.* 14: 183-225.

Carlson, B.A. 1987. Aquarium systems for living corals. *Int. Zoo Yearbook* 26: 1-9.

Carpenter, K.E., Miclat, R.I., Albaladejo, V.D. and Corpuz, V.T. 1981. The influence of substrate on the local abundance and diversity of Philippine reef fishes. *Proc. 4th Int. Coral Reef Symp.* 2: 497-502.

Glynn, P.W., Wellington, G.M. and Birkeland, C. 1979. Coral reef growth in the Galapagos: limitation by sea urchins. *Science* 203: 47-49.

Grigg, R.W. 1984. Resource management of precious corals: a review and application to shallow reef-building corals. *Marine Ecology* 5(1): 57-74.

Grigg, R.W. and Maragos, J.E. 1974. Recolonization of hermatypic corals on submerged lava flows in Hawaii. *Ecology* 55: 387-395.

Guzman, H.M. 1991. Restoration of coral reefs in Pacific Costa Rica. *Cons. Biol.* 52: 189-195.

Harriott, V.J. and Fisk, D.A. 1988. Coral transplantation as a reef management option. *Proc. 6th Int. Coral Reef Symp., Australia* 2: 375-379.

Hodgson, G. 1989. Coral fills the gap in bone surgery. *Asia Technology* Dec 89: 21-23.

Joannot, P. 1990. Etude d'un recif exploite pour son corail: le recif Tetembia, Nouvelle-Caledonie. Thesis, Universite D'Aix-Marseille.

Joannot, P. and Bour, W. 1988. Assessment of the biomass of corals of the Faviidae family on a commercially exploited reef in New Caledonia. Workshop on Pacific Inshore Fishery Resources, South Pacific Commission, Noumea, New Caledonia.

Lewis, A.D. (Ed.) 1985. Fishery Resource Profiles: information for development planning. Fiji Fisheries Division, 90 pp. (Chap. 6 - Ornamental Coral (lase)).

Maragos, J.E. 1990. Workshops on Environmental Procedures for Coastal Construction. 2-14 Oct 1990. Federated States of Micronesia. After Action Report to SPREP.

Maragos, J.E. 1992. Restoration of Pacific coral reefs. In: Thayer, G.W. (Ed.). *Restoring the Nation's Marine Environment.* Maryland Sea Grant College, Pub. UM-SG-TS-92-06.

Maragos, J.E. 1993. Impact of coastal construction on coral reefs in the U.S. affiliated Pacific islands. *Coastal Management* 21: 235-269.

MCS Coral Reef Conservation Team 1991. The Marine Curio Trade: conservation guidelines and legislation. Marine Conservation Society, Ross-on-Wye, UK. 23 pp.

Mulliken, T.A. and Nash, S.V. 1993. The recent trade in Philippine corals. *TRAFFIC Bulletin* 13(3): 97-105.

Oliver, J. and McGinnity, P. 1985. Commercial coral collecting on the Great Barrier reef. *Proc. 5th Int. Coral Reef Symp. Tahiti* 5: 563-567.

Pearson, R.G. 1981. Recovery and recolonization of coral reefs. *Marine Ecol. Progress Series* (4): 105-122.

Ross, M.A. 1984. A quantitative study of the stony coral fishery in Cebu, Philippines. *Mar. Ecol.* 5(1): 75-91.

Viala, F. 1988. An assessment of coral exploitation in Fiji. SPC/ Inshore Fish. Res./BP 91, Workshop on Inshore Fishery Resources, South Pacific Commission, Noumea, New Caledonia.

Wells, S.M. and Barzdo, J.G. 1991. International trade in marine species - is CITES a useful control mechanism? *Coastal Management* 19: 135-154.

Wells, S. and Wood, E. 1989. A strong case for hard corals in CITES. *TRAFFIC Bulletin* 10(3/4): 40-44.

Wheaton, J.L. 1989. The marine life fishery for 'live rock': biological and ecological assessment of the product and implications for harvest. Florida Marine Research Institute Report, 18 pp.

Wood, E.M. 1992. Trade in tropical marine fish and invertebrates for aquaria: proposed guidelines and labelling scheme. Report for the Marine Conservation Society.

Wood, E.M. and Wells, S.M. 1988. The Marine Curio Trade: conservation issues. Marine Conservation Society, Ross-on-Wye, UK.

Yap, H.T. and Gomez, E.D. 1988. Aspects of benthic recruitment on a northern Philippine reef. *Proc. 6th Int. Coral Reef Symp., Australia* 2: 279-283.

Yap, H.T., Alino, P.M. and Gomez, E.D. 1992. Trends in growth and mortality of three coral species (Anthozoa: Scleractinia), including effects of transplantation. *Mar. Ecol. Prog. Ser.* 83: 91-101.

Yates, K.R. and Carlson, B.A. in press. Corals in aquariums: how to use selective collecting and innovative husbandry to promote reef conservation. *Proc. 7th Int. Coral Reef Symposium, Guam.*

4. Monitoring

Dahl, A.L. *Coral Reef Monitoring Handbook.* Published a) by South Pacific Commission, Noumea, New Caledonia (1981); and b) as Reference Methods for Marine Pollution Studies 25, UNEP (1984).

Monitoring coral reefs for global change. Published a) as Reference Methods for Marine Pollution Studies 61, UNEP (1993); and b) by IUCN, Gland, Switzerland as a Marine Conservation and Development Report (1993).

UNESCO, 1984. Comparing coral reef survey methods. *UNESCO Repts Mar. Sci.* 21.

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