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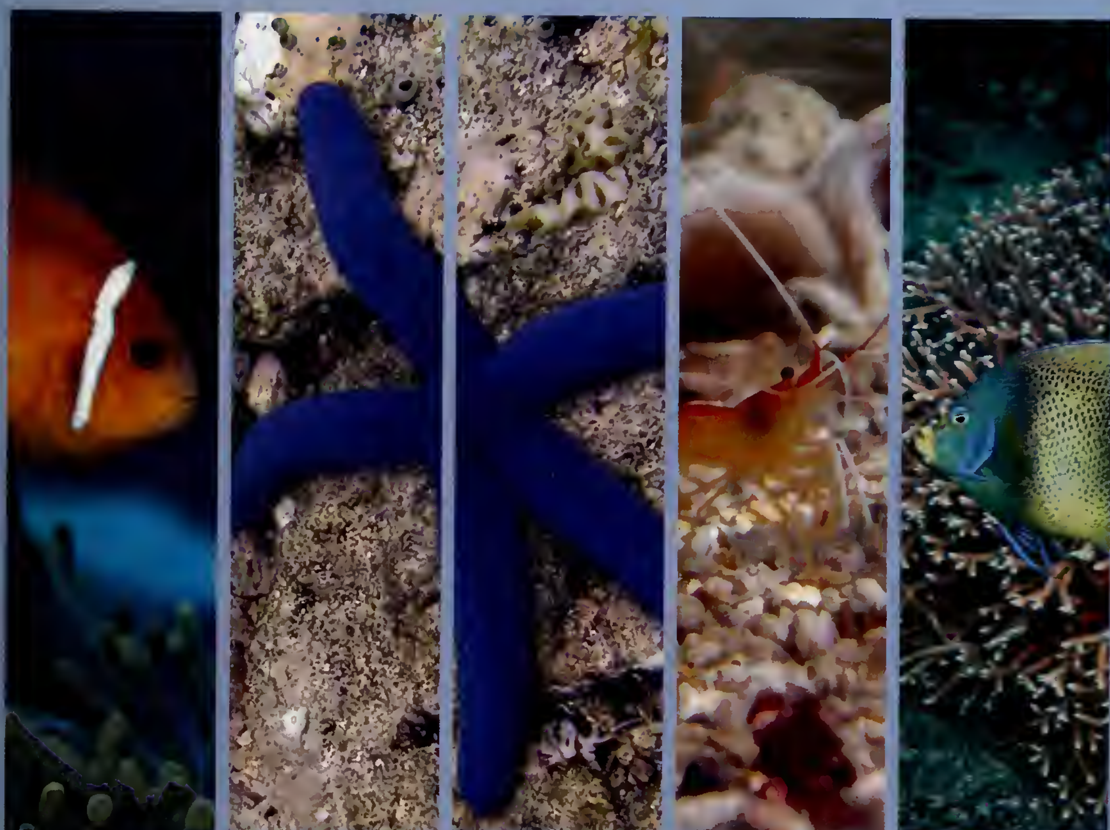
From **Ocean** to **Aquarium**



The global trade in marine ornamental species

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Edmund Green and Tries Razak

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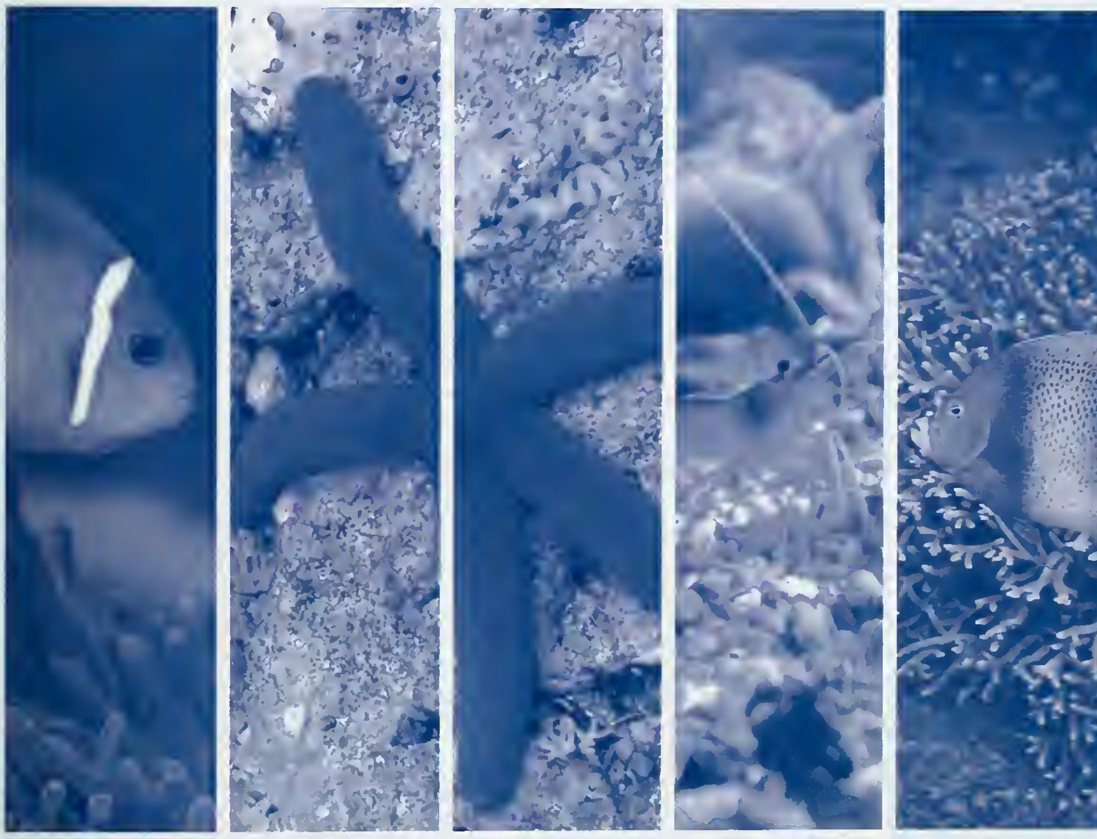

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Foreword

Most of us at some time or another have enjoyed the relaxing experience of gazing into an aquarium, in a dentist's waiting room or during a special visit to a public aquarium. In admiring the playfulness of clownfish wriggling amongst the anemones' tentacles, the grace of angelfish swimming in open water and in our delight at spotting reclusive shrimp and crabs crawling behind iridescent living corals, it is all too easy to overlook the fact that all these wonderful creatures are far from their natural home. The great majority of animals in aquaria across Europe and North America were collected from coral reefs far away and flown, bagged in plastic and packed in styrofoam boxes, thousands of miles to our hospitals and living rooms.

This report, *From Ocean to Aquarium: The Global Trade in Marine Ornamental Species*, takes a clear objective look at this international industry. A potential source of income for communities living close to coral reefs, the aquarium trade has been heavily criticised for the use of unsustainable collection techniques and poor husbandry practices. Policy makers have been faced with something of a dilemma in trying to control the environmentally undesirable aspects of the industry without risking the economic incentive which aquarium fishers have in caring for the coral reefs that provide their livelihoods. Where previously much controversy existed between opponents and supporters of the aquarium trade, most of it based on polarized opinion and poor information, this publication presents sound quantitative data on the species in trade. Through linking trade data to what is known about the life histories of the target organisms, conservation priorities and management recommendations are identified.

I have great pleasure in presenting this report and wish to extend the gratitude of the authors to the long list of collaborating organizations and companies that have made it possible. I am confident that the information contained here will assist efforts to promote sustainable practice within the industry, as well as providing information to casual admirers of marine organisms.

Mark Collins
Director
UNEP World Conservation Monitoring Centre

Contents

Executive summary

Between 1.5 and 2 million people worldwide are believed to keep marine aquaria. The trade which supplies this hobby with live marine animals is a global multi-million dollar industry, worth an estimated US$200-330 million annually, and operating throughout the tropics. Ornamental marine species (corals, other invertebrates and fish) are collected and transported mainly from Southeast Asia, but also increasingly from several island nations in the Indian and Pacific Oceans, to consumers in the main destination markets: the United States, the European Union (EU) and, to a lesser extent, Japan.

Very few of the species in trade are exploited directly for other purposes, and there is little doubt that aquarium animals are the highest value-added product that can be harvested from a coral reef. If managed sustainably, the trade could support jobs in predominantly rural, low-income coastal communities and so provide strong economic incentives for coral reef conservation in regions where other options for generating revenue are limited. However, damaging techniques occasionally used to collect the animals, possible over-harvesting of some species and the high levels of mortality associated with inadequate handling and transport of sensitive living organisms undermine this potential, and continue to pose significant challenges to achieving sustainability. As a result the trade has seldom been free of controversy as traders try to generate a profit, conservationists try to avoid further decline in coral reefs also suffering from other pressures, and policy makers try to assemble a legislative framework that protects coral reefs without threatening a legitimate business activity or the incomes of communities engaged in aquarium fishing.

Bluestreak cleaner wrasse, *Labroides dimidiatus*.

In the main, this debate has taken place without access to impartial and quantitative data on the trade and, with so many different viewpoints, achieving consensus on its impacts, and hence the identification of suitable responses, has been difficult. In 2000, the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), the Marine Aquarium Council (MAC) and members of various aquarium trade associations began, in collaboration, to address this need for better information and created the Global Marine Aquarium Database (GMAD). Trade data have been obtained from wholesale exporters and importers of marine aquarium organisms, most often through copies of trade invoices, integrated and standardized into quantitative, species-specific information which has been placed in the public domain: www.unep-wcmc.org/marine/GMAD. Fifty-eight companies, approximately one-fifth of the wholesalers in business, and four government management authorities have provided data to GMAD. In August 2003 the dataset contained 102,928 trade records (7.7 million imported and 9.4 million exported animals) covering a total of 2,393 species of fish, corals and invertebrates and spanning the years 1988 to 2003. These data have permitted the most accurate quantitative estimates to date of the size of the global trade in marine ornamental fish and corals, and the first ever estimates for invertebrates other than corals, a previously overlooked section of the industry.

FISH

A total of 1,471 species of fish are traded worldwide with the best estimate of annual global trade ranging between

Copperhead butterflyfish, *Chelmon rostratus*: from ocean to aquarium.

20 and 24 million individuals. Damselfish (Pomacentridae) make up almost half of the trade, with species of angelfish (Pomacanthidae), surgeonfish (Acanthuridae), wrasses (Labridae), gobies (Gobiidae) and butterflyfish (Chaetodontidae) accounting for approximately another 25-30 per cent. The most traded species are the blue-green damselfish (*Chromis viridis*), the clown anemonefish (*Amphiprion ocellaris*), the whitetail dascyllus (*Dascyllus aruanus*), the sapphire devil (*Chrysiptera cyanea*) and the threespot dascyllus (*Dascyllus trimaculatus*). The ten most traded species account for about 36 per cent of all fish traded for the years 1997 to 2002. Trade data, correlated with aquarium suitability information, indicate that two species known not to acclimatize well to aquarium conditions are nonetheless very commonly traded. They are the bluestreak cleaner wrasse (*Labroides dimidiatus*: GMAD records 87,000 worldwide imports of this species from 1997 to 2002) and the mandarin fish (*Synchiropus splendidus*: GMAD records 11,000 live individuals exported to the EU in the same period). Data further indicate that species characterized as 'truly unsuitable', mainly due to their restricted dietary requirements, such as the foureye butterflyfish (*Chaetodon capistratus*), the harlequin filefish (*Oxymonacanthus longisrostris*) and the Hawaiian cleaner wrasse (*Labroides phtirophagus*), are also commonly traded, albeit in lower numbers.

CORALS

A total of 140 species of stony coral, nearly all scleractinians, are traded worldwide, with the best

Coral collected for trade.

estimate of annual global trade ranging between 11 and 12 million pieces. Although difficulties associated with accurate coral identification probably make species data less reliable for corals than for fish, it is clear that species in seven genera (*Trachyphyllia*, *Euphyllia*, *Goniopora*, *Acropora*, *Plerogyra*, *Catalaphyllia*) are the most popular, accounting for approximately 56 per cent of the live coral trade between 1988 and 2002. Sixty-one species of soft coral are also traded, amounting to close to 390,000 pieces per year. *Sarcophyton* spp. (leather/mushroom/toadstool coral) and *Dendronephthya* spp. (carnation coral) are two of the most commonly traded species. However, whilst the biology of the former makes it a hardy, fast-growing and easily propagated species under aquarium conditions, *Dendronephthya* spp. usually die within a few weeks, mainly due to the fact that they lack photosynthetic symbionts and rely on filtering particles and nutrients in the water column for food.

INVERTEBRATES

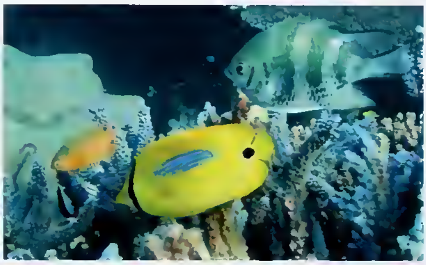
More than 500 species of invertebrates (other than corals) are traded as marine ornamentals, though the lack of a standard taxonomy makes it difficult to arrive at a precise figure. The best estimate of global annual trade ranges between 9 and 10 million animals, mostly molluscs, shrimps and anemones. Two groups of cleaner shrimp, *Lysmata* spp. and *Stenopus* spp., and a group of anemones, *Heteractis* spp., account for approximately 15 per cent of all invertebrates traded.

Overall, there is a pressing need for basic information on the population dynamics and life history characteristics of organisms targeted by the ornamental trade. Combined with accurate trade data, such information is essential for making more informed decisions regarding the sustainable collection of marine ornamentals.

Other efforts needed to achieve sustainable management of the aquarium trade include the continued development and wider application of third-party certification, whereby the consumer is empowered to assist in reducing the environmental impacts of the trade by selectively purchasing specimens produced in an environmentally friendly manner. At the source country level, the implementation of measures such as quotas and size limits, and restricted access to the ornamental fishery through, for example, the use of permits and the establishment of areas closed to the fishery, are recommended where appropriate, though proper consultation is essential. Further research in developing mariculture protocols for raising commonly traded species in source countries, to take pressure off wild stocks and to avoid removing livelihoods from local communities, should also be promoted. To date, only one-fifth of giant clams are cultured, while only 1-10 per cent of fish and fewer than 1 per cent of coral species are capable of being captive bred. Even fewer species are bred in commercial quantities.

Cleaner shrimp, *Stenopus* spp.

Introduction



Species including striped thread fin, *Polydactylus plebeius*.

Although reefs cover less than one quarter of 1 per cent of the marine environment, they are considered to be amongst the most biologically rich and productive ecosystems on Earth, often described as the 'rainforest of the seas'[1,2]. Coral reefs support over 4,000 species of fish (or a third of the world's marine fish species), about 800 species of reef-building corals[3], and a great number of other invertebrates and sponges.

Coral reefs provide millions of people with benefits, both direct and indirect, including fisheries, tourism and coastal protection[2]. Most coral reefs are located in developing countries, with millions depending directly on them as a source of protein and, at least in part, for their livelihoods. Reefs also support an important array of non-food commercial fisheries including the marine ornamental fishery.

It is generally acknowledged that the collection and export of tropical marine fish for the aquarium trade started in Sri Lanka in the 1930s, on a very small scale[4,5]. Trade expanded during the 1950s, with an increasing number of places (e.g. Hawaii and the Philippines) issuing permits for the collection of species destined for the marine aquarium trade[i,6]. Although demand has fluctuated and trends vary from year to year, the overall value of the marine fish trade, accounting for about 10 per cent of the international ornamental fish trade (marine and freshwater included), has remained fairly stable in recent years. Figures for exports of live pieces of coral, on the other hand, showed annual growth of 12-30 per cent from 1990[7] until 1999, only stabilizing in the last three years.

It is estimated that 1.5 to 2 million people worldwide keep marine aquaria[8], with 600,000 households in the United States alone[9]. Estimates place the value of the marine ornamental trade at US$200-330 million per year[10,11] with 80 per cent of the trade in stony corals and 50 per cent of the trade in marine fish going to the United States[12].

Unlike freshwater aquaria species, where 90 per cent of fish species are currently farmed, the great majority of marine aquaria are stocked from wild caught species[13]. With nearly all tropical marine aquarium fish and invertebrates in trade taken directly from coral reefs and adjacent habitats, the aquarium industry has attracted some controversy[14-17], particularly regarding its sustainability[18]. The high visibility of marine ornamental products has made the trade a magnet for criticism[19]. Articles in the press have tended to focus on the negative impacts of the trade with headlines often making the

Value of the aquarium industry

The aquarium industry as a whole is of relatively low volume yet very high value[21,26], thus potentially providing an incentive to conserve reef habitats[17,30] and offering a livelihood to coastal communities often living in low-income areas. In 2000, 1 kg of aquarium fish from the Maldives was valued at almost US$500, whereas 1 kg of reef fish harvested for food was worth only US$6[31]. Similarly, the live coral trade is estimated to be worth about US$7,000 per tonne whereas the use of harvested coral for the production of limestone yields only about US$60 per tonne[32]. In Palau, live rock is exported for the aquarium trade at US$2.2 to US$4.4 per kilo whereas it is sold locally as construction material for less than US$0.02 per kilo[33]. Sri Lanka earns about US$5.6 million a year by exporting reef fish to around 52 countries[5] and estimates indicate that 50,000 people are directly involved in the export of marine ornamentals[34]. In the Philippines, about 7,000 collectors depend on the reefs for their livelihood[35].

Harlequin tuskfish, *Choerodon fasciatus*. Typical retail value can be as much as US$115 for an Australian specimen.

Seahorse fisherman in the Philippines at night.

assumption that the trade of marine ornamentals is incompatible with reef conservation.

Opponents to the trade emphasize:

- the damaging techniques sometimes used to collect reef specimens[20, 21]; sodium cyanide for example is a non-selective technique used to capture fish that adversely impacts the overall health of fish and coral and also kills non-target organisms[22, 23]
- the over-harvesting of target organisms[5, 13, 17, 24], and
- the high levels of mortality associated with insensitive shipping and poor husbandry practices along the supply chain[21, 25, 26].

Some regulation has already been established; more is being called for[17] and may follow. With more than 2.2 billion people (39 per cent of the world's population) living within 100 km of the coast[27], coral reefs are facing an increasing plethora of threats such as pollution, sedimentation, coral bleaching, overfishing and tourism. Reefs of Southeast Asia, the most important source of the majority of animals in the marine ornamental trade, are particularly at risk, with 88 per cent of all reefs at medium to very high threat from anthropogenic impacts[28]. It is therefore important that aquarium species' collection does not further compound these problems[29].

Supporters of the trade maintain that, if managed properly, the aquarium industry could support long-term conservation and sustainable use of coral reefs. Some collection techniques have minimal impact on coral reefs. Well-managed shipping and husbandry practices, particularly relevant in the case of fish, can also allow mortality levels to be kept to minimal levels (as has been shown by some operators in the industry). In addition, aquarium animals are the highest value-added product that can be harvested sustainably from coral reefs, so collecting and exporting marine ornamentals in developing countries creates jobs in rural, low-income, coastal areas[26] where resources and alternative options for generating income can be limited. Aquarium fisheries therefore have the potential to provide an alternative economic activity for coastal populations, an important source of foreign exchange for national economies[5] and a strong economic incentive for the sustainable management of reefs. They may also help foster marine conservation by providing a strong incentive for subsistence fishers to harvest wild populations sustainably so as to maintain fish stocks and reef environments in good condition.

Domestic or public saltwater aquaria can provide a unique opportunity to educate the public about coral reefs and increase awareness and understanding of what is, for the most part, a hidden ecosystem[13, 21, 30]. By allowing people to explore the complexities and appreciate the beauty of reefs, the need for creative solutions to environmental problems can be illustrated. In addition, an understanding of, and respect for, reefs can be sparked among users who are ultimately responsible for their conservation[38].

Only 1 per cent (about 25 species)[36] to 10 per cent[6, 37] of marine ornamental fish are captive-bred and probably less than 1 per cent of the total trade in hard corals is derived from cultured origins[32]. The development of mariculture facilities could in theory allow pressure to be taken off wild populations. It should preferably be located in the

Petites îles de la Sonde, a specimen collection site in Indonesia.

mostly developing source countries, in order not to deprive these nations of the income generated by trade. The application of international certification schemes[ii] may provide an important tool for achieving this. Although still in its infancy, the Marine Aquarium Council (MAC) certification process has made some considerable progress (see chapter on Conservation efforts, p 48). As more certified organisms become available, aquarium hobbyists will be in a position to make purchases in the knowledge that the organisms they are buying have been collected and transported according to a set of agreed and monitored standards.

The controversy over the environmental costs and benefits of the trade continues, largely due to a lack of quantitative data. Global species trade data are available for all species of hard coral and giant clams that are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[iii] on Appendix II (species vulnerable to exploitation but not yet at risk of extinction). Shipments of corals and clams involving Parties to the Convention must be accompanied by a CITES export permit issued by the national CITES management authority. Parties to CITES are then obliged to produce annual reports specifying the quantity of trade that has taken place in each listed species. No marine aquarium fish (although *Hippocampus* spp. will be from 15 May 2004) or invertebrates, other than clams or corals, are listed in CITES Appendices.

The Global Marine Aquarium Database (GMAD) was set up in 2000 as a collaborative project between the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), MAC and members of trade associations in exporting and importing countries (e.g. the Indonesia Coral, Shell and Ornamental Fish Association (AKKII), the Philippine Tropical Fish Exporters' Association (PTFEA), Ornamental Fish International (OFI), the Ornamental Aquatics Trade Association (OATA)). It compiles accurate quantitative information on the aquarium trade through centralizing and standardizing sales records provided by aquarium wholesalers. Relevant information from these records is then placed in the public domain.

This study presents an up-to-date report on the marine aquarium trade. It first briefly describes the organizational structure of the trade both in source countries and at destination. The next chapter then introduces existing sources of data on the aquarium trade whilst the chapter on Analysis of trade data presents statistics and analyses of the trade in corals, fish and invertebrates derived from GMAD and other sources of information (e.g. CITES) where applicable. Conservation issues, including the use of destructive collection practices, impacts on marine ornamental populations, species' suitability for aquarium conditions, issues of invasive species and user conflict arising from the marine aquarium industry, are discussed in the chapter of the same name. The chapter on Conservation efforts presents steps taken by the industry and future efforts to be made at local, regional and global levels to ensure the marine ornamental trade develops sustainably whilst providing local communities with livelihood opportunities, promoting reef conservation by giving local people an incentive to maintain their reefs in a healthy state. The final chapter concludes the report and provides some recommendations based on its findings.

Organization of the trade

Fish being bagged for export.

The organization of the marine ornamental trade is complex and extremely dynamic. In exporting nations it is likely to involve a series of collectors/ fishers, wholesalers, middlemen and exporters, while in importing nations it involves a number of importers, wholesalers, retailers and, more recently, transhippers.

COLLECTION

Collectors tend to be small-scale fishermen from tropical countries who work alone or in small groups, often composed of family units, and who are either self-employed or working for a wholesaler/exporter. They typically work with artisanal equipment, with divers often using wooden palms as fins[39]. Fish are collected using nets (e.g. hand nets, cast nets) and fishing lines. In Sri Lanka and the Maldives collectors catch most of their fish using hand nets[20]. In Australia[40, 41], the Pacific region[42] and Florida[43] fishers often use much larger barrier, drop or fence nets.

Collecting fish effectively, without inflicting damage to either fish or substrate, requires considerable skill and experience[6]. At times, special techniques are developed for collecting particular species. In Sri Lanka, for example, fishers make use of small, tubular nets for capturing species that live in small holes. Using a fine rod the fish are 'tickled' out of their cavity into a net strategically placed at the burrow's entrance[44 in 6]. In areas of Southeast Asia where aquarium fisheries are most developed, fishers are assisted by a method called 'hookah', whereby compressors are installed on their vessels and connected to long plastic tubes that divers bite between their teeth or to which a regulator is attached.

Some collection methods can be particularly damaging to the substrate. Previously, in Sri Lanka for example, small cast nets used to be draped over corals and fish scared into them by hitting the coral with a stick. This method was recently banned due to damage inflicted upon the reef[6]. Branching corals, which provide shelter to a variety of fish, are often snapped off to extract any fish hiding in between branches[20]. In some countries, such as Indonesia and the Philippines, collectors stun fish with poison, to make their collection easier. The most common poisons used are sodium cyanide and quinaldine. The extent to which cyanide is used is discussed in Conservation issues, under Destructive harvesting practices.

Collectors harvesting corals and other immobile invertebrates (e.g. sponge) also often use hookah and a hammer, iron crowbar, chisel or screwdriver to remove target colonies. Although specimens are preferably removed with a small portion of the reef to which the organism is attached[45], minimal damage is usually inflicted to the surrounding reef or connected corals[46]. Typically, collectors tend to target small-sized colonies of hard and soft corals that can be removed whole. However, sometimes only fragments are taken[45].

Upon collection, fish, corals and invertebrates are placed separately in plastic containers or individual bags. Coral pieces tend to be covered with plastic wrap to prevent injury[45]. To avoid the fishes' air bladders rupturing due to decreasing hydrostatic pressure associated with ascent, individuals caught on deeper parts of the reef are often placed in a dark mesh cage and lifted to the surface very slowly (3 m every 30-40 minutes[47]) to allow their bladders to decompress. The deeper the fish have been caught the slower they need to be brought to the surface, ranging from hours to days depending on the species' sensitivity[48]. To avoid the wait, fishers often bring the fish to the surface immediately and pierce the inflated swim bladder with a hypodermic needle. When performed well and with a clean needle this method is considered safe[42].

Fishermen typically bring collected fish and invertebrates back to shore the same day. However, in areas of the Philippines and Indonesia where collection sites tend to be fairly isolated, fish may be on board the boat for several days before being landed[49]. Once ashore, fish and invertebrates are placed in separate holding tanks, or immediately packaged for transport and/or export.

Collectors are usually paid for the number of fish/invertebrates they have collected and prices for individual species vary greatly depending on their popularity on the market. However, there is a fairly large discrepancy between the sum they earn and prices paid by the end consumer. In Indonesia, for example, a fisher typically receives US$0.10 for every orange clownfish (*Amphiprion percula*) collected yet an American hobbyist is likely to pay US$12[50]. The greater the number of middlemen employed in the market chain between collector and wholesaler, the higher this discrepancy is likely to be. A study carried out in the Philippines showed that, of the price paid for fish by exporters, about 85 per cent went to middlemen whereas only 15 per cent went to collectors[51].

At their origin, fish are quarantined (this can last from a few hours to a few months) and starved for at least 48 hours prior to shipment to ensure they do not foul their bags. Most fish (and invertebrates) are then packed in double polyethylene bags filled with one third water and two thirds oxygen, sealed and placed in a cardboard box (often reinforced with polystyrene foam for added insulation). Aggressive species are placed in opaque bags or have paper placed at the bottom of the bag to minimize stress. To avoid putting the health of fish at risk, a recommended maximum travel time of 40 hours has been suggested for shipments (with 24 hours being considered reasonable)[47]. For each consignment a licence has to be issued allowing it to leave the exporting country. Cartons of coral species and giant clams need to be accompanied by the relevant CITES permits. Although practices vary between individual countries, a health certificate issued by the local veterinary services is usually required before the shipment is declared for customs. Further information on shipping practices in the ornamental industry can be found in Cole *et al.*[25].

Bagged specimens.

AIRLINE TRANSPORT

International airline companies transport fish from exporting to importing states. Shipping charges are the main reason behind the discrepancy between marine ornamental prices in the exporting country and final retail price – in the case of fish, shipping charges often correspond to approximately half to two thirds of the landed price incurred by the importer[39]. Transport associations such as the International Air Transport Association (IATA)[iv] and the Animal Transportation Association (AATA)[v] organize and manage the transport of live marine ornamentals. Fish are packaged according to a list of criteria set out by these organizations.

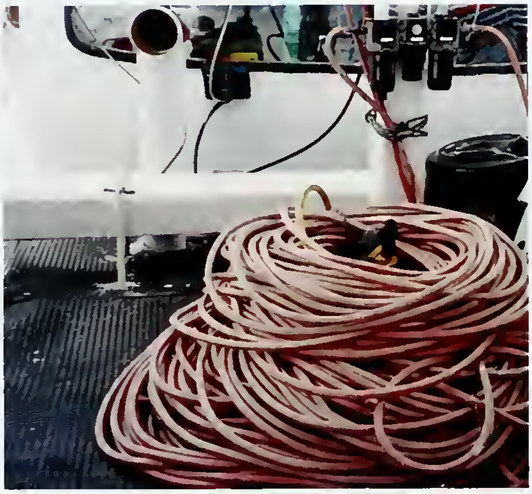
AT DESTINATION

At the receiving end, importers must clear the shipment with customs and the consignment undergoes another veterinary check. However, criticism has been expressed towards the latter as there is a general lack of veterinary control and individuals performing the checks are often not qualified to examine fish. The importer then transfers the shipment to a wholesale facility and the boxes are opened under dimly lit conditions to minimize stress to the fish. Individuals are quarantined in order to acclimatize them to life in captivity, particularly to new feeding cycles and different water chemistry. Care is taken to keep certain species separate and provide others with shelter to minimize aggressive behaviour and associated stress and thus ensure maximum survival rates. Following acclimatization, fish are either sold to other wholesalers or retailers or re-exported. Invertebrate species tend to be kept separately from fish species. Appropriate lighting, i.e. the provision of the right colour spectrum at the appropriate intensity, is of crucial importance to the survival of coral species. Unlike fish species corals do not need to be acclimatized prior to being shipped or sold.

In recent years, wholesalers have found it more and more difficult to remain established, mainly because of the introduction of transhipping, but also due to the expansion of garden centres and pet supermarkets. These centres tend to sell fish (and to a lesser extent invertebrates) in bulk quantities at low prices. They also often lack qualified staff, which frequently results in a lack of information and technical advice at the point of sale and a lack of interest from the purchaser[39].

Transhipping

Transhipping is an activity that emerged during the 1970s and 1980s. It involves grouping the orders of several retailers and/or wholesalers and placing them with an exporter, collecting the shipment at the airport, clearing customs and redistributing the boxes without opening



Divers' breathing equipment (hookahs) on deck.

Boxes at the airport

them[39]. The responsibility for the entire shipment falls onto the retailer. All transhippers require to operate is a telephone, fax and vehicles to pick up shipments upon arrival. Where additional services, beyond picking up the consignment, clearing customs and transport are required, the activity is referred to as 'consolidating'[39]. In the latter case, a more complete service is provided whereby the transhipper takes responsibility for the fish during a 48-hour period following delivery and offers refunds for any animals that died during transport[39].

Increasingly, particularly in Europe, transhippers are required to hold a licence in order to operate[39]. However, no skills with respect to fish handling are necessary to obtain such a licence. Transhippers do not need large facilities to acclimatize marine fish, and so they can afford to sell individuals at half the price that wholesalers would charge. Despite severe criticism about the quality of transhipped invertebrates and non-acclimatized fish these businesses are expanding in Europe, unlike in the United States where increased commercial use of the Internet has led to a decline in the number of transhippers[11]. In response to criticism, and to abide by the Marine Aquarium Council Standards and Certification[vi], transhippers are transforming their businesses to be able to provide increased quality and services.

Despite the advent of transhipping and consolidating, established wholesalers who are able to maintain a core set of customers as retailers are only able to import directly through transhippers if they have both authorization from the veterinary services and the required and appropriate equipment/infrastructure for acclimatization[40]. Moreover, the results of a survey of US marine ornamental wholesalers revealed that firms in states outside Florida believed there was a growing market for small environmentally conscious companies[53].

GOVERNMENTS

Governments of many exporting countries often play an important role in the trade of marine ornamentals, ranging from financial assistance to improved management schemes and trade regulations[21]. Certain countries/states set fishing quotas (e.g. Florida[43]), prohibit collection from certain sites (such as designated restricted areas in Hawaii) or prohibit certain capture methods (such as cyanide in Indonesia). Rules and regulations naturally vary from one country to the next. In the European Union (EU), for example, traders must contact the appropriate national ministry (e.g. Ministry of the Environment) and file an application for technical certification as well as declare all imported and exported goods to the Ministry of Finance[39].

ASSOCIATIONS

Individuals involved in the marine ornamental industry often join forces and form associations or syndicates. Examples include AKKII, PTFEA, the Singapore Aquarium Fish Exporters' Association (SAFEA), OFI, OATA and the Pet Industry Joint Advisory Council (PIJAC). The last is the world's largest pet trade association, representing all segments of the pet industry including retailers, wholesalers/distributors, companion animal suppliers, manufacturers, manufacturers' representatives, hobbyist groups and other trade organizations.

Sources of trade data

Unknown species of echinoderm (sea star) in an aquarium.

All species of giant clams and stony coral are listed in Appendix II of CITES, an international agreement that protects wildlife by ensuring that international trade is based on sustainable use and does not threaten the survival of a species in the wild. The treaty, established in 1973 and which entered into force in 1975, currently has 162 Member Parties. Species listed in Appendix II can be traded, provided an export permit accompanies shipments and a 'non-detriment finding' is made (i.e. the collection is not detrimental to the survival of the species).

Although one of the benefits of the Appendix II listing is that it allows for global trade to be monitored, there are a number of difficulties associated with implementing CITES in relation to the aquarium trade. Due to the complexities of coral identification, exports of corals need only be identified to genus level – under the provisions of the Convention, exports usually have to be identified to species level. Within one genus the abundance and distribution, and thus threat of overcollection (and that of other impacts), of individual coral species varies immensely. Hence, issuing CITES permits at genus level may lead to certain species being driven to extinction through overcollection[7]. Further limitations include differences in traded numbers between reported and actual exports, differences in units recorded (e.g. specimens and kilos), and confusion arising in cases where corals are imported and then re-exported without appropriate reference to the country of origin[54]. However, an expert group established in 2000 is to discuss and revise listing requirements[55].

The EU has been fully implementing CITES since 1 January 1984. On 9 December 1996, it adopted Council Regulation (EC) No. 338/97 on the Protection of Species of Wild Fauna and Flora by Regulating Trade Therein (OJ L61 of 3/3/97) which entered into force on 1 June 1997. Commission Regulation (EC) No. 338/97 lists species on four Annexes[vii] :

- **Annex A**: All CITES Appendix I species and some CITES Appendix II and III species, for which the EU has adopted stricter domestic measures, as well as some non-CITES species.
- **Annex B**: All other CITES Appendix II species, some CITES Appendix III species and some non-CITES species.
- Annex C: CITES Appendix III species not listed in other Annexes.
- Annex D: Some CITES Appendix III species for which the EU holds a reservation and some non-CITES species. Seahorses are listed under Annex D. Species listed on Annex D require an import notification, to be completed by the importer, upon entry into the EU. In theory, all imports of Annex D species should be recorded, but in practice it is likely that there are some discrepancies in the trade data.

Besides CITES, and for species not listed under the Convention's appendices, national governments routinely produce statistics, through customs or other officials with responsibility for monitoring trade, regarding the export or import of marine ornamentals, particularly fish. Unfortunately, the utility of these trade data may be limited as:

- trade categories are rarely fully reported[6], and
- data are often aggregated so that marine fish are categorized as 'tropical fish' and combined with freshwater fish, in some cases even including invertebrates (e.g. starfish, sea cucumbers, marine molluscs) or other commodities under the same category[8, 26, 53].

Even in cases where trade statistics are available through government sources, difficulties often arise because of the use of different units. Exports and imports tend to be registered by value (e.g. US Customs and imports to the nations of the EU) and/or weight rather than number of individuals. Import values are always higher than export values as the former include the costs of livestock and carriage as well as insurance and freight[56] whereas for exports the value of the organisms is declared without packing, freight, tax or transport[6]. Trade statistics available as weight values include water and packaging, hence substantially overestimating the volume of live material, especially for fish and non-coral invertebrates. Moreover, trade data obtained through customs' statistics should be treated with caution as some operators have been known to overstate quantities on their invoices for insurance purposes[8], or on other occasions understate quantities so as to reduce the amount of tax payable and keep annual shipments within the individual allowable quotas[57]. In Hong Kong, a study comparing information obtained from trade statistics with data collected through market surveys indicated that official declarations of imports are under-reported by at least two- to three-fold[24].

In very few cases will countries report trade statistics in terms of the number of specimens exported. Singapore and the Maldives present exceptions to this, holding government records of the number of marine ornamental fish exported, showing a total of 1,294,200 fish being exported in 1998 for the former, and 262,641 in 1997, 182,916 in 1998, and 167,000 in 1999 for the latter[6]. Furthermore, in order to comply with governmental guidelines for obtaining a licence, collectors in Vanuatu, Tonga and the Solomon Islands are required to submit records of their exports, in terms of number of each species exported[8]. State governments in Australia are unique in that they require collectors to register catch data as opposed to export data[41].

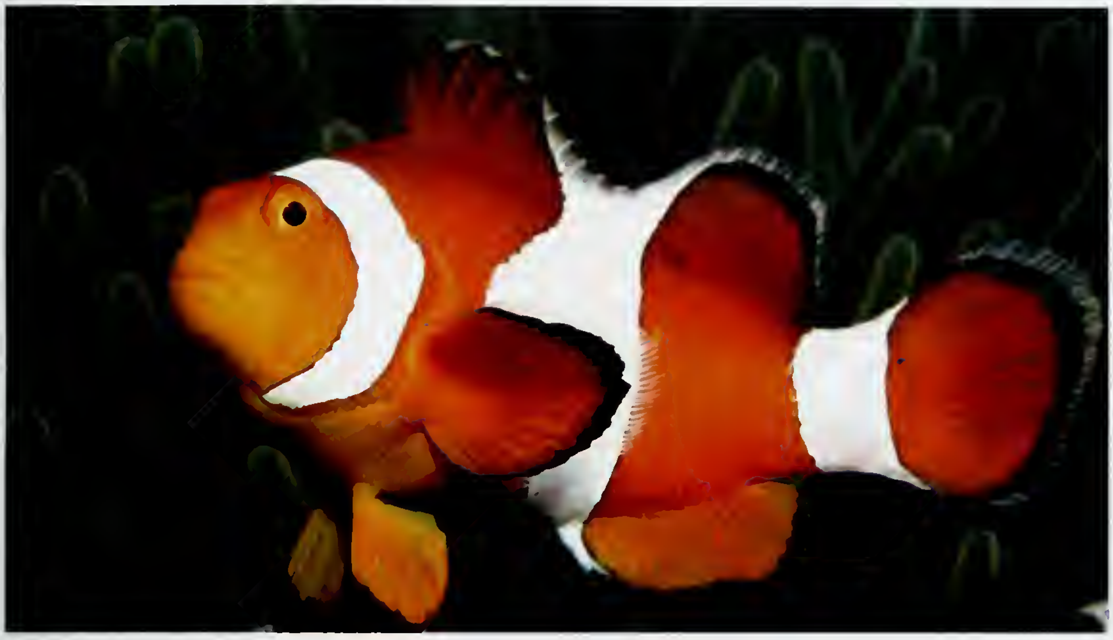
Thus, the available sources of data generally provide, at best, qualitative information and little reliable quantitative information on numbers, countries of origin and destinations of the main species in trade[8].

THE GLOBAL MARINE AQUARIUM DATABASE (GMAD)

Since April 2000, UNEP-WCMC and MAC have been collaborating with members of trade associations such as AKKII, PTFEA, SAFEA, OFI and OATA to establish GMAD as a freely available source of information on the global aquarium industry. The common objective of GMAD is to gather, integrate, collect, standardize and provide fast and easy access to data on the trade of individual species by placing this information in the public domain, through a web-searchable interface (http://www.unep-wcmc.org/marine/GMAD).

For their own files, companies keep records of their sales, either on company computer databases or, more commonly, as paper copies of their invoices. Although the way in which companies register their trade records varies, all records show species name, quantity, date and usually origin and/or destination. A number of these companies provided UNEP-WCMC with access to their sales records. These data have been processed, checked and formatted: species names have been verified and electronic data from different electronic systems placed into a single standardized database. As at August 2003, GMAD contained 102,928

Royal angelfish, *Pygoplites diacanthus* (left) and a nudibranch (right).



Clown anemonefish, *Amphiprion ocellaris*.

records. Data records in GMAD cover 2,393 species (corals, other invertebrates and fish) from 1988 to 2003. In order to avoid confusion, unless otherwise stated, the term invertebrates will be used to refer to all invertebrate species other than corals.

Each record in GMAD is the total number of specimens traded for a unique combination of: species name, country of export, country of import and year. However, for importers' data, a large number of records were submitted by wholesalers without information about country of origin.

GMAD trade data are linked to two external databases:

- FishBase[58] for photographs of fish species, and fish distribution and taxonomy, and
- the Species Conservation Database[59] for information on invertebrate taxonomy, distribution, relevant legislation, conservation status and associated literature and common names.

It is important to note that trade data cannot be pooled because some of the contributing importers trade with some of the contributing exporters. Hence, pooling data would create duplications. In order to avoid such confusion, GMAD was designed to allow for import and export data to be queried separately.

As an example, if interested in the number of clown anemonefish (*Amphiprion ocellaris*) traded between Indonesia and the United States for the year 1999 one can calculate two numbers. The first, based on importers' data, shows that 4,223 *Amphiprion ocellaris* were imported into the United States from Indonesia between those years. The second number, based on export data, shows that 5,565 specimens were exported from Indonesia to the United States. As of August 2003, GMAD contains export data from 20 Indonesian companies (though most of the data provided pertains to coral exports), and importers' data from four US wholesalers. There are, of course, other companies in Indonesia and the United States trading in *Amphiprion ocellaris* that have not contributed their data to GMAD, and therefore these figures are just a quantitative total based on data contributed to GMAD by August 2003.

As a consequence of this, GMAD cannot be used to calculate net volumes of trade in any one species, or between any pair of countries. Calculations of quantities of specimens traded in a particular species will be more or less indicative of the trade in this species depending in part on the proportion of operational wholesale export and import companies contributing data to GMAD. However, it is a very useful tool as an indicator of trends and, for the first time in the case of fish and invertebrates, it allows estimates based on quantitative, rather than qualitative, data to be derived.

Analysis of trade data

Blue-green damselfish, *Chromis viridis*.

The following section will describe analyses of CITES data for trade in stony corals and giant clams, Annex D data for seahorses and GMAD data for fish, corals and invertebrates. Based on sales data supplied by the 58 companies in GMAD and applying the method described in Green[8] the best estimate of annual global trade is between 20 million and 24 million for marine ornamental fish, 11-12 million for corals and 9-10 million for marine ornamental invertebrates.

FISH

Records within GMAD for marine ornamental fish range from 1988 to 2003. However, the data are not uniformly distributed and most data were collected for the years 1998 and 1999 for importers' data and 2000 and 2001 for exporters' information. Data provided by importers and exporters show that a total of 7,938,828 fish and 3,588,406 fish respectively were traded between 1991 and 2003. (See Table 1.)

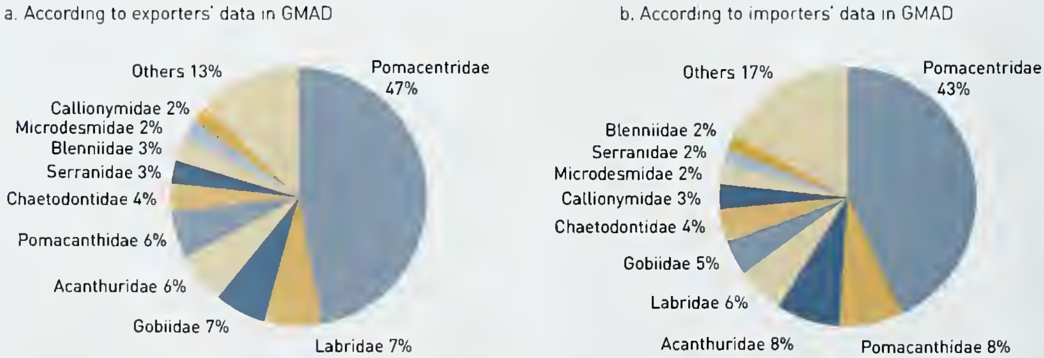
According to data held in GMAD a total of 1,471 species of fish are traded globally. Most of these species are associated with coral reefs although a relatively high

Table 1: Total number of fish traded as ornamentals

As derived from exporters' and importers' data in GMAD.

Year	Total fish traded (exporters' data)	Total fish traded (importers' data)
1991	-	530,612
1992	-	639,070
1993	-	541,063
1994	-	467,715
1995	-	550,028
1996	8,540	812,661
1997	5,268	629,847
1998	15,739	1,326,953
1999	642,961	1,383,106
2000	1,695,414	605,532
2001	1,122,217	434,760
2002	94,084	17,481
2003	4,183	-
Total	3,588,406	7,938,828

Figure 1: Global trade of fish broken down by family



number of species are associated with other habitats such as seagrass beds, mangroves and mudflats.

According to data provided by exporters, the Philippines, Indonesia, the Solomon Islands, Sri Lanka, Australia, Fiji, the Maldives and Palau, together, supplied more than 98 per cent of the total number of fish exported between the years 1997 and 2002. (See Table 2.)

GMAD trade records from importers for years 1997-2002 showed that the United States, the United Kingdom, the Netherlands, France and Germany were the most important countries of destination, comprising 99 per cent of all imports of marine ornamental fish. Exporters' data revealed Taiwan, Japan and Hong Kong to be important importing areas. (See Table 3.)

Looking at the most commonly traded families, species of Pomacentridae dominate, accounting for 43 per cent (according to importers' data in GMAD) of all fish traded. They are followed by species belonging to Pomacanthidae, Acanthuridae, Labridae, Gobiidae, Chaetodontidae, Callionymidae, Microdesmidae, Serranidae and Blenniidae. (See Figure 1.)

For the years 1997-2002, the blue-green damselfish (*Chromis viridis*), the clown anemonefish (*Amphiprion ocellaris*), the whitetail dascyllus (*Dascyllus aruanus*), the sapphire devil (*Chrysiptera cyanea*) and the threespot dascyllus (*Dascyllus trimaculatus*) are the most commonly globally traded species. (See Table 4, overleaf.) The top ten species together account for 36 per cent of all fish traded from 1997 to 2002, according to data provided by importers.

Table 2: Main source countries of marine ornamental fish

Total number of fish traded as derived from exporters' and importers' data for the years 1997 to 2002 in GMAD. Percentage of total trade for individual countries is also presented

Origin	No. of fish exported (exporters' data)	% of total no. of fish traded	Origin	No. of fish exported (importers' data)	% of total no. of fish traded
Philippines	1,523,854	43	Unknown	3,556,772	81
Indonesia	943,059	26	Indonesia	316,355	7
Solomon Islands	416,262	12	Fiji	237,872	5
Sri Lanka	183,537	5	Philippines	81,294	2
Australia	173,323	5	Sri Lanka	60,220	1
Fiji	131,746	4	Solomon Islands	25,732	1
Maldives	78,018	2	Maldives	22,165	1
Palau	63,482	2			
Total	**3,513,281**	99	**Total**	**4,300,410**	98

Table 3: Main importers of marine ornamental fish

Total number of fish traded as derived from exporters' and importers' data for the years 1997 to 2002 in GMAD. Percentage of total trade for individual countries is also presented.

Destination	No. of fish imported (exporters' data)	% of total no. of fish traded	Destination	No. of fish imported (importers' data)	% of total no. of fish traded
USA	1,462,347	41	USA	3,054,273	69
Unknown	788,230	22	United Kingdom	874,557	20
Taiwan	244,454	7	Netherlands	264,976	6
Japan	223,613	6	France	103,234	2
Hong Kong	152,738	4	Germany	99,955	2
France	132,439	4			
Germany	119,739	3			
Netherlands	117,248	3			
Italy	70,686	2			
United Kingdom	48,911	1			
Total	**3,360,405**	93	**Total**	**4,396,995**	99

Table 4: The ten most traded species of ornamental fish worldwide

Totals for number of fish are derived from exporters' and importers' data in GMAD for years 1997 to 2002. Species common to both datasets are in bold.

Species	No. of specimens (exporters' data)	Species	No. of specimens (importers' data)
Amphiprion ocellaris	145,015	***Chromis viridis***	322,587
Chrysiptera cyanea	111,705	*Zebrasoma flavescens*	198,869
Dascyllus aruanus	103,948	***Amphiprion ocellaris***	166,119
Amphiprion percula	101,092	***Dascyllus aruanus***	164,094
Chromis viridis	99,451	*Pomacentrus australis*	161,796
Abudefduf spp.	78,945	*Chrysiptera parasema*	156,069
Dascyllus trimaculatus	78,536	***Chrysiptera cyanea***	121,657
Paracanthurus hepatus	74,557	*Dascyllus spp.*	116,861
Dascyllus albisella	73,726	***Dascyllus trimaculatus***	102,650
Chrysiptera hemicyanea	61,914	*Labroides dimidiatus*	86,885
Total	**928,889**	**Total**	**1,597,587**

Table 5: The top ten species of ornamental fish imported into the EU

Totals for number of fish are calculated from exporters' and importers' data in GMAD for years 1997 to 2002. Species common to both datasets are in bold

Species	No. of specimens (exporters' data)	Species	No. of specimens (importers' data)
Amphiprion ocellaris	44,881	***Amphiprion ocellaris***	123,640
Chromis viridis	29,717	***Chromis viridis***	103,682
Labroides dimidiatus	21,833	***Chrysiptera cyanea***	43,767
Chrysiptera hemicyanea	12,111	*Chrysiptera parasema*	42,576
Salarias fasciatus	12,019	*Zebrasoma flavescens*	38,411
Chrysiptera cyanea	11,776	*Dascyllus trimaculatus*	33,078
Paracanthurus hepatus	11,345	***Labroides dimidiatus***	33,073
Synchiropus splendidus	11,168	***Paracanthurus hepatus***	28,674
Pseudanthias squamipinnis	10,892	***Pseudanthias squamipinnis***	23,134
Acanthurus leucosternon	10,290	*Nemateleotris magnifica*	21,897
Total	**176,032**	**Total**	**491,932**

For the years 1997-2002, *Amphiprion ocellaris*, *Chromis viridis*, the bluestreak cleaner wrasse (*Labroides dimidiatus*), *Chrysiptera cyanea*, the palette surgeon-fish (*Paracanthurus hepatus*), and the sea goldie (*Pseudanthias squamipinnis*) are the most commonly imported species into the EU. Together the top ten species make up 37 per cent of all fish imported into the EU between 1997 and 2002, according to importers' data. (See Table 5.)

A similar analysis for the United States showed that the top ten species (common to both exporters' and importers' datasets), including *Dascyllus aruanus*, *Chrysiptera cyanea*, *Dascyllus trimaculatus* and *Labroides dimidiatus*, accounted for 39 per cent of all fish species exported to the United States. (See Table 6.)

Seahorses

GMAD importers' data showed that for all years (1988-2002) the United States imported a total of 67,998 seahorses. The main exporters were Sri Lanka, Brazil, Indonesia and the Philippines. Based on exporters' information (1999-2003), the United States imported 5,638 live specimens, Japan 2,711, Taiwan 3,412 and the rest of the world 2,688.

Table 6: The top ten species of ornamental fish imported into the United States

Totals for number of fish are derived from importers' and exporters' data in GMAD for years 1997 to 2002. Species common to both datasets are in bold.

Species	No. of specimens (exporters' data)	Species	No. of specimens (importers' data)
Abudefduf spp.	78,749	*Chromis viridis*	218,905
Chrysiptera cyanea	73,536	*Pomacentrus australis*	161,740
Dascyllus aruanus	72,435	*Zebrasoma flavescens*	160,458
Dascyllus albisella	60,328	***Dascyllus aruanus***	147,525
Amphiprion percula	59,710	*Dascyllus spp.*	116,306
Chrysiptera hemicyanea	38,162	*Chrysiptera parasema*	113,493
Paracanthurus hepatus	31,636	***Chrysiptera cyanea***	77,890
Chromis atripectoralis	30,912	***Chrysiptera hemicyanea***	76,960
Dascyllus trimaculatus	30,267	***Dascyllus trimaculatus***	69,572
Labroides dimidiatus	28,110	***Labroides dimidiatus***	53,812
Total	**503,845**	**Total**	**1,196,661**

The threespot dascyllus, *Dascyllus trimaculatus*.

Seahorse, *Hippocampus erectus*.

EC Annex D data show that 106,662 seahorses were reported as imported into the EU between 1997 and 2001. GMAD data for this period show a total of 20,477 seahorses reported as imported into EU countries (or 24,647 specimens between 1996 and 2002). Data from exporters show a total of 6,138 seahorses exported to the EU between 1999 and 2003. Annex D data show the Netherlands, Germany, Italy, Austria and the United Kingdom as the main importers of seahorses in the EU, accounting for some 94 per cent of all EU imports. Similarly GMAD data from both importers and exporters show the Netherlands, Germany, Italy and the United Kingdom to have been the main European importers.

The Philippines, Indonesia, Sri Lanka, Brazil and Singapore were the main countries of export and accounted for 96 per cent (102,074 specimens) of all reported imports of seahorses into EU countries between 1998 and 2001 according to Annex D data. GMAD importers' data show Sri Lanka, Indonesia, Brazil and the Philippines to be the most significant exporters of seahorses. Singapore does not appear as a significant exporter of seahorses based on GMAD data compared to more than 7,000 exports using Annex D figures.

Trade data from both Annex D and GMAD indicate that *Hippocampus erectus* and *Hippocampus kuda* are the most commonly traded species and show that a large number of individuals are being traded as *Hippocampus* spp. (35 per cent of Annex D data, 73 per cent of GMAD importers' data). The large number of traded individuals recorded as *Hippocampus* spp. is undoubtedly a reflection of the difficulties experienced in identification of individual species. The high level of synonymy in the *Hippocampus* genus also means that there may be errors in the trade data. For example, reports indicate that there may be more than one species traded under the name *H. kuda*[60]. Indeed, seahorse taxonomy (identification of individual species) has undergone many changes over recent years and a number of new species have been described[60-62].

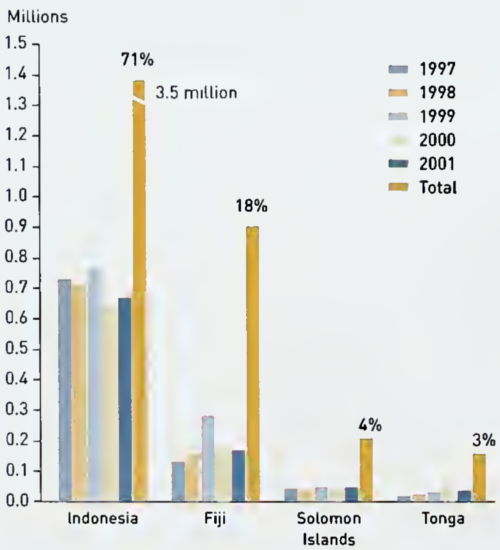
As an interesting note, although it is strictly illegal to import tropical species under the name of *H. kuda* into France[166], GMAD lists a total of 328 specimens from Indonesia, Sri Lanka and the Philippines as imported into France as *H. kuda* between the years 1997 and 2001.

CORALS

The term 'corals' encompasses both stony corals, defined as 'marine colonial polyps characterized by a calcareous skeleton that often form reefs[63], soft corals and sea fans. However, most literature found on trade in live coral specimens refers to the trade in stony coral species. There has been much debate about what exactly constitutes a 'soft coral'. The term is most commonly used to refer to species of the subclass Octocorallia (class Anthozoa), which have no massive skeleton. However, the term 'soft coral' often extends to contain sea fans, which are actually supported by an internal axis[64] and hence will be addressed separately here. In this report, we will use the term 'soft coral' to include all species under the order Alcyonacea (soft coral and Stolonifera) with the exception of *Tubipora musica* which, due to its calcified skeleton, we have included under stony corals. Overall, according to data held in GMAD, there are 61 species of soft corals and 140 species of stony corals in trade, although this number is to be treated with caution due to the complexity experienced in coral taxonomy.

Figure 2: Major exporters of live and wild-sourced coral (pieces)

Totals are derived from importers' data.



Stony corals

According to CITES data, the global live coral trade rose steadily from 1997 to 1999 with 934,463 live pieces and 1,142,242 live pieces being traded worldwide respectively in those years. The trade decreased to 942,661 pieces in 2001. Since the late 1980s, Indonesia has become the largest coral exporting country[32]. CITES figures show that direct exports of live wild-sourced coral from Indonesia represented 78 per cent (729,703 pieces) of the global total for all coral species in 1997, 66 per cent (640,190 pieces) in 2000 and 71 per cent (669,192 pieces) in 2001. (See Figure 2.) The numbers are based on data reported by importers because values based on exporters' information are an indicator of the number of permits issued rather than the actual quantity of corals exported for the aquarium trade. To illustrate the difference, in 2001 data from all importers showed a total of 669,192 pieces having been exported from Indonesia, whilst information provided by exporters indicate 1,442,413 pieces were exported from Indonesia.

Data from 1997 to 2001 show Indonesia, Fiji, the Solomon Islands and Tonga together supplying more than 95 per cent of live coral exports. Since the late 1990s Fiji has been playing an increasing role as an exporter of live coral. It is the major source country of live coral for the aquarium trade in the Pacific Islands with smaller contributions from Tonga, Vanuatu and the Solomon Islands. Fiji presently receives approximately US$12 million per year in export revenue from the trade in live coral[65]. Although statistics on live coral exports are available from the Fijian Fisheries Division, values cannot be used to assess the volume of live coral being extracted from Fiji as they include re-exports that originated primarily from Tonga, the Solomon Islands, Vanuatu and Bali, and data represent maximum permitted exports rather than actual exports. Moreover, live coral export figures have often tended to include live rock exports, thus artificially inflating live coral statistics. Based on these issues, the Fijian coral industry is presently under review by the Fisheries Division to ensure that harvest

Table 7: The top ten most commonly traded genera of corals worldwide

Totals for number of pieces are derived from importers' and exporters' data in GMAD for years 1988 to 2002 and 1998 to 2003 respectively. Genera common to both datasets are in bold.

Genera	No. of pieces (exporters' data)	Genera	No. of pieces (importers' data)
Scleractinia*	208,122	***Trachyphyllia***	37,082
Goniopora	192,697	***Euphyllia***	31,614
Euphyllia	191,670	***Goniopora***	27,322
Trachyphyllia	115,262	***Acropora***	26,451
Catalaphyllia	90,498	***Plerogyra***	13,878
Acropora	79,720	*Lobophyllia*	11,933
Heliofungia	77,924	**Scleractinia***	11,035
Plerogyra	60,691	***Catalaphyllia***	10,907
Porites	48,889	*Favia*	9,531
Turbinaria	47,729	***Turbinaria***	8,955
Total	**1,113,202**	Total	**188,708**

* Unidentified stony corals

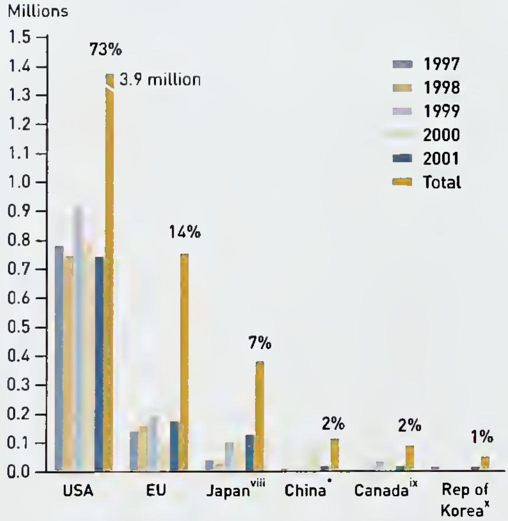
levels are sustainable and to agree a system under which export statistics reflect true imports. A recent audit at one of the largest Fijian export companies showed that the actual export figure was approximately 9 per cent of the recorded declared value[45]. Until this case has been resolved and the CITES Secretariat has published agreed quotas on the CITES website, Parties to the Convention should not accept any export permits for specimens of CITES-listed coral species from Fiji[66].

For the years 1997 to 2001, CITES statistics show the major importers of stony corals to be the United States, Japan[viii], Germany, France, China (including Hong Kong), Canada[ix], the Netherlands and the United Kingdom, together importing more than 95 per cent of the total number of live corals being traded worldwide. Taking the EU as one statistical entity, 73 per cent of total live coral imports are accounted for by the United States, 14 per cent by the EU, 7 per cent by Japan, 2 per cent by China (including Hong Kong), 2 per cent by Canada and 1 per cent by the Republic of Korea[x]. (See Figure 3.)

Commonly traded coral genera, based on CITES export and import data 1999-2001, include *Acropora* (staghorn, cluster, bluetip, bush, cat's paw or bottlebrush coral), *Catalaphyllia* (elegance coral), *Euphyllia* (anchor or hammer coral), *Galaxea* (galaxy coral), *Goniopora* (flowerpot coral), *Heliofungia* (mushroom coral), *Lobophyllia* (lobed brain coral), *Plerogyra* (bubble or grape coral), *Trachyphyllia* (open brain coral), *Turbinaria* (cup coral) and Scleractinia. However, the last is likely to include a large proportion of traded live rock[67]. These findings are corroborated by data within GMAD showing the same genera as the top ten species in trade from both importers' and exporters' datasets, from 1988 to 2002 and 1998 to 2003 respectively. GMAD also lists *Favia* and *Porites* as common in trade. With the exception of *Acropora*, most of the genera listed are slow-growing and

Figure 3: Major importers of live and wild-sourced coral (pieces)

The EU is taken as one 'entity'. Totals are derived from importers' data except where otherwise stated.



* Including Hong Kong

Table 8: The top ten species of corals imported into the United States, the EU and Japan

Totals for number of pieces are derived from importers' data in CITES for years 1997 to 2001. Japan's data are based on exporters' reports for 1997 and years 1999-2001, as Japan's Annual Reports for 1999-2001 are not available and they did not report any coral imports for 1997.

Top ten imports USA

Taxon	No. of pieces
Scleractinia spp.	1,838,843
Euphyllia spp.	304,257
Goniopora spp.	201,847
Acropora spp.	191,475
Trachyphyllia spp.	180,351
Catalaphyllia spp.	159,693
Plerogyra spp.	116,623
Heliofungia actiniformis	96,515
Lobophyllia spp.	65,016
Turbinaria spp.	63,508

Top ten imports EU

Taxon	No. of pieces
Scleractinia spp.	153,244
Acropora spp.	47,917
Euphyllia spp.	40,207
Goniopora spp.	37,356
Trachyphyllia spp.	26,254
Plerogyra spp.	25,035
Catalaphyllia spp.	23,884
Goniopora lobata	19,178
Heliofungia actiniformis	18,626
Goniopora stokesi	17,353

Top ten imports Japan

Taxon	No. of pieces
Scleractinia spp.	44,232
Trachyphyllia geoffroyi	28,622
Catalaphyllia jardinei	20,657
Euphyllia glabrescens	17,099
Goniopora minor	16,342
Goniopora stokesi	15,836
Goniopora lobata	15,103
Heliofungia actiniformis	14,895
Euphyllia cristata	10,010
Goniopora spp.	9,963

some generally occur at low densities, although information on both densities in the field and growth rates is usually limited.

For the United States, the EU and Japan (the three main importers), according to CITES data the top ten species imported were combinations of species of the above listed genera. (See Table 8.)

Button/meat coral, *Cynarina*.

In 1997, Indonesia established quotas for coral export. In 1999, the CITES Scientific Review Group of the European Commission (SRG-EC) questioned the scientific basis for the export quotas set by the Indonesian authorities. This resulted in a temporary suspension (still ongoing for many) of the export of the following seven species of stony coral from Indonesia into the 15 EU Member States[xi]: *Blastomussa merleti, Catalaphyllia jardinei, Cynarina lacrymalis, Euphyllia divisa, Euphyllia glabrescens, Plerogyra simplex* and *Trachyphyllia geoffroyi*. In 2000, the trade suspension was extended to additional species: the complete genera of *Euphyllia* and *Plerogyra, Hydnophora exesa, Hydnophora microconos* and *Blastomussa wellsi*. Since then positive opinions (temporary import suspension is lifted) have been given for *E. ancora, E. glabrescens* and *H. exesa* from Indonesia. In addition negative opinions[vii] (temporary trade suspensions) on *Goniopora lobata, Plerogyra turbida, Scolymnia vitiensis* and *Wellsophyllia radiata* for Indonesia and *Blastomussa wellsi, Scolymnia vitiensis, Catalaphyllia jardinei, Euphyllia yaeyamaensis, Hydnophora rigida, Plerogyra simplex, P. sinuosa* and *Trachyphyllia geoffroyi* for Fiji have been formed[69].

The EU import restrictions for stony corals have been put in place mainly due to a lack of information on their population status and life history characteristics. Understanding the biology and life history of stony corals is essential in developing ecologically sustainable quotas, and the need for such research should be highlighted.

Soft corals and sea fans

Most of the soft corals in trade originate from the Indo-Pacific Ocean. Although soft coral farming is considered to be simple and straightforward[70], very few specimens are of cultured origin. American Samoa represents an exception[52]. Despite high numbers of specimens being traded for use in aquaria, soft corals are not, unlike stony corals, covered under CITES[54]. No mechanisms other than GMAD exist to monitor quantity, origin and destination of species in trade. GMAD data indicate that a total of 386,849 pieces of live soft coral (according to importers' data) were traded between 1988 and 2002. Based on exporters' data, the quantity of soft corals traded between 1998 and 2003 accounted for 7 per cent of all coral exports (soft and stony).

The United States is the world's largest soft coral importer, receiving 67 per cent (according to importers' data for years 1988-2002 and equivalent to 259,472 live pieces) of the total trade in soft corals. Indonesia appears as the largest exporting country of soft corals.

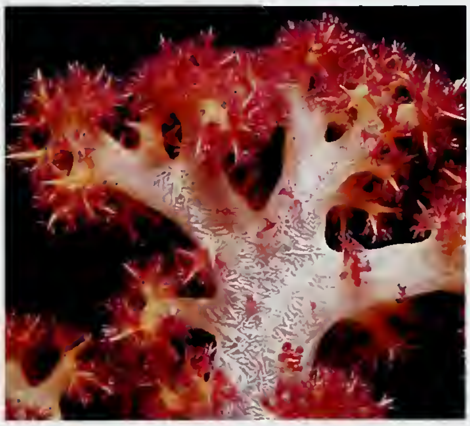
Based on GMAD importers' data (1988-2002), the most commonly traded soft coral genera worldwide are (ordered by genera most traded): *Sarcophyton* (leather/mushroom/toadstool coral), *Sinularia* (finger leather/soft finger/digitate leather coral), *Xenia* (pulse coral), *Cladiella* (cauliflower/finger/colt/blushing coral), *Clavularia* (clove polyp), *Anthelia* (waving hand polyp), *Lobophytum* (finger leather coral), *Nephthea* (broccoli coral), *Dendronephthya* (carnation/strawberry coral) and *Cespitularia* (blue xenia).

The trade in leather coral, *Sarcophyton* spp.

Sarcophyton spp. is the most commonly traded soft coral. This mushroom-like zooxanthellate[xiii] species is hardy, fast growing and easily propagated in aquarium conditions. Under the *Sarcophyton* genus at least five species are known to be traded as aquarium specimens: *S. ehrenbergi*, *S. glaucum*, *S. latum*, *S. tenuispiculatum* and *S. trocheliophorum*. As reported by importers in GMAD these five species made up 17 per cent of the total amount of soft corals traded (importers' data 1988-2002).

Indonesia emerged as the world's major exporter of *Sarcophyton* spp., supplying 85 per cent of the total global trade in this species (exporters' data 1998-2003). The United States was the world's largest importer, accounting for 64 per cent (according to importers' data) of the total number of soft corals traded.

The trade in carnation coral, *Dendronephthya* spp.

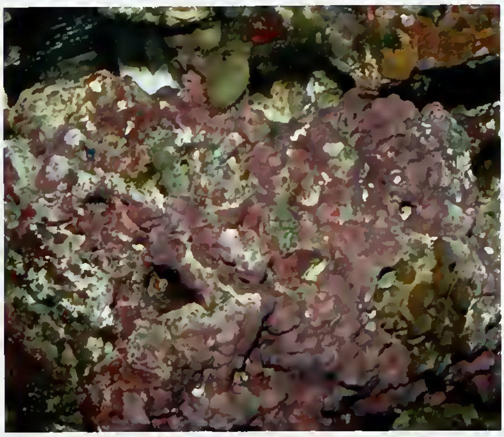


Dendronephthya spp. is among the top ten traded soft corals. Species under this genus are extremely difficult to maintain in aquaria as they are azooxanthellate and hence entirely dependent on filtering particles and absorbing dissolved nutrients from the water column. In captivity they usually die within a few weeks. Aquarists are strongly encouraged not to keep *Dendronephthya* spp. Two species in particular are known to be traded as ornamentals: *D. klunzingeri* and *D. rubeola*.

Between 1988 and 2002 a total of 12,618 live pieces of *Dendronephthya* spp. were traded globally. Worldwide, the United States emerged as the largest importer, accounting for 51 per cent of the total trade in *Dendronephthya* spp. Indonesia emerged as the biggest exporter of *Dendronephthya* spp. (20 per cent of all soft coral traded according to importers' data).

Eight genera of sea fans appear in GMAD trade records: *Ctenocella*, *Echinogorgia*, *Ellisella*, *Euplexaura*, *Gorgonia*, *Lophogorgia*, *Pseudopterogorgia* and *Rumphella*. The genus *Gorgonia* is the most well known and commonly traded sea fan (14 per cent or 55,375 pieces according to importers' data 1988-2002), with at least two species often recorded in GMAD: *G. flabellum* and *G. ventalina*. US imports accounted for 99 per cent (54,976 pieces) of all imported *Gorgonia* spp. specimens.

Live rock



Fiji is the world's primary supplier of live rock, with data showing that in 2001 more than 800 tonnes of live rock were harvested from its reefs[73], about 95 per cent of which were destined for the United States[74]. True collection figures are likely to be greater as large quantities of harvested live rock, subsequently considered unsuitable for export, are often discarded and thrown back into the sea. In Fiji, the extraction of live rock takes place along the edges of the reef or within the shallow lagoon. During collection villagers selectively target rocks with a diameter of 15-35 cm[45] covered with light to dark pink coralline algae and remove them from the reef framework using iron rods. These are then loaded up onto a *bilibili*, or bamboo raft, and dragged onto the beach by horses. The rocks are placed into boxes and loaded onto a waiting truck that takes them to a processing facility. Once at the facility, the rock is placed under showers, which continually spray salt water for 24–72 hours before shipment. It is trimmed of all visible green algae growth and graded according to shape, weight and percentage of coralline algae cover.

Live rock trade constitutes an important source of revenue for the inhabitants of Malomalo (one of the most important live rock collection sites in Fiji). Since 1994, live rock has been collected at Malomalo for Ocean 2000, a local wholesaler, by the traditional male users of the reef, both on a full time and an occasional basis. The rock is reimbursed at a price of US$0.70 per kilo, which is divided among the collectors (US$0.50), the custodian (US$0.10) and the marine reserve that forms part of the village's traditional fishing grounds (US$0.10). As this item is bought and sold by weight it is the highest income earner for the villagers participating in the aquarium trade industry. A full-time harvester extracts on average 7,500 kg a year (an average of 150 kg live rock extracted per week) contributing US$3,750 to annual household income.

However, after nine years of extraction, the villagers raised concerns that live rock collection could have detrimental long-term consequences for their reefs. Large-scale removal of live rock, the result of hundreds of years of accretion, can destroy reef habitat, undermining the structure of coral reefs and leading to increased erosion as well as reduced biodiversity. Some fishers noticed that quantities of fish and other marine species typically collected from areas used for collection of live rock had been reduced[45]. The World Wide Fund for Nature (WWF) and MAC joined forces to respond to the villagers' concerns and those expressed by the Fijian government about the sustainability of the industry. They worked to develop community-based processes for wise coral harvesting and management, which also involved helping the government structure sound policies and legislation that would support a sustainable aquarium trade. Moreover, the villagers of Malolomo designated part of their traditional fishing grounds a *tabu* area, in which extractive use was banned.

The International Coral Reef Action Network (ICRAN) recently also developed a project with the major objective of ensuring the sustainability of the coral trade industry in Fiji. Should this be achieved, coastal communities (mainly around Viti Levu, where returns often do not reflect the market value of the product) will be able to share fairly the benefits of the marine aquarium trade industry without compromising the health of their reefs.

Source: WWF[73] and ICRAN[76]

Live rock

CITES defines live rock as 'pieces of coral rock to which are attached live specimens of invertebrate species and coralline algae not included in the CITES Appendices and which are transported moist, but not in water, in crates[71]. Typical inhabitants of live rock are anemones, tunicates, bryozoa, octocorals, sponges, echinoids, molluscs, sabellarid and serpulid tubeworms, and calcareous algae. Besides the aesthetic role live rock plays in aquaria, the organisms which live in live rock, through consumption of waste and production of oxygen, filter the water and prevent the build-up of nitrate.

There are three 'types' of live rock in trade: Pacific, Atlantic and aquacultured. Hobbyists tend to prefer Pacific rock because it is very porous, light, and usually has a nice cover of coralline algae[72]. Atlantic live rock is less popular because it is fairly dense and the rock's shapes are less intricate than those commonly found in Pacific rock. Due to the large amounts of coral rock being exported from the Florida Keys in the early 1990s, the State banned the harvest of live rock from its waters in 1997. As a result, marine ornamental companies in the United States started to develop aquaculture for live rock. To 'create' such live rock,

Table 9: Main source countries of marine ornamental invertebrates

Total number of invertebrates traded as derived from exporters' data (1998-2003) and importers' data (1988-2002) in GMAD. Percentage of total trade for individual countries is also presented.

Origin	No. of invertebrates imported (exporters' data)	% of total no. traded	Origin	No. of invertebrates imported (importers' data)	% of total no. traded
Indonesia	561,506	44	Unknown	2,441,742	80
Philippines	460,817	36	Mexico	246,485	8
Sri Lanka	100,309	8	Indonesia	104,282	3
Solomon Islands	75,305	6	Singapore	68,190	2
Fiji	53,823	4	Fiji	48,358	2
Palau	10,315	1	Sri Lanka	33,782	1
			Philippines	29,440	1
			Vanuatu	15,904	1
Total	**1,262,075**	**99**	**Total**	**2,988,183**	**98**

Table 10: Main importing countries of marine ornamental invertebrates

Total number of invertebrates traded as derived from exporters' data (1998-2003) and importers' data (1988-2002) in GMAD. Percentage of total trade for individual countries is also presented.

Destination	No. of invertebrates imported (exporters' data)	% of total no. traded	Destination	No. of invertebrates imported (importers' data)	% of total no. traded
USA	445,085	35	USA	2,454,350	80
Taiwan	275,024	22	United Kingdom	453,430	15
France	140,032	11	Netherlands	61,525	2
Unknown	127,342	10	France	51,768	2
Germany	69,840	5	Germany	49,359	1
Japan	50,456	4			
Netherlands	37,253	3			
Italy	33,667	3			
United Kingdom	22,545	2			
Hong Kong	18,190	1			
Total	**1,219,434**	**96**	**Total**	**3,070,432**	**100**

regular dry rock is placed in the ocean and harvested one to several years later.

Live rock can be purchased either 'cured' or 'uncured'. On collection from the ocean the rocks harbour a large variety of sea life some of which, such as certain species of anemones and mantis shrimp, are common pests on live rock. 'Uncured' rock is rock that has been collected and directly exported. 'Cured' rock, on the other hand, is material that has been placed under a fine spray of high salinity water for several hours or days prior to export. The objective is to keep the coralline algae alive but kill and wash out less hardy, unwanted organisms, which would foul the tank water.

According to CITES importers' data (1990-2001) the United States, the EU, the Republic of Korea, Hong Kong and Canada, together, imported a total of 3,897,654 pieces of live Scleractinia spp. of which one can assume a large component to be live rock[67]. The same data also show the United States, the EU and Canada importing 2,048,630 kg of Scleractinia spp. Based on importers' data (1990-2001) Fiji, the Marshall Islands, Tonga, Samoa, the Solomon Islands, the ex-Trust Territories (Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia), Vanuatu, Haiti, Indonesia and the Dominican Republic emerged as the top ten exporters of live wild-sourced Scleractinia spp. supplying 2,047,785 kg

Table 11: The ten most traded species of marine ornamental invertebrates worldwide

Totals for number of invertebrates are derived from exporters' and importers' data in GMAD for years 1998 to 2003 and 1988 to 2002 respectively. Species common to both datasets are in bold

Species	Common name	No. of specimens (exps' data)
Trochus spp.	Topshell or trochus shell	272,203
Unspecified invertebrates		247,038
***Lysmata* spp.**	Cleaner shrimp	107,452
***Heteractis* spp.**	Sea anemone	54,369
***Stenopus* spp.**	Banded coral shrimp	42,802
Tridacna spp.	Giant clam	37,521
Linckia spp.	Blue sea star	32,509
Rhynchocinetes spp.	Camel shrimp	30,846
Stichodactyla spp.	Carpet anemone	27,341
Strigopagurus spp.	Hermit crab	24,512
Total		**876,593**

Species	Common name	No. of specimens (imps' data)
Turbo spp.	Turbo snail	328,778
***Lysmata* spp.**	Cleaner shrimp	288,484
Condylactis spp.	Condy/Atlantic/Haitian anemone	229,925
***Heteractis* spp.**	Sea anemone	149,025
Dardanus spp.	Hermit crab	147,006
Tectus spp.	Mollusc	143,448
Paguristes spp.	Hermit crab	136,280
Sabellidae spp.	Feather worm	128,248
Actinodiscus spp.	Disc/Mushroom anemone	123,357
***Stenopus* spp.**	Banded coral shrimp	93,449
Total		1,768,000

Topshell or snail

***Tectus* spp., *Trochus* spp. (pictured) and *Turbo* spp. are gastropod molluscs found on shallow tropical reefs throughout the Indo-Pacific. These species are mainly herbivorous, feeding on fleshy algae and algal films**

that typically develop on live rock, although they are also known to forage on organic detritus[77]. They do well in aquarium conditions when provided with ample hiding places and room to forage, since overcrowded conditions may cause stress and disease. Although trochus farms are now well established in many of the Pacific Island states, they are mainly cultured to craft buttons and jewellery and for food consumption. Thus most specimens in trade as marine ornamentals were probably collected in the wild[78].

to the trade (probably mostly aquarium). CITES data based on importers' information showed Indonesia, Fiji, Tonga, Solomon Islands, Samoa, the Marshall Islands, Haiti, the ex-Trust Territories, Singapore and Vanuatu to also supply the trade with 3,892,169 pieces.

As with live coral export statistics, government statistics for Fijian live rock exports cannot be used to assess the volume of live rock being extracted from Fiji. From January to July 1999, the largest Fijian exporter shipped 291,837 kg of live rock, 48 per cent of the permitted quota of 606,000 kg. Despite this fact, and the fact that the shipment included live rock from Tonga, 606,000 kg is the figure recorded in Fiji export data[45].

INVERTEBRATES

Many invertebrates other than corals are popular in the aquarium trade. According to data held in GMAD, 516 species of invertebrates are being traded for the aquarium trade. However, this figure needs to be treated with some caution due to the lack of a standard taxonomy for marine invertebrates.

Based on GMAD a total of 1,271,547 invertebrates were traded between 1998 and 2003, according to exporters' information (or 3,071,385 according to records from importers between 1988 and 2002). Mexico, Indonesia, Singapore, Fiji, Sri Lanka, the Philippines and Vanuatu emerged as the main exporters (according to importers' data for the years 1988-2002), accounting for close to 17 per cent of the trade. Exporters' data for the years 1998-2003 also showed the Solomon Islands and Palau to be significant source countries of marine ornamental invertebrates. (See Table 9, p 27.)

Based on importers' data the main destination countries were: the United States, the United Kingdom, the Netherlands, France, Germany, Italy and Canada, constituting close to 100 per cent of all marine invertebrates imported for the marine aquarium trade between 1988 and 2002. Looking at exporters' data for the years 1998-2003 Taiwan, Japan and Hong Kong also emerged as important importers. (See Table 10, p 27.)

The main species in trade and common to both exporters' and importers' datasets within GMAD are *Lysmata* spp., *Heteractis* spp. and *Stenopus* spp. (See Table 11, p 28.) Other species, which occur in only one dataset's top ten, include *Turbo* spp., *Tridacna* spp. and *Trochus* spp. All top ten species together account for 67 per cent of all invertebrates traded between 1998 and 2003 (according to exporters' data).

The ten most traded invertebrates are mainly comprised of species that feed on algae (e.g. *Tectus* spp., *Trochus* spp. and *Turbo* spp.), parasites or dead tissue (e.g. cleaner shrimp) and dead animals (e.g. hermit crabs). These species are particularly important in controlling algae growth and parasites that may find a host in fish kept in aquaria. However, removal of cleaner species from their natural habitats may lead to a reduction in diversity on harvested reefs as their function is then absent (see box on Cleaner fish in Conservation issues, page 36).

Giant clams

Giant clams represent an increasingly large proportion of the exports of live invertebrates destined as aquarium specimens. Although additional lighting is often required in order to maintain giant clams, they play an important role in removing nitrates, nitrites and ammonia from aquaria water, elements considered as

Blue starfish, *Linckia laevigata*

The most commonly imported sea star in the aquarium trade is *Linckia laevigata*. According to exporters' data within GMAD this species accounted for 3 per cent (32,509 pieces) of the total trade in invertebrates. Experienced hobbyists warn that they are very difficult to maintain in aquarium conditions[79]. Their poor survival rate in aquaria may be due to their dietary needs of organically enriched films (or detritus) that typically cover live rock[77]. They should therefore not be placed in a newly set up tank (less than six months), or one in which there is not enough live rock to explore. Furthermore, they are known to often refuse artificial aquarium food. As common predators of sea stars in captivity are dog-faced puffers (*Arothron nigropunctatus*), these two species should not be allowed to co-exist in an aquarium. Small parasitic snails (*Thyca crystallina*) are also known to prey on *L. laevigata*[79].

The nine giant clams (tridacnids) common in trade

❑ *Tridacna maxima*: the rugose or small giant clam is the most wide-ranging of all giant clam species, being found from the east coast of Africa, through the Indian Ocean and across the Pacific to Polynesia and Pitcairn[83]. It is still relatively abundant throughout its range although its status in the Indian Ocean is poorly known. It has a distinct brightly coloured mantle (blue, green and brown), which makes it particularly attractive for the aquarium trade. GMAD data show a total of 15,172 specimens as exported from Viet Nam, Fiji, the Solomon Islands, Tonga, Vanuatu, the United States and unknown countries between 1991 and 2001 (importers' data) (or a total of 8,215 from Fiji and the Solomon Islands between 2000 and 2001 based on exporters' data).

❑ *T. squamosa*: the fluted or scaly giant clam has a generally speckled mantle in blue, brown and green. Like *T. maxima*, it is fairly abundant throughout its range although little is known of its status in the Indian Ocean. GMAD data show a total of 6,711 *T. squamosa* as exported from Fiji, Indonesia, the Solomon Islands, Vanuatu, Viet Nam and unknown source countries between 1991 and 2001 (importers' data) (or a total of 2,339 from Fiji, Indonesia and the Solomon Islands between 1999 and 2001 based on exporters' data).

❑ *T. crocea*: the crocus or boring giant clam, although smaller, is similar to *T. maxima* in that it has a brightly coloured mantle. It is assumed to be generally widespread throughout its distribution area, from the west coast of the Malaysian peninsula, the South China Sea, the Coral Sea, southern Japan to southern Australia, to Micronesia and east to Palau[83]. Like *T. maxima* it is a popular species in the aquarium trade. GMAD data show a total of 11,685 *T. crocea* as exported from the Solomon Islands, Vanuatu, Viet Nam and unknown source countries between 1991 and 2001 (importers' data) (or a total of 17,881 from Fiji, Indonesia and the Solomon Islands between 2000 and 2001 based on exporters' data).

❑ *T. gigas*: is considered to be the true giant clam as it can reach dimensions of more than 1.4 m in shell length. The mantle is brown-green with blue or green spots. This species is particularly sought after for food. It has suffered extensive reductions throughout its range due to overexploitation and is extinct in Fiji, Guam, New Caledonia, most areas of the Philippines and the Northern Marianas. Population levels have been dangerously reduced in most of Japan, Taiwan, Tuvalu, the Federated States of Micronesia and Vanuatu. GMAD data show a total of 1,808 *T. gigas* as exported from the Solomon Islands, Vanuatu and unknown source countries between 1991 and 2000 (importers' data) (or a total of 149 from Palau, Indonesia and the Solomon Islands between 2000 and 2001 based on exporters' data).

❑ *T. derasa*: the smooth or southern giant clam is the second largest species with its shell reaching lengths of up to 60 cm. Its mantle has elongate brown, green and blue patterns. It is known to be fairly abundant in Palau, northern Papua New Guinea, Australia, the Solomon Islands, New Caledonia, Fiji and Tonga. Although it has been reintroduced in a number of locations outside its natural range, wild stocks have only become established in Yap. GMAD data show a total of 24,960 *T. derasa* exported from the Solomon Islands, Vanuatu and unknown source countries between 1988 and 2001 (importers' data) (or a total of 8,937 from Fiji, Palau, Indonesia and the Solomon Islands between 2000 and 2001 based on exporters' data).

❑ *T. tevoroa*: the deep water devil clam is a rare species that only lives at depths greater than 20 m in the northern Tonga Islands and eastern Fiji Islands. No data in GMAD.

❑ *T. rosewateri*: is a newly described species similar to *T. squamosa*. It has a very restricted range, only occurring on the Saya de Malha Bank, Mauritius, in the Indian Ocean. No data in GMAD.

❑ *Hippopus hippopus*: the bear paw, horse's hoof or strawberry giant clam has a heavy and thick shell with a dull yellow-brown mantle. Its distributional range is similar to that of *T. crocea* but population numbers are lower and local extinctions have occurred. GMAD data show a total of 58 *H. hippopus* as exported from the Solomon Islands and unknown source countries between 1999 and 2000 (importers' data) (or a total of 551 from Palau and the Solomon Islands between 2000 and 2001 based on exporters' data).

❑ *H. porcellanus*: the china clam, has a very limited range in the region of Indonesia, the Philippines and Palau. Its appearance is similar to that of *H. hippopus*. No data in GMAD.

Source: Wells[80], Ellis[81], Raymakers et al[82] and data from GMAD

Table 12: Number of giant clams wild sourced, captive bred and from other origins traded worldwide

Totals for number of clams are derived from CITES data for years 1993 to 2001. Percentage of total trade for each source category is also presented.

Source	1993	%	1994	%	1995	%	1996	%	1997	%	1998	%	1999	%	2000	%	2001	%	Total
Wild	9,485	20	15,739	26	55,830	62	60,449	85	47,394	61	92,671	82	93,198	74	94,159	82	96,662	76	565,587
Captive bred	7,402	15	5,731	10	6,913	8	9,303	13	28,989	37	19,783	18	32,789	26	20,695	18	27,318	22	158,923
Other	31,546	65	38,249	64	27,721	30	1,153	2	1,256	2	157	0	319	0	531	0	2,735	2	103,876
Grand total	**48,433**	**100**	**59,719**	**100**	**90,464**	**100**	**70,905**	**100**	**77,639**	**100**	**112,611**	**100**	**126,306**	**100**	**115,385**	**100**	**126,715**	**100**	**828,386**

Other: unspecified, no reported source, pre-convention, ranched, Illegal/seizure

poisonous in high quantities for other living animals in the tank.

Belonging to the family Tridacnidae and composed of two genera, *Tridacna* (seven species) and *Hippopus* (two species), giant clams are the largest bivalves in the world. Their range stretches across the Indo-Pacific region from the eastern coast of Africa in the west to the south Pacific in the east[80].

All species of giant clams have traditionally been harvested as a subsistence food source throughout their range. Clam shells have also been used as ornaments in the curio trade and as troughs for holding water or feeding livestock[80]. More recently, their meat has been served as a delicacy, even considered as an aphrodisiac in some Asian and Pacific countries. The more brightly coloured (*T. maxima*, *T. crocea* and *T. derasa*) species have been popular organisms in the marine ornamental trade[81], with *T. squamosa* and *T. gigas* also being traded but in smaller numbers. Unsustainable exploitation ranging from legal commercial and subsistence use to illegal poaching activities of giant clam species has led to the local extinctions of some species such as *T. gigas* in at least four of the 20 countries and territories where it is known to have occurred[84]. As a result of overexploitation, all species of giant clams are listed in CITES Appendix II. However, CITES annual report data do not include trade by non-CITES signatories, which include all South Pacific countries except Papua New Guinea and Vanuatu and large importers such as Taiwan[85]. According to the IUCN Red List 2000, four species of Tridacnidae are classified as vulnerable (*T. derasa, T. gigas, T. rosewateri* and *T. tevoroa*) and the five others are considered to be at lower risk. Import suspensions into the EU exist for all wild specimens of the following country-species combinations: *H. hippopus* from New Caledonia, *T. crocea* from Viet Nam, *T. derasa* from Tonga, *T. gigas* from Guam, Federated States of Micronesia, Fiji, Indonesia, Marshall Islands, Palau, Papua New Guinea and Vanuatu, and *T. squamosa* from Tonga, Viet Nam and New Caledonia[86]. Negative opinions were also formed for *Hippopus hippopus* from Tonga, Vanuatu and Viet Nam, *T. crocea* from Fiji, Tonga and Vanuatu, *T. derasa* from Fiji, New Caledonia and Vanuatu, *T. gigas* from Tonga and Viet Nam, *T. maxima* from the Federated States of Micronesia, Fiji, the Marshall Islands, Mozambique, New Caledonia, Tonga, Vanuatu and Viet Nam, *T. rosewateri* from Mozambique, *T. squamosa* from Fiji, Mozambique and Vanuatu and *T. tevoroa* from Tonga[69].

Figure 4: Major exporters of live and wild-sourced clams

Totals are derived from importers' data as Viet Nam, Philippines, Fiji and Vanuatu report on the basis of permits issued and not on actual trade, and not all exporters are Party to CITES.

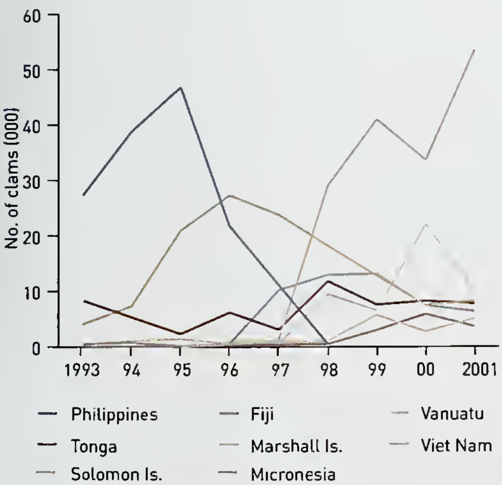
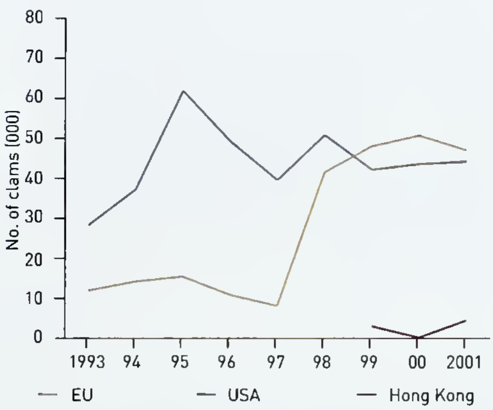


Figure 5: Top three importers of live and wild-sourced clams

Totals are derived from importers' data



Several source countries have also implemented legislation to better manage and protect their giant clam stocks. In 1996, the Philippines, previously dominating exports for the international shell trade and one of the main suppliers of live clams for the international aquarium trade, adopted a total prohibition on all exports of giant clam[82]. The Solomon Islands reported that only exports of cultured giant clams were allowed, while with help from the International Marinelife Alliance, the government of Vanuatu recently banned collection and exports of wild specimens of *T. crocea* for the aquarium trade and proposed the establishment of quotas for collection of other giant clam species on outer islands[87].

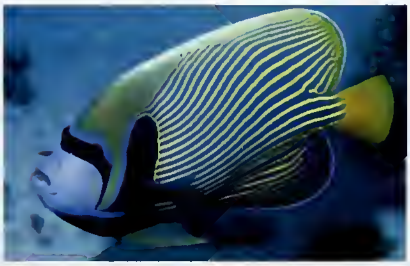
Wild stocks of giant clams (especially of the largest species *T. gigas*, *T. derasa* and *T. tevoroa*) have experienced drastic declines over the last 20-30 years as a result of high levels of exploitation for subsistence purposes, and probably to a greater extent due to commercial harvesting for their meat and shells. However, the demand for live giant clams for aquaria has also grown considerably in recent years. Figures for the extent of the trade are patchy and fluctuate considerably between years (see Table 12, p 31), but CITES data show that total exports of giant clams (all species included) have significantly increased from a total of 48,642 individuals in 1993 to 126,715 individuals in 2001. In 1993, wild-caught giant clams represented 20 per cent of all live specimens, versus 15 per cent originating from mariculture facilities. In 2001, 76 per cent of all giant clams in trade as marine ornamentals had been caught in the wild, whereas 22 per cent had been reared.

Although maricultured clams sold for the aquarium trade command the highest prices, hobbyists often prefer wild-caught specimens, as farmed individuals tend to have less highly coloured mantles[45]. However, advances in selective breeding techniques have meant that clams can now be bred for brighter mantle colours. Pacific island nations such as (ranked in order of importance) the Solomon Islands, Marshall Islands, Fiji and Tonga are the main exporters of live captive-bred giant clams.

Based on CITES data from 1993 to 2001, the major source countries of live wild-sourced giant clams for the aquarium trade are Viet Nam, the Philippines, the Solomon Islands, Tonga, Fiji, Vanuatu, the Marshall Islands and Micronesia. However, the role of individual countries changed considerably over those years. With exports from the Philippines being banned in 1996, exports from other source countries increased slightly (with the exception of the Solomon Islands whose trade has decreased) allowing Viet Nam to dominate exports as early as 1998 (see Figure 4, p 31).

The main importers of giant clams are the United States, the EU and Hong Kong (using CITES data from 1999 onwards). Although the United States used to dominate imports of live giant clams, the total number of specimens imported into the EU has been greater than numbers imported into the United States since 1999 (see Figure 5).

Conservation issues



Imperator angelfish, *Pomacanthus imperator*.

Accounts of destructive collection practices, the introduction of alien species, over-harvesting, the lack of scientific information for many species collected and the threat of extinction of target species have raised concern about the marine aquarium trade among politicians and conservation organizations alike. A number of policy regulations have already been put in place; more are being called for[17] and may follow. The US government, for example, is considering 'taking appropriate action to ensure that international trade in coral reef species for use in US aquariums does not threaten the sustainability of coral reef species'[12].

DESTRUCTIVE HARVESTING PRACTICES

Destructive fishing techniques include the use of sodium cyanide and other chemicals to stun and catch fish. Cyanide usually only stuns fish (although high mortality rates are often recorded post-capture), but it may destroy coral reef habitat by poisoning and killing non-target animals, including corals[88, 89]. Other chemicals, including quinaldine and plant toxins, are also used to capture reef fish alive. Field data are difficult to obtain due to the often clandestine nature of these practices.

During the collection of coral pieces for the coral trade, many more colonies may be damaged or broken than are actually harvested[19]. The breaking of corals to ease access to fish for capture is also not unusual in many collection areas. This tends to be more common with branching species in which small fish, such as a number of species of the genera *Dascyllus* and *Chromis*, often find refuge[90]. However, there are a number of collection areas that support many species for the aquarium trade that are rocky or 'rubbly' in nature, thus reducing damage to coral reefs. In soft bottom habitats for example, where corals are not attached to the substrate, the use of tools to remove colonies is unnecessary[46].

Collection of live rock has been considered as potentially destructive as it may lead to increased erosion and loss of important fisheries habitat[91]. Some harvesting areas in Fiji, for example, have been converted into unconsolidated rubble, possibly preventing areas from recovering over the long term[19]. A study looking at the impact of the collection of coral and other marine organisms for the aquarium trade showed that areas fully utilized for the collection of live rock had experienced severe disruption of the reef flat, leading to algal predominance and potential declines in fisheries[45]. By contrast other collection sites showed that harvest of live rock had little effect on the relatively sparse coral growth and probably also on the three-dimensional structure of the reef as the entire reef flat had little topographic variability[45]. Overall, this relatively new trade, and its impacts, have not been well studied and more research should look into the potential impact of live rock removal on surrounding reef habitat and associated fauna. Monitoring of extraction activities and of trade in live rock is also recommended.

Fishing on coral reefs with dynamite and explosives is not part of the marine aquarium trade: this is a common misconception. Dynamite is a method commonly used for food fishing. It causes terrible damage not only to fish populations but also to the reef habitat itself and may be an issue worthy of more concern than the use of cyanide[92].

Cyanide

Cyanide fishing involves crushing cyanide pellets into makeshift squirt bottles filled with seawater. The fishers then dive down to coral formations and squirt cyanide into crevices where fish often hide. The poison stuns fish, thus making them easier to catch. Large percentages of fish captured through this method die in transit due to their weakened state[93], resulting in more fish being collected than would otherwise need to be, to allow for a fatality margin[94]. Reports indicate that between as few as 5 per cent[95 in 6] and as many as 75 per cent[96] of fish collected using narcotics die within hours of collection, and 20 per cent[95] to 50 per cent die soon after that[97]. About another 30 per cent on average[96] die prior to export and it is not unusual for retail outlets in importing countries to register mortalities of 30 per cent or more[50]. A 1997 survey of US retailers[98] found that between one third and more than half of the aquarium fish imported from Southeast Asia died shortly after arrival, most probably due to poisons used in capture and/or the stress of handling and transport.

Cyanide fishing is not without risks to the divers themselves, who often go to considerable depths for extended periods of time and may suffer from decompression sickness, 'the bends', upon return to the surface.

The use of cyanide to capture reef fish originated in Taiwan and/or the Philippines in the 1960s and was specifically targeted at fish destined for the aquarium market[94, 102, 103]. Estimates suggest that in the mid-1980s more than 80 per cent of all fish harvested in the Philippines and destined for the aquarium trade were collected using cyanide[94]. More recent studies in the country indicate that 70 per cent of marine ornamental reef fish are caught with cyanide[102, 104]. Its use then spread to Indonesia (in about 1985[105]) where, in the mid-1990s, it was estimated that about 90 per cent of vessels transporting live fish in the eastern islands of Indonesia had cyanide on board[106]. Reports also indicate its use in Thailand[6], Papua New Guinea[105, 107], Malaysia, Viet Nam, the Maldives[108] and Yemen[109]. There are unconfirmed reports that its use may have spread to the Red Sea, Palau, Tanzania, the Seychelles, Sri Lanka, the Marshall Islands, the Solomon Islands, Fiji and Haiti[108].

Cyanide fishing is illegal in most countries. In Indonesia, for example, legislation from 1985 includes specific prohibition of the use of destructive fishing practices, such as the use of poison, with penalties up to ten years in prison and/or a fine of 100 million rupiahs[110] (equivalent to US$12,000). The marine police and navy, in collaboration with the fisheries service, are in charge of enforcing the law[110]. However, the high premium paid (often allowing for large bribes), the ease with which a great number of fish can be caught in a short time period, the often poor law enforcement capacities and high levels of corruption have allowed the use of poison to spread rapidly throughout the Asia-Pacific region[102] and have made the eradication of this illegal and highly destructive fishing technique nearly impossible.

In 1989, the Haribon Foundation in collaboration with Ocean Voice implemented, in the Philippines, the Alternative to Cyanide Fishing project in order to train aquarium collectors in the use of nets as an alternative to sodium cyanide. Results showed that 29 per cent of the trainees monitored were fully converted net users whilst the majority of fishers persisted in using sodium cyanide, though at a greatly reduced rate[111]. Subsequently, the Philippines government and the International Marinelife Alliance implemented a second, more aggressive programme to retrain fishers in alternatives to cyanide[51, 112]. Public campaigns in the media and schools are also helping to raise awareness about the values of the reefs of the Philippines and the negative impacts of cyanide fishing[113]. Five cyanide-detection facilities, capable of detecting low levels of cyanide in fish tissues as well as organs, have also been established. After five years of intensive efforts, live reef fish that test positive for cyanide declined from 80 per cent in 1993 to 20 per cent in 1998[51, 98].

A similar programme initiated in Indonesia for fishers in northern Sulawesi showed that barrier nets did

Cyanide use and corals

One of the greatest threats posed by cyanide fishing is to reef ecosystems[99, 100]. Cyanide kills non-target organisms, such as other invertebrates and fish, although only relatively limited scientific data are available on this. Reports have demonstrated that exposure of corals to cyanide causes bleaching[xiv, 88, 89]. Results from a recent study[101] demonstrated that exposure of colonies of the commonly traded species *Acropora millepora*, *Goniopora* spp., *Favites abdita*, *Trachyphyllia geoffroyi*, *Plerogyra* spp. (grape coral, pictured), *Heliofungia actiniformis*, *Euphyllia divisa* and *Sarcophyton* spp. to varying concentrations of cyanide over different time periods caused mortality in all corals (through, for example, bleaching and progressive tissue detachment from the skeleton). *Acropora*, the genus most likely to be specifically targeted by fishers for the collection of fish, as these tend to hide amongst its branches, was most vulnerable to cyanide exposure, showing rapid signs of stress and bleaching[101].

not prove to be an effective collection method and many collectors have been slow to switch to nets or have reverted to cyanide after the net training programme[102]. Although considerable demand for 'green' marine products exists in overseas specialty markets, and possibly even locally, the markets have failed to convey this to producers in an explicit way.

Consequently, an ever-increasing percentage of fishes are caught in Australia, Hawaii, Florida, the Greater Caribbean[6, 102] and the Pacific Islands such as Fiji, where collectors are often the exporters (90 per cent in Australia[40]) and are known to use more sustainable capture techniques, such as nets. As a result, survivorship post-capture is higher and mortality for the target species following shipping and handling often negligible.

There is hope that the use of cyanide can be curtailed. However, in order to accomplish this a number of major steps are required. The first, and probably the most difficult one, requires governments of source countries to face up to this problem by reforming their policies and strengthening their institutions (e.g. mount public awareness campaigns in the media and schools; regulate the importation, distribution and use of cyanide). Secondly, governments of importing countries must take steps to reinforce measures adopted by the source countries (e.g. monitor imports of live fish and provide data to exporting countries; raise awareness of the impacts of cyanide fishing)[102]. A reduction in the number of middlemen often involved would help ensure that a greater percentage of the price paid by exporters for ornamental fish goes to collectors. Consumers also have an important role to play: if sufficient numbers of informed consumers demand fish that have been caught using sustainable techniques it is likely that this will have important positive repercussions on fishing methods in Southeast Asia.

IMPACTS ON POPULATIONS

Most traders argue that the collection of marine ornamentals for the aquarium trade has no negative impact on reef fish populations. This is likely to be true for fisheries that are fairly small in comparison to the available resource base (fish population). A study in the Cook Islands showed that the total catch per unit effort remained constant between 1990 and 1994[114], an indicator that fish populations on these islands were probably being harvested sustainably. In Australia, through the use of permits, the aquarium trade fishery is such that current levels of exploitation are sustainable[41]. However, Australia is an unusual case, as the Great Barrier Reef is the largest reef system in the world. The available habitat and the interconnectivity of fish populations provide resilience to adverse effects from a comparatively small marine ornamental fishery[41]. Nevertheless, no matter how large a fishery is, not all fish are equally available or equally attractive to the industry and the most common fish are not necessarily those most favoured by hobbyists. Consequently, the effects of collecting for the aquarium fish trade should be measured with respect to their potential to deplete particular species or locations rather than viewed in terms of their global impact[41].

A typical collector's boat, called *bancas*, in the Philippines.

Several countries in Asia and South America, for example, have begun to implement collection restrictions of certain ornamental fish species due to fears of reduction beyond recovery of population numbers[115] and possible restructuring of reef communities due to sustained collection pressures on favoured species[18, 47]. Although no marine species collected for the aquarium trade is known to have been driven to global extinction, studies carried out in Sri Lanka[116], Kenya[116], the Philippines[117, 118], Indonesia[119] and Hawaii[120] and anecdotal information from Australia[41] all reported localized depletion of a number of target aquarium species of fish (e.g. butterflyfish, angelfish), due to heavy collecting pressure. However, there is a need for improved information on fishing effort[121], catch and location, as well as more research on the effects of collection of fish for the aquarium trade. To date, most evaluations of direct impacts of the aquarium trade on reef fish (coral and invertebrates) populations come from visual censuses of fish densities, calculations of potential yield from

Cleaner fish, *Labroides dimidiatus*

Cleaner fish and shrimp have stimulated discussion regarding the impact of marine ornamental fisheries on ecological processes. The two main groups of cleaner fish, which remove parasites and other material such as mucus and dead tissue[125] from other reef organisms, are gobies and wrasses, but juvenile species of angelfish have also been observed feeding this way[6]. Many of these species are popular marine ornamental species (e.g. the French angelfish *Pomacanthus paru*, grey angelfish *Pomacanthus arcuatus*) with reports of the bluestreak cleaner wrasse, *Labroides dimidiatus*, being traded in large numbers – at least 20,000 a year from Sri Lanka[44]. GMAD importers' data (exporters' data from 1996-2003 in parenthesis where applicable) for the years 1988-2002 showed 33 individuals (173) exported from Fiji, 7,258 (23,597) from Indonesia, 62 from Kenya, 3,164 (3,707) from the Maldives, 30 from the Netherlands (re-export), 831 (23,159) from the Philippines, 97 from Singapore (re-export), 5,347 (11,100) from Sri Lanka and 132,092 from an unknown origin. Exporters' records also showed 43 individuals exported from the Marshall Islands, 51 from Palau, 78 from Saudi Arabia and 412 from the Solomon Islands.

Labroides dimidiatus tend to be more abundant at sites with greater numbers of sedentary fish, fewer predators, fewer fish aggregating in large schools and where the species richness of the fish community is higher[125]. Due to their role in maintaining the health and diversity of their 'clients', concerns have been raised about the impact on population levels of the species and reef health in general of removing large quantities of *Labroides dimidiatus* for the aquarium trade[57]. Most experimental removals of cleaner fish have failed to show significant effects[126-128], although parasite load was shown to increase four-fold on selected clients within 12 hours of being deprived of access to cleaner fish[129].

A recent study which analysed the causal link between cleaner fish presence/absence and reef fish diversity at Ras Mohammed, Egypt, demonstrated that *Labroides dimidiatus* has a significant effect on local reef fish diversity with a more rapid increase in diversity being recorded when cleaner fish are added to individual reef patches[130]. Indeed, the removal of *Labroides dimidiatus* had no effect on fish abundance within the first few weeks, but a significant decline in fish diversity was recorded after a 4-20 month time period. On the other hand, the immigration or addition of *Labroides dimidiatus* individuals to reef patches led to an immediate, i.e. within 2-4 weeks, significant increase in fish diversity.

In addition to playing a key role in reef health – the removal of *Labroides dimidiatus* in large quantities for the aquarium trade is likely to have negative impacts on reef diversity – this species tends to fare poorly in aquarium conditions unless kept with a large community of fishes, and is not likely to accept substitute foods, so aquarists are advised to avoid it[131].

modelling, estimated exports from custom records, or observations by experienced biologists and commercial fishers, often without quantitative validation[37]. The most thorough attempt at quantifying the impact of coral harvesting on species distribution and abundance was carried out in the Philippines. Results of the study, which compared coral community parameters at two sites, one where no collection occurred, the other heavily harvested, showed that coral collection had resulted in a reduction of coral cover (31 per cent) and coral density (64 per cent)[122]. Six commonly collected corals experienced declines in abundance, by more than 70 per cent[122]. Although coral exports have since been banned from the Philippines, it is possible that similar impacts would be observed at heavily exploited sites in Indonesia. No comparable study to date has been carried out for Indonesia.

The only systematic study assessing the effects of harvesting fish for the aquarium trade on resource populations was carried out in Hawaii[120, 123]. The study reported that eight of the ten species most targeted by collectors showed declines in abundance at harvesting sites relative to control sites (i.e. where no collection of organisms was taking place). The magnitude of the overall decline was highest for Achilles tang (*Acanthurus achilles*) (57 per cent) and lowest for pebbled butterflyfish (*Chaetodon multicinctus*) (38 per cent). However, temporal effects such as yearly fluctuations in recruitment[xv] of common species (e.g. yellow tang (*Zebrasoma flavescens*)) might be substantial for the time frame of such a study and thus results need to be evaluated with care. The study also showed that, although the three most heavily collected species were herbivorous (*Zebrasoma flavescens*, spotted surgeonfish (*Ctenochaetus strigosus*) and *Acanthurus achilles*), and suffered significant reductions in abundance at collection sites, no increases in algae abundance were recorded when compared with control sites[120].

Life histories

While a huge diversity of species is demanded for the aquarium trade, a large part of the trade tends to be centred on individual species. These species' vulnerability to collection will depend on a number of life history parameters, in particular growth, reproduction and recruitment[54].

Stony corals

Overall, there is very little information available on the life history characteristics, growth rate or reproduction mode of most coral genera in trade. Environmental conditions influencing individual corals tend to be responsible for great variations in life history characteristics. The same species of coral sampled in two different locations may display a different mode of reproduction and great variation in growth rate. For example, coral specimens at shallower depth tend to grow faster than specimens found in deeper water[135].

Corals show various sexual characteristics, including two different types of sex, gonochoric (separate male and female colonies) and hermaphroditic (single individual is both male and female). In a hermaphroditic coral (e.g. most corals in the genera *Acropora* and *Cynarina*), a single individual is capable of producing both eggs and sperm. Examples of gonochoric corals include *Catalaphyllia*, *Euphyllia*, *Goniopora* and *Heliofungia*. Corals also exhibit two distinct modes of reproduction: brooding and spawning. In brooding corals, eggs are fertilized inside the coral polyp and are released as fully formed planula larvae that are ready to settle onto reef substrate. Spawning corals, on the other hand, release their gametes into the water column, where fertilization and larval development takes place externally. Spawning in hermaphroditic species is usually restricted to one or a few nights each year, and occurs synchronously throughout each population. Gonochoric spawners, on the other hand, tend to have longer breeding periods and less tightly synchronized spawning episodes[136]. Significant reductions in population densities of corals due to collection of colonies for the aquarium trade could have implications on their reproductive success, and thus long-term reef stability and health.

Sea anemones

Of all 100 species of sea anemones occurring throughout the world's oceans, only ten are hosts to anemonefish[132]. Anemonefish, on the other hand, with the exception of *Dascyllus trimacutatus*, are always associated with anemones and can only be found in parts of the Indian Ocean, Red Sea and Pacific Ocean (pictured are Barrier Reef anenomefish, *Amphiprion akindynos*). Anemones and their obligate symbionts[xvi] are very popular with marine aquarists due to their colourful displays, ease of care and longevity in captivity. In the Florida Keys, collectors with the appropriate licence may harvest 400 giant sea anemones (*Condylactis gigantean*) per vessel per day. Estimates show that an annual average of approximately 11.8 million anemones were landed between 1997 and 1999, with more than 90 per cent of these collected in the Florida Keys[133]. Data from collectors' logbooks in the Olango region, Philippines, revealed that fishers in the region landed 510 sea anemones (equivalent to 1.7 per cent of all collected organisms) and 17,160 anemonefish between January and April 2002[134].

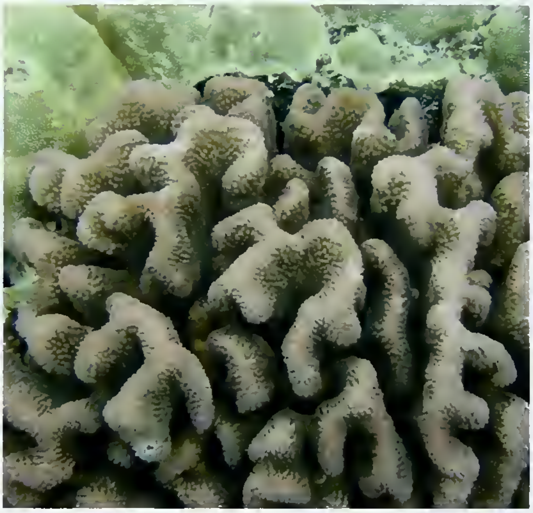
In an analysis of the marine ornamental fish trade undertaken in the Maldives in 1992, the authors voiced concern over the potential local overexploitation of sea anemones and the possible negative impacts a lack of suitable habitat (i.e. anemones) may have on local clownfish populations[90]. Indeed, anemonefish strictly depend on anemones, recruiting to them as larvae and utilizing them as adults. Results of the only study to date addressing the population-level impacts of collecting marine ornamentals (in this case sea anemones) show that close to 60 per cent of the catch of collectors in the Philippines consisted of anemone-fish and anemones, and that both these resources exhibited significantly lower densities at exploited sites[134]. Moreover, the low abundance of sea anemones explained 80 per cent of the reduced density of anemonefish recorded in collection areas[134].

Stony corals are known to reproduce both sexually and asexually. A variety of environmental factors are known to regulate reproduction in corals. These include sea temperature, day length, lunar phases, tidal cycles, daily light/dark cycles, water quality, salinity and food availability. Variations of these factors in aquaria have allowed public aquaria and a few dedicated hobbyists to witness sexual reproduction of corals in a closed system. Sexual reproduction requires the fertilization of eggs by sperm and results in small planula larvae, which disperse into the plankton and may eventually settle on their reef of origin or on distant reefs. Rates of recruitment (the process whereby newly formed individuals become part of the reef community[137]) differ greatly between coral species, with species of *Acropora* and *Pocillopora* characterized by high recruitment rates, and individual reefs vary markedly in the number of coral recruits they receive. Hence, replacement rates of harvested corals for these two species tend to be relatively high. In contrast other species, particularly in areas experiencing lower recruitment rates, may have a lower capacity to recover from collection pressures[138].

Asexual reproduction is a common process for a large number of coral species, particularly in branching corals. Fragmentation, an important means of asexual reproduction[139], is the most common method used by aquarium hobbyists for propagating corals. It is a straightforward process that involves carefully breaking off branches or pieces from the parent colony and placing them elsewhere in the tank. Fragmentation can be applied to most species of stony coral. The Waikiki aquarium, for example, distributed 780 fragments in 1997[32]. Fragments of various species are frequently traded between individual hobbyists, thus providing an alternative supply source (although a minor one), at least for some species, to corals harvested from the wild.

To date little more information is available at a species-specific level than the general descriptive reproduction biology described above. Acquiring more information and detailed species- and country-specific data on these basic aspects of coral biology, and how collection for the aquarium trade may impact populations, is important and necessary when attempting to derive management strategies based on sustainable yields for the aquarium trade.

Coral growth rate is another important factor to take into consideration when developing a sustainable coral harvest management plan. Although different environmental conditions such as light, temperature and depth can have a tremendous impact on variation in growth rates, massive corals (with dense skeletons) are said to exhibit average annual growth rates of 10-12 mm[140] and branching species (with more porous structures) 30-40 mm, with some *Acropora* species growing up to 100-200 mm per year[141]. Hence, fast-growing corals will tend to suffer less from collection pressure whereas slow-growing species will take longer to recover.



Cauliflower/alabaster coral, *Pocillopora* spp.

However, overall, it is important to put the potential impacts of harvesting coral species for the ornamental trade in perspective. Results from a study looking at the amount of corals gathered from reef areas for the production of lime show that in West Lombok 60 families produce an annual total of 900 tonnes of lime per year[142], necessitating the collection of approximately 1,600 tonnes of coral. Considering that in the mid-1990s Indonesian exports never exceeded an annual total of 2,000 tonnes, it is clear that practices such as coral mining for the production of lime rock have a much more significant impact on the alteration of coral populations and community structure than the collection of corals for the ornamental trade.

Soft corals and sea fans

Similarly to stony corals, soft corals reproduce sexually (spawning and brooding) and asexually. Most soft coral and sea fan species are gonochoric; however some species such as *Xenia* are hermaphroditic. Many gonochoric species, such as the genus *Clavularia*, the family Xeniidae and many gorgonians, are brooders. Alcyoniid soft corals (e.g. *Cespitularia*, *Sinularia*, *Sarcophyton*, *Lobophytum*) are spawners, where mass spawning is synchronized by lunar phase and/or water temperature. Asexual propagation, for example through fission, is very common in soft coral reproduction. Most soft corals, both in the wild and in captivity, propagate themselves this way.

Fish

Although coral reef fish exhibit a wide variety of mating strategies, ranging from mass spawning events to established nests and incubating eggs in a special pouch on the abdomen, most fish larvae distribute widely through wave and wind-driven ocean currents[xvii, 143-145]. This makes replenishment of reefs with new fish larvae highly dependent on these currents, and by extension the number of fish available for sustainable aquarium collection is highly variable.

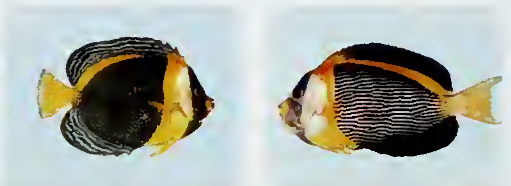
Just as mating systems differ widely between species, fish display unusual plasticity in their sexuality. Some species are gonochoristic, with individual fish being permanently male or female. However, for many species sex is not fixed and is determined through social interactions. In anemonefish, for example, the largest individual is a female. New recruits start their life as male. Should the female be removed from the colony, the largest male changes sex and becomes the dominant female[41, 132]. The effects of fishing are significantly different for species that are hermaphroditic compared with species that do not change sex. A fishery selectively removing larger animals first will mean that animals will have to start changing sex at smaller sizes, possibly reducing the fitness of individuals, and thus making hermaphroditic stocks more vulnerable to overfishing. Greater fishing pressure, together with the biological and ecological characteristics of some of these species, may make them more vulnerable to exploitation than other fish species[41]. Life history traits of fish are associated with their vulnerability to exploitation[146, 147], their rarity[148] and their risk of extinction[149-151].

Trade in ornamental marine fishes tends to be characterized by extreme selective harvesting. For all species, with the possible exception of smaller species such as gobies, blennies and dottybacks, juveniles are preferentially targeted by aquarium fish collectors due to their distinctive coloration, ease of maintenance and size-ratio with respect to tank size[37]. A study carried out in Hong Kong showed that 56 per cent of 12,652 fishes ready for retail sale were juveniles[24]. Such preferences may potentially reduce the risk of over-harvesting by leaving

The scribbled angelfish, *Chaetodontoplus duboulayi*

Anecdotal information has suggested that some populations of the scribbled angelfish (*Chaetodontoplus duboulayi*, pictured) may be depleted. Although this information has not as yet been validated by scientific surveys, local fishers in Queensland, Australia, have observed significant fluctuations in population densities over the years and thus have raised concerns. Population estimates between the Keppel Island group and the southern extent of the species in Hervey Bay, Australia, show lower population numbers than in the past. Scribbled angelfish are an important species in the aquarium trade because they are 'endemic' to Australia and Papua New Guinea, hence rare and therefore in high demand. According to GMAD data 3,544 (total) of this species were exported from Australia[xviii] between 1988 and 2001.

Individuals of this species tend to be found relatively close to shore, in soft reef and sponge reef habitats, in the turbid waters that stretch from Hervey Bay north to Papua New Guinea. In the Cairns region, anthropogenic influences have severely impacted this habitat and may have indirectly led to declines in scribbled angelfish populations. Although fishing pressure is thought to be one of a number of impacts to have affected numbers, biological and other



Scribbled angelfish, *Chaetodontoplus duboulayi*: female (left) and male (right).

characteristics, such as annual recruitment patterns dependent on seasonal temperature or rainfall, habitat alteration due to trawling, and sedimentation and pollution may have contributed to their decline.

Baseline information and general life history data are needed on this species to help make more informed decisions regarding its collection for the aquarium trade. Establishing areas closed to the fishery of this species, as well as limiting commercial effort in the fishery, have been suggested as recommendations to prevent further depletion of these fish stocks.

Source QFMA[41]

breeding adults on the reefs. However, should juveniles consistently be heavily harvested, adult populations will suffer as only a limited number of young will grow to reach adult size and replenish the adult stock.

Most coral reef fishes have broad distributions[152]. Some species such as the Moorish idol, *Zanclus cornutus*, are distributed throughout most of the Pacific and Indian Oceans. A small number of species, on the other hand, are known only from restricted waters and/or are known as endemics. In assessing the conservation value of these endemic species, distribution and abundance must be distinguished. Some species are naturally rare, occurring only in very restricted locations, or naturally occur in lower numbers, even though they may be widely distributed[6]. Other species may be abundant at different sites, but their distribution is limited to specific habitats[41]. The more widespread and/or abundant a species is, the less vulnerable it is to exploitation.

Increased rarity often implies higher prices[6]. Individuals of two rare species, the yellow-faced angelfish, *Pomacanthus xanthometapon*, and the blue-girdled angelfish, *Pomacanthus navarchus*, fetch prices in the range of hundreds of dollars in the United States[37]. The peppermint angelfish *Centropyge boylei* may command a price as high as US$10,000[37]. Officially protected species may artificially drive prices up for the few licensed to trade in them (e.g. seadragons, *Phycodurus eques* and *Phyllopteryx taeniolatus*)[37]. However, high prices are not necessarily an indication that a species is rare and therefore vulnerable to overcollection[6]. The deep reef species, Tinker's butterflyfish, *Chaetodon tinkeri*, can sell for up to US$1,000 per pair and has a restricted range, occurring only in the Marshall, Johnston and Hawaiian Islands. However, the high price is probably driven by the difficulty in collecting the fish as it lives at depths of 27 to 135 m[153]. Furthermore, due to the depth at which this species occurs it is possible that it is more abundantly distributed than at first appears.

Caution should be exercised when examining the rarity of individual species. For example the raccoon butterflyfish, *Chaetodon lunula*, the blackwedged butterflyfish, *Chaetodon falcula*, the dwarf angelfish, *Centropyge multispinis*, and the regal angelfish, *Pygoplites diacanthus*, are rare off Sri Lanka, making collection inadvisable, but abundant in the Maldives where populations could maintain sustainable collection[6]. Hence, in order to encourage protection and conservation of these species in Sri Lanka's waters, hobbyists should try to purchase specimens originating from the Maldives (and/or Mozambique in the case of the dwarf angelfish)[6].

Information relating to *Pterapogon kauderni* and *Hippocampus* spp. will be presented and used as examples to demonstrate species vulnerability to collection for the marine ornamental trade.

Pterapogon kauderni

The Banggai cardinalfish, originally described by Koumans in 1933 and 'rediscovered' in 1991[121], is a popular fish amongst hobbyists and public aquarists due to its attractive appearance and the ease with which most individuals readily acclimatize to aquarium confines[131]. A paternal mouth brooder (males incubate the female's eggs in their mouths until after hatching of the young), the Banggai cardinalfish is a small (maximum 55 mm[58]) species of fish that is relatively common, but whose distribution is restricted to the shallow waters (reef and seagrass habitat) of the Banggai Islands, an area of approximately 10,000 km^2 off the east coast of central Sulawesi, Indonesia. It usually lives in groups of 20 to 200 individuals that hover above long-spined sea urchins, *Diadema setosum*, or branched corals that the species uses as a refuge if threatened[154, 155]. Juveniles are also known to associate and take shelter in the fungiid coral *Heliofungia actiniformis* and anemones[156, 157].

Biologists and conservationists have expressed concern about the potential impact of collecting this species for the aquarium trade[155] due to:

- the high and increasing fishing levels recorded over the species' entire distributional range[156], e.g. 180,000 fish per month being sold in the Banggai region[75]
- its restricted habitat[158]
- its low fecundity (lowest recorded fecundity rate of all apogonids) and increased energy invested in parental care
- its low dispersal rate due to the lack of planktonic dispersal of its eggs[121]

Banggai cardinalfish, *Pterapogon kauderni*.

The mandarinfish, *Synchiropus splendidus*

Extremely limited scientific information, particularly on its biology and fishery, is available for the small, benthic dragonet of the Western Pacific. All individuals traded for the aquarium industry are taken from the wild and the impact of heavy collection (21,458 individuals based on importers' data or 11,168 individuals based on exporters' data in GMAD, traded within the EU only) on fish populations is unknown. It is subject to a sex-selective fishery (up to 70 per cent of fish caught are male) as larger males are most attractive to hobbyists. This has the potential to disrupt exploited populations, both by direct removals and through the indirect effects of removing larger adult males in a mating system where females prefer to spawn with large males.

In the Philippines, Batasan Island fishers heavily targeted mandarinfish between 1987 and 1995. In 1998, average size was recorded at 30 mm total length compared with 60 mm in the 1980s, and reduced numbers were recorded at capture sites. After the mid-1990s, prices fetched by mandarinfish on the aquarium market dropped and the fishery declined. Though species size has recovered somewhat since 1995, abundances are still low – 1,000 fish in three hours of fishing when fish were common, versus 23 fish in two hours in 2001.

In addition to being vulnerable to collection in the wild, this species is difficult to maintain in captivity as it needs to be provided with large amounts of live prey and must be kept in a

well established aquarium with live substrate and plenty of hiding places[131].

It is recommended that continuous efforts be made to rear this species in captivity to lessen sex-selective pressure on wild populations. However, due to its aquarium 'unsuitability' (see below, p 43) overall imports of this species should be closely monitored and restricted. Individual specimens should only be considered for sale to experienced aquarists.

Source: Sadovy[170]

- the fact that very little is known about existing populations
- the degraded and deteriorating state of its habitats, mainly due to destructive fishing practices[159], and
- its popularity amongst hobbyists.

A recent study showed that, despite the use of non-destructive fishing methods, the fishery had a negative effect on fish density when sites with high fishing pressure were compared to sites with low fishing levels[155]. Fishing also had a significant effect on group size (halving of average group size where sites with high and low fishing pressure were compared), which may lead to strong negative impacts on individual fitness in the future (referred to as the Allee effect in the scientific literature)[155, 160, 161].

As a precautionary measure the species has been informally proposed for listing on the IUCN Red List of Threatened Species as 'Critically Endangered'[157]. Should such a listing be made official it would merely draw attention to the threats facing this species without imposing any trade restrictions.

Soon after the Banggai cardinalfish appeared in the aquarium trade, a breeding programme was developed at the New Jersey State Aquarium[162]. As this fish can be reared through its entire life cycle in captivity[162], it is strongly recommended that efforts be developed to raise this species in captivity and in the field (preferably in Indonesia to avoid removing livelihoods from local communities). This would reduce the need to capture wild specimens to supply the trade. It is further recommended that a trade monitoring system be established through direct collaboration with aquarium fish exporters. Targeting and inputting trade volumes of the Banggai cardinalfish into GMAD could help spearhead such a monitoring initiative and allow better estimates of traded numbers to be derived. Improvements in the sustainability of the current trade through directed training programmes on holding, packing and shipping, to reduce mortality rates of the species, are also recommended[75]. The development of environmental education material and programmes to promote public awareness are strongly encouraged and the potential implementation of marine protected areas should be investigated[75].

Hippocampus spp.
Seahorses are distinctive, bony fishes, which belong to the family Syngnathidae, a family that also includes seadragons, pipefishes and pipehorses. All seahorses are included in one genus, *Hippocampus*. There are approximately 40 recognized species of seahorse, with a few more likely to be described in the future[163]. New species of seahorses recently described include *Hippocampus denise*[61] and *H. queenslandicus*[164].

Seahorses have a global distribution, with the highest diversity occurring in the Indo-Pacific. They typically inhabit marine or brackish water and occur at depths of 1-15 m, among seagrasses, kelp beds, algal and rocky reefs, mangrove prop roots and coral reefs, with a few species preferring open sand or muddy bottoms[165]. Very little is known about the basic life history parameters of most seahorse species. For species where data are available individuals mature between the age of six and twelve months[166]. In all species of seahorses it is the male who becomes pregnant and broods the developing embryos for ten days to six weeks depending on species and water temperature. Seahorses form faithful long-term pair bonds and a male will mate exclusively with a female partner. Once the young are born, they are fully independent and receive no care from either parent. Seahorses are particularly vulnerable to overcollection as they have a limited reproductive rate (due to lengthy brooding) and their social structure can easily be disrupted (due to faithful pair bonding) further reducing the reproductive rate[166]. To compound the problem their habitat range is under threat from anthropogenic activities, which are quickly destroying ecosystems of the coastal zone. A number of reports[167] have expressed concern over overexploitation in the wild and consequent declines in populations of seahorses.

All seahorses are listed as 'Vulnerable' or 'Data Deficient' on the IUCN Red List of Threatened Species, except for *H. capensis*, which is listed as 'Endangered'. In November 2002, *Hippocampus* spp. was listed in Appendix II of CITES, to become effective on 15 May 2004, meaning that permits will be required to import and export species of this genus (32 species as recognized by CITES Appendix II). Six species were listed on the basis that harvest for trade exceeds sustainable levels that can be continued in perpetuity, and the remaining 26 were listed to bring trade in specimens of the other species under effective control, as individual *Hippocampus* species can be extremely difficult to differentiate. The European Regulation, which entered into force in 1997, lists *Hippocampus* spp. on Annex D. Until their inclusion in CITES Appendix II and thus corresponding up-listing to Annex B on 15 May 2004[168], *Hippocampus* spp. will remain listed in Annex D.

In Australia, seahorses have been protected since 1 January 1998[169] as their populations are considered to be rare/and or threatened with overexploitation[6]. Export permits will be granted only for specimens that have been reared in approved captive breeding programmes, or taken from the wild during an approved harvesting operation.

It is also important to remember that once caught and placed in an aquarium seahorses are notoriously difficult to keep, requiring a steady supply of varied live foods. Moreover, they are highly vulnerable to a number of fungal, parasitic and bacterial infections. Even public aquaria, with access to vast resources and often highly competent and trained staff, admit that these are among the most difficult fishes to maintain in captivity.

Invertebrates
Giant clams, popular invertebrates in the aquarium trade, occur in association with coral reefs throughout the tropical Indo-Pacific region. These bivalve molluscs obtain food in two ways: by filtering phytoplankton (small algae) from the surrounding water and through zooxanthellae embedded in their mantle that are able, through photosynthesis, to produce nutrients, using sunlight. Giant clams are susceptible to over-harvesting due to the ease with which they can be collected (they are sessile, live in shallow water to maximize use of sunlight and can easily be spotted due to their colourful appearance), their late sexual maturity (with size and age at maturity varying with species and geographical location), slow growth, sporadic reproduction patterns and low natural recruitment rates. Insufficient life history information exists to identify conservation issues for the vast majority of more than 500 invertebrate species in trade.

Sex-selective fisheries
Males of many coral reef fish species tend to be preferred due to their distinctive coloration. Male mandarinfish, *Synchiropus splendidus*, for example, bear attractive dorsal fins and displays[170]. Male wrasses, such as the bird wrasse *Gomphosus varius*, and the sapphire devil *Chrysiptera cyanea*, are also often preferred to plain-looking females[37]. Such brightly coloured specimens are also likely to fetch higher prices on the market. Selectively harvesting for males of particular populations on a regular basis may lead to reproductive failure and ultimately population collapse due to heavily biased sex ratios in remaining schools (i.e. reduced male biomass)[171, 172].

Male sea goldie, *Pseudanthias squamipinnis*.

Female sea goldie, *Pseudanthias squamipinnis*.

SPECIES SUITABILITY

Fishes

Michael[131] gives each species of fish an aquarium suitability index rating from 1 to 5 (see box) giving an indication of that species' durability, hardiness, and/or adaptability to captive conditions and food. Factors such as readiness to feed, dietary breadth, competitiveness, tolerance of sudden changes and ability to withstand less-than-ideal water conditions have been taken into account when applying a rating. For example, a species typically loses one rating point on this scale if live food is required.

Two of the most traded fish species (see Tables 4-6, pp 20-21), the mandarin fish and the bluestreak cleaner wrasse, have an aquarium suitability ranking of 2, indicating that they do not acclimatize well to aquarium conditions. Two others, the powder blue tang (*Acanthurus leucosternon*) and the palette surgeonfish (*Paracanthurus hepatus*), have an aquarium suitability ranking of 3 indicating that they are relatively sensitive to aquarium conditions. All other of the most frequently

Michael's aquarium suitability index[131]

1. These species are almost impossible to keep and should be left on the reef.

2. Most individuals of these species do not acclimatize to the home aquarium, often refusing to feed, and waste away in captivity.

3. These species are moderately hardy, with most individuals acclimatizing to the home aquarium if species care is provided.

4. These species are generally durable and hardy, with most individuals acclimatizing to the home aquarium.

5. These species are very hardy with almost all individuals readily acclimatizing to aquarium confines.

Table 13: Top ten species of ornamental fish according to datasets derived for the United States, the EU and worldwide, and their suitability for aquaria according to criteria defined by Scott Michael and John Brandt

Where labelled 'na', no suitability code is assigned for this marine ornamental fish species according to Scott Michael and/or John Brandt. See box and text for explanation of codes.

Species	Suitability code (Michael)	Suitability code (Brandt)
Abudefduf spp.	na	na
Acanthurus leucosternon	3	na
Amphiprion ocellaris	4	na
Amphiprion percula	4	na
Chromis viridis	4	na
Chrysiptera cyanea	5	na
Chrysiptera hemicyanea	na	na
Chrysiptera parasema	5	na
Dascyllus albisella	na	na
Dascyllus aruanus	5	na
Dascyllus trimaculatus	5	na
Labroides dimidiatus	2	B
Nemateleotris magnifica	5	na
Paracanthurus hepatus	3	na
Pomacentrus australis	na	na
Pseudanthias squamipinnis	4	na
Salarias fasciatus	4	na
Synchiropus splendidus	2	B
Zebrasoma flavescens	4	na

Table 14: Species classified as most unsuitable for maintenance in aquaria by Scott Michael and John Brandt

Species' names, quantity traded and most frequent country of origin according to exporters' and importers' data in GMAD.

Species	Suitability code		Common name	Quantity traded		Most frequent country of origin	
	(Brandt)	(Michael)		(exps' data)	(imps' data)	(exps' data)	(imps' data)
*Holacanthus arcuatus**	A	na	Black-banded angel	–	131	–	Unknown
Chaetodon austriacus	A	1	Blacktail butterflyfish	2	48	Sri Lanka	Saudi Arabia
Chaetodon baronessa	A	1	Eastern triangular butterflyfish	450	1,318	Indonesia	Indian Ocean
Chaetodon bennetti	A	1	Bluelashed butterflyfish	603	811	Indonesia	Indian Ocean
Chaetodon capistratus	na	1	Foureye butterflyfish	–	5,280	–	Caribbean
Chaetodon larvatus	A	1	Hooded butterflyfish	504	191	Saudi Arabia	Yemen
Chaetodon lunulatus	A	1	Redfin butterflyfish	50	–	Saudi Arabia	–
Chaetodon melapterus	A	na	Arabian butterflyfish	14	–	Bahrain	–
Chaetodon meyeri	A	1	Scrawled butterflyfish	421	123	Indonesia	Indian Ocean
Chaetodon octofasciatus	A	1	Eightband butterflyfish	2,025	421	Solomon Islands	Indian Ocean
Chaetodon ornatissimus	A	1	Ornate butterflyfish	648	149	Philippines	Indonesia
Chaetodon plebeius	A	1	Blueblotch butterflyfish	233	1,712	Fiji	Fiji
Chaetodon reticulatus	A	na	Mailed butterflyfish	232	45	Philippines	Indian Ocean
Chaetodon speculum	A	1	Mirror butterflyfish	939	236	Philippines	Indian Ocean
Chaetodon triangulum	A	na	Triangle butterflyfish	85	130	Indonesia	Indonesia
Chaetodon trifasciatus	A	na	Melon butterflyfish	863	874	Sri Lanka	Fiji
Ginglymostoma cirratum	na	1	Nurse shark	–	632	–	South America
Labroides phthirophagus	A	1	Hawaiian cleaner wrasse	–	5,338	–	USA
All *Labropsis* species (about 6 species)	A	na	Tubelips	94	33	Indonesia	Indonesia
Myrichthys colubrinus	na	1	Harlequin snake-eel	294	2,532	Philippines	Indian Ocean
Orectolobus maculatus	na	1	Spotted wobbegong	–	23	–	Unknown
Oxymonacanthus longirostris	A	1	Harlequin filefish	1,393	15,731	Philippines	Fiji

* Also known as *Apolemichthys arcuatus* or *Desmoholocanthus arcuatus*. See box p 43 and text for explanation of codes.

traded fish species have been allocated suitability ratings of either 4 or 5. (See Table 13 on the previous page.)

John Brandt, an experienced aquarium hobbyist, categorizes fish species according to two lists, which are dynamic and continually open to revisitation and revision[xii].

List A: These species have the most disappointing record of captive care. They are the truly unsuitable species, dominated primarily by obligatory feeders such as coral-eating butterflyfishes. In most cases aquarists regard these species as impossible to maintain in captivity and many feel that they should not be collected for the aquarium trade. In general, relatively few of these animals are collected, as demand is much lower than with other species. There should be almost universal agreement among aquarists that these species do belong in this category, and not on List B.

An analysis including all species in GMAD and listed with a suitability code of 1 according to Michael[131] or classed in list A by Brandt showed that the following species were traded the most: the harlequin filefish (*Oxymonacanthus longirostris*), Hawaiian cleaner wrasse (*Labroides phthirophagus*), foureye butterflyfish (*Chaetodon capistratus)*, harlequin snake-eel (*Myrichthys colubrinus*), blueblotch butterflyfish (*Chaetodon plebeius*), eastern triangular butterflyfish (*Chaetodon baronessa*), melon butterflyfish (*Chaetodon trifasciatus*), bluelashed butterflyfish (*Chaetodon bennetti*), nurse shark (*Ginglymostoma cirratum*), eightband butterflyfish (*Chaetodon octofasciatus*) (see Table 14). All these species with the exception of *Ginglymostoma cirratum* are difficult to keep in captivity due to their restricted diets. Nurse sharks are common in the aquarium trade although, with a growth rate of approximately 19 cm a year in captivity, they will almost certainly outgrow all home aquaria[131]. Furthermore, they are highly predatory, often eating other organisms kept in the same tank[131]. *Myrichthys colubrinus* is a very selective eater whilst the remaining species are obligate corrallivores, meaning

The harlequin filefish, *Oxymonacanthus longirostris*

In 1998 an extensive bleaching event was observed in reef areas worldwide. This event severely impacted the fringing reefs of Bise, off the northwest coast of Okinawa, Japan, with most of the living coral dying and filamentous algae quickly covering the dead corals. Of all species, acroporid corals seemed the most susceptible to bleaching[174, 175]. Among coral-reef fishes, the species that are most likely to be affected by coral disturbances are obligate coral-dwelling or coral-feeding species, including butterflyfishes (Chaetodontidae)[176]. In response to the bleaching event, *Chaetodon trifasciatus* and *Chaetodon trifascialis* showed significant declines in abundance. The small (maximum 9 cm) harlequin filefish, *Oxymonacanthus longirostris*, typically inhabits shallow coral reefs in the Indo-West Pacific and spends most of the day feeding almost entirely on the polyps of corals of the genus *Acropora*[177]. It lives in an exclusive and heterosexual pair, with the male and female sharing the same territory to feed.

Growth rates of adult *Oxymonacanthus longirostris* during coral bleaching were significantly lower, and tagged harlequin filefish were found to disappear at rates significantly higher than in previous years. In March 1999, no juvenile, young or adult fish of this species were observed at the site. This species is known to exhibit high site fidelity[178], and abundance of *Oxymonacanthus longirostris* on surrounding reefs where the bleaching event was less severe was low, so the fish inhabiting this site seem to have died as a result of bleaching. Considering this species' diet, the study clearly indicates that the occurrence of healthy acroporid corals is essential to the survival of this species in the wild. High collection rates of this fish for the aquarium trade in addition to the higher frequency of natural disaster events such as bleaching observed in recent years may genuinely put at risk local populations and drive stocks below their critical recovery level.

Source: Kokita and Nakazono[179]

they feed exclusively on live coral polyps, a diet that cannot be duplicated in normal aquarium conditions.

List B: These species have a disappointing record of captive care. Very few individuals acclimatize to captivity or thrive over time. When individuals can be maintained, the lifespan is usually reduced. Feeding and nutrition are the primary cause of difficulties. Experienced aquarists or those using special techniques may have limited success with these species. Overall, much more research should be conducted on these species to determine the best methods for proper husbandry, or if any of these should be included on List A.

In general, there is a reduced demand for these animals and so fewer are collected compared with the more hardy species. Some aquarists would argue that a number of species on this list should not be included. These aquarists feel that there are enough documented cases of success to regard the species as being suitable. List B includes (as too extensive for full inclusion in this report): all seahorse and pipefish species, bicolour angelfish *Centropyge bicolour*, keyhole angelfish *Centropyge tibicen*, scribbled angelfish *Chaetodontoplus duboulayi*, bluespotted ribbontail ray *Taeniura lymma*, bluestreak cleaner wrasse *Labroides dimidiatus*, Moorish idol *Zanclus cornutus*, all dragonets and all parrotfish species.

Corals

Although no authoritative lists similar to the ones produced for fish by John Brandt and Scott Michael are available for corals, general aquarium suitability, toxicity (i.e. how strongly one coral species is likely to react to toxins from another) and sensitivity parameters are available from *The Modern Coral Reef Aquarium*[180]. Corals such as *Acropora elseyi*, *Cynarina lacrimalis* and *Lobophyllia hemprichii* rank highest in ease of maintenance. Species of the genera *Heliopora* and *Goniopora*, on the other hand, do not survive well in aquarium conditions. *Goniopora* is one of the most

A branching coral ready for export.

abundant corals in trade, partly because these species survive poorly in captivity and so must be regularly replaced. Aquarists have reported that, in aquaria, these species usually deteriorate and eventually die within a period of three to six months. A regular feature of aquarium specimens is unexplained stunted growth. Corals are also easily damaged during collection and are susceptible to disease[74]. *Heliofungia* is one of the oldest species in the history of the coral trade[181]. Like *Goniopora*, *Heliofungia* has a poor survival record in aquarium conditions as it is very sensitive, can easily be infected by bacteria, and colonies can quickly die due to changing ultraviolet (UV) light conditions[181].

Overall, mortality rates of coral pieces in home aquaria are fairly high, with one study concluding that complete mortality occurs after 18 months[182] and others registering up to 76 per cent mortality in hard corals kept in aquaria for more than 18 months[183]. *Plerogyra* spp. and *Catalaphyllia* spp. registered lowest mortality rates, 54 per cent and 60 per cent respectively, whilst *Heliofungia* spp. (100 per cent), *Goniopora* spp. (95 per cent) and *Tubastrea* spp. (100 per cent) registered the highest mortalities[183]. Nonetheless, species in these genera are commonly traded. (See Tables 7 and 8, pp 23-24.)

Recent advances in the maintenance of corals in aquaria, through improved and more affordable technologies, may lead to an increase in coral longevity in aquaria. Further improvements in coral husbandry techniques and the wider dissemination of information on how to keep and maintain coral species (especially as more information is available over the internet) should also minimize coral mortality.

Soft corals and sea fans

Most of the common traded species of soft corals such as *Cladiella*, *Clavularia*, *Cespitularia*, *Lobophytum*, *Nephthea*, *Sarcophyton*, *Sinularia* and *Xenia* possess zooxanthellae. They generally do not require plankton or special foods and thus are fairly easy to keep in aquaria. Described as hardy species, they are able to survive stress during collecting and shipping and to heal wounds as well as regenerate tissue relatively fast. Once established they tend to grow quickly and are regularly observed to propagate asexually. Cutting off their branches may even be necessary to prevent overgrowth in aquarium conditions. Their suitability as aquarium specimens may be related to the fact that they are more tolerant to fluctuations in water quality (although many soft coral species will not tolerate salinity levels of less than 30‰[181]) than other species of corals[64]. Notable exceptions to this are the more sensitive species *Anthelia* spp., *Cespitularia* spp. and *Xenia* spp., which do not fare well after fragmentation, are vulnerable to transport and sudden changes in aquarium conditions[181, 184]. Nevertheless, they grow fast once established.

Unfortunately, most of the more colourful and beautiful soft corals do not contain zooxanthellae (i.e. they are non-photosynthetic). Azooxanthellate soft corals, for example *Dendronephthya* spp. (one of the ten most traded soft corals, see box p 25) and *Studeriotes* spp., cannot easily be propagated and are extremely difficult to maintain in aquaria as they are entirely dependent on filtering particles and absorbing dissolved nutrients from the water column[64, 181, 184]. Due to these dietary requirements, these species usually die within a few weeks under aquarium conditions. Scientists and experts in the aquarium industry strongly recommend that people do not collect or keep azooxanthellate soft corals in captivity, unless they are the subject of scientific research[185].

Azooxanthellate sea fans such as *Ctenocella* spp., *Echinogorgia* spp., *Ellisella* spp., *Euplexaura* spp. and *Lophogorgia* spp. are just as difficult to maintain. They attract aquarists' interest due to their bright red or yellow colour, but show poor survival rates in captivity. On the other hand, zooxanthellate species such as *Gorgonia* spp., *Pseudopterogorgia* spp. and *Rumphella* spp., often brown to yellowish brown, are fast growing, their maintenance in aquaria is fairly straightforward and they can be easily fragmented for propagation purposes.

POST-HARVESTING MORTALITY

There are many factors that lead to post-harvesting mortality, such as physical damage and use of chemicals during collection, poor handling practice and disease. Even when collected in an environmentally sound manner, aquarium organisms often suffer from poor handling and transport practices resulting in stress and poor health of marine individuals[30]. Accurate figures of post-harvesting mortality are not available due to the sensitivity of such

Bagging specimens for the ornamental trade.

Yellow tang, *Zebrasoma flavescens.*

information. However, research on the marine ornamental trade between Sri Lanka and the United Kingdom demonstrates that in the mid-1980s about 15 per cent of fish died during and immediately after collection, another 10 per cent died during transit and a further 5 per cent in holding facilities[20]. Similar levels of mortality of 10-20 per cent were found in a study examining the Puerto Rican trade[186]. As a result of such mortality, more fish often need to be collected than would be necessary to harvest in order to meet market demand[32]. Where organisms are collected, stored and handled by adequately trained individuals, and transported in suitable conditions, estimated levels of fish mortality have been as low as a few per cent. Although post-harvest mortality levels are generally lower for corals than they are for fish, more live rock and coral fragments are often collected than would be needed to satisfy trade demand as originally harvested pieces are often considered of inadequate size, shape or colour and discarded.

State-of-the-art equipment may help reduce losses, but it is also expensive and thus beyond the budget of many wholesalers in source countries. Fortunately, this trend is reversing with an increasing number of facilities in source nations investing in high-tech equipment, particularly UV lighting systems and protein skimmers.

INVASIVE SPECIES

The introduction of aquarium fish species to areas where they do not occur naturally is a problem more acute for freshwater species than for marine species. Reports have indicated that a number of individuals of the species *Pterois volitans*, lionfish (marine fish native to the Indo-Pacific region), have been observed on four wrecks and one natural hard bottom off the coast of North Carolina at depth ranges between 40 and 45 m during 2000 and 2001[187]. Some individuals were also observed off the Atlantic coast of Georgia during 2001[187]. Previous reports include six lionfish accidentally released in Biscayne Bay, Florida, from a home aquarium during Hurricane Andrew (1992) and diver reports of lionfish off Palm Beach and Boca Raton, Florida, in the early 1990s[187]. The US Geological Survey (USGS) invasive species database lists fish species (http://nas.er.usgs.gov/fishes/index.html) that have been introduced into US waters through intentional and accidental stocking, release of bait fish, release of unwanted aquarium fish, escape from aquaculture facilities and discharge of ballast water[188]. Examples of species introduced through the potential release of unwanted aquarium fish include Moorish idol (*Zanclus cornutus*), sailfin tang (*Zebrasoma desjardinii*), yellow tang (*Zebrasoma flavescens*), bursa triggerfish (*Rhinecanthus verrucosus*), racoon butterflyfish (*Chaetodon lunula*), orbiculate batfish (*Platax orbicularis*), imperator angelfish (*Pomacanthus imperator*) in Florida and lemonpeel angelfish (*Centropyge flavissimus*) in Kaneohe Bay, Hawaii.

USER CONFLICT

One of the most vocal complaints against the aquarium trade has been that it reduces fish populations in areas where tourism is thriving and constitutes an important source of revenue. This has been an issue of particular concern in Australia and Hawaii[30] and more recently in Fiji[35]. In popular Australian tourist areas such as Cairns, Moreton Bay and Whitsunday tourists and recreational divers often interact with fish and coral collectors[41]. After a study was carried out in Hawaii showing a significant reduction in several species of fish due to collection for the marine aquarium trade, fishing of marine ornamentals was banned along 30 per cent of the west coast of the island of Hawaii[123].

In some Pacific Islands local fishers have also expressed concern at the aquarium fishery being unwanted competition for food fish[33].

Conservation efforts

A healthy reef off Nusa Penida, Indonesia.

Marine ornamental fisheries need to be managed in such a way that they are biologically sustainable, do not conflict with other resource uses and keep post-harvest mortalities to a minimum. Biologically sustainable means that harvested species need to be replenished in their natural habitat at the same or a greater rate than they are collected[6]. At the same time, it is important to ensure that habitat damage as well as impacts to other species are minimized. Fisheries must also check that species unsuited to life in aquaria are not collected. From a socio-economic point of view, trade needs to be equitable and resource conflicts between users (especially with members of the tourism industry) need to be minimized.

The establishment of marine reserves where the collection of marine ornamentals is made illegal may help reduce this conflict, whilst at the same time removing a section of the fish population from exploitation and boosting recruitment to adjacent areas. Other measures that can be taken to control collection pressure on marine resources whilst conserving stocks of ornamental species to ensure future sustainable harvests include the setting of quotas and size limits, and restricting access to the ornamental fishery through, for example, the use of permits.

Governments and the industry itself play an important role in supporting conservation initiatives and promoting best practice. However, the consumer can also encourage and promote change in the trade. Third-party certification of the trade, whereby the consumer is empowered to assist in the reduction of the environmental impacts of the trade by selectively purchasing products produced in an environmentally friendly manner, has been recommended by many as a possibility for improved management and monitoring of the trade.

In conjunction with efforts at local and governmental levels to develop management plans guaranteeing the sustainable collection of marine ornamentals from the wild, pressure can be taken off wild populations by supplying the trade with tank-bred rather than wild-caught specimens.

MARINE AQUARIUM COUNCIL AND CERTIFICATION

MAC[xix], on behalf of hobbyists, the industry and various environmental groups, is developing a certification scheme that will track an animal from collector to hobbyist. Established in 1996, the goals of MAC are to develop standards for quality products and sustainable practices and a system to certify compliance with these standards, and to create consumer demand for certified products. With a network of 2,600 stakeholders in more than 60 countries, it is recognized as the lead organization for developing and coordinating efforts to ensure that the international trade in ornamental marine organisms is sustainable. MAC certification covers both practices (industry operators, facilities and collection areas) and products (aquarium organisms), and is often lauded as the most effective means to ensure market demand and support for quality products and sustainable practices in the industry[30].

Industry operators at any link in the chain of custody (collectors, wholesalers, exporters, importers, retailers) can be certified through an evaluation for compliance with the appropriate MAC standard for the Certification of Practices. For the Certification of Products, MAC-certified marine ornamentals must be harvested from a certified collection area and pass from one certified operation to another, for example, from collector to exporter to importer to retailer. MAC-certified marine organisms bear the 'MAC-certified' label on the tanks and boxes in which they are kept and shipped. To ensure that MAC certification is credible and internationally acceptable, MAC does not verify compliance with its own standards. It accredits independent third-party certification companies (Accredited Certifiers), which in turn assess compliance with the appropriate MAC standard.

The MAC Core Standards outline the requirements for third-party certification of quality and sustainability in

The SMART project

The South Pacific Forum Secretariat, together with the Marine Aquarium Council, has started a programme to implement marine ornamentals certification within the South Pacific Region. It will focus primarily on the islands of Fiji, the Cook Islands and the Solomon Islands and will address the negative impacts the ornamentals industry presently has or may have. It will also introduce market-driven third-party certification for established operators to ensure sustainable development of the industry whilst maintaining reef ecosystem health. The programme is to be implemented using a two-step process whereby national consultations and workshops will be conducted first and profiles of local industry partners derived. Recent funding from the EU towards the Sustainable Management of Aquarium Reef Trade (SMART) Project will help build on these efforts and extend the number of countries targeted to also include Kiribati, Vanuatu, Federated States of Micronesia, Marshall Islands, Palau, Tonga and Samoa.

The two-year initiative seeks to alleviate poverty in Pacific Small Island Developing States by involving coastal communities in the MAC-certified marine aquarium trade, thus enabling communities to engage in economically viable enterprises whilst sustainably managing their coral reef resources. Furthermore, it will disseminate tools in ecosystem management planning, sustainable collection of aquarium products and market linkages to communities within the added-value context of MAC certification. These activities will implement the Barbados Programme of Action for Small Island Developing States, which highlights the need for international cooperation and partnership in efforts made by Small Island Developing States to conserve, protect and restore their ecosystems.

Source: Lovell[45] and Scott[189]

the marine aquarium industry from reef to retail. There are three MAC Core Standards covering the 'reef to retail' supply chain.

- The Ecosystem and Fishery Management (EFM) Core Standard: addresses *in-situ* habitat, stock and species management and conservation by verifying that the collection area is managed according to principles that ensure ecosystem health and the sustainable use of the marine aquarium fishery.
- The Collection, Fishing and Holding (CFH) Core Standard: addresses harvesting of fish, coral, live rock and other coral reef organisms, handling prior to export, holding, plus packaging and transport, to ensure the health of the collection area, sustainable use of the marine aquarium fishery and optimal health of the harvested organisms.
- The Handling, Husbandry and Transport Core Standard: addresses the handling of marine life forms during export, import and retail to ensure their optimal health, their segregation from uncertified organisms and proper documentation to show that they pass only from one MAC-certified industry operator to another.

The Core Standards are accompanied by Best Practice Guidance documents that provide advice to industry operators on how they might be able to comply with the standards.

This programme is not without cost to participating companies, which initially will have to pay fees to an independent certification authority as well as to MAC. In the future, MAC certification hopes to develop into a largely self-financed system, based on superior economic returns from certified marine ornamentals through the industry's as well as the consumer's willingness to pay a premium for marine organisms of demonstrable quality[30]. A list of companies that are seeking to be certified or already sell certified marine organisms is available from: www.aquariumcouncil.org

Another important aspect of this certification programme is the establishment of a monitoring system within collection areas to ensure early detection of any changes to fish populations resulting from collection for the trade. ReefCheck, a non-profit community-based coral reef education and monitoring organization, developed this monitoring system, entitled the Marine Aquarium Trade Coral Reef Monitoring Protocol (MAQTRAC), in conjunction with MAC. MAQTRAC was tested in the field in the Philippines, Indonesia, Fiji, Hawaii and the Maldives from summer 2001 through spring 2002.

MARICULTURE

One way to reduce the pressure on coral reef ecosystems brought about by an increasing demand for marine ornamentals is to improve and further develop the ability to culture desirable organisms for trade[190].

Corals

Mariculture can be an environmentally sound way to increase the supply of hard and soft corals, and has proved successful for a large number of species. In light

Finger leather/cabbage coral, *Lobophytum* spp.

of this, coral aquaculture is increasingly mentioned as a priority solution for reducing the harvest pressures on coral reefs[190]. An additional advantage is that cultured coral is acknowledged as adapting better to aquarium conditions than wild-caught coral[191].

To date, based on CITES importers' data (1997-2001), 99 per cent of the total global trade in live corals originates from 'wild' sources and only 0.3 per cent is captive bred/ranched, with China (42 per cent), Indonesia (25 per cent), Taiwan (10 per cent), the Marshall Islands (5 per cent), the Solomon Islands (4 per cent), Nicaragua (2 per cent), Tonga, the United States and Micronesia accounting for 99 per cent of total non-wild exports.

The aquaculture of corals, both soft and stony, refers to coral propagation by fragmenting a large colony (mother colony) into smaller pieces, or pruning the tips of larger colonies, and subsequently attaching the fragments to a new substrate using superglue or suspending them in water on a nylon line. These fragments are then left to grow in holding tanks or placed back into the sea until they have reached a marketable size. Most branching corals, for example, can be easily propagated from small trimmings clipped from a parent colony and achieve, in about a year, a five- to ten-fold increase in biomass. Soft coral fragments can grow to a marketable size within four to twelve months[184] and stony corals (e.g. *Acropora* spp.) within four to six months[192]. Pacific Farms, a company based in Los Angeles, and with stations in Fiji and Tonga, is one of the largest in the coral mariculture business with a team capable of fragmenting and planting 1,500 new corals a day[193].

More than 75 species of coral can be captive bred, but only fast-growing corals appear to be economically profitable[74]. Hence propagation in species of stony coral is mainly targeted at the fast growing branching species such as *Acropora*, *Pocillopora*, *Seriatopora* and *Stylophora*[194]. Unfortunately, most of the popular species in trade such as *Blastomussa*, *Plerogyra*, *Trachyphyllia* and *Goniopora* are slow growing, have little presently known about their life histories and characteristics and so are difficult to propagate.

Soft corals such as *Clavularia*, *Sarcophyton*, *Lobophytum*, *Sinularia*, *Alcyonium* and *Cladiella* are suitable for aquarium propagation, due to their ability to heal wounds and regenerate tissue rapidly. The most commonly used practice for soft coral propagation is to simply remove, underwater, a piece of tissue from the parent colony using sharp scissors or a scalpel. Freshly cut specimens should be left exposed to fresh seawater motion or dipped in fine sand, for one or two weeks. They can subsequently be tied or glued to appropriate substrate and harvested within four to twelve months. *Cladiella* spp. and other azooxanthellate species that are sensitive to fragmentation are almost impossible to propagate[64, 184].

When setting up coral farms, besides investigating which species are most suitable for propagation, the cost effectiveness of such enterprises needs to be explored [195]. A study of the economic viability of a community-based coral farm situated on an Indo-Pacific Island demonstrated that even after ten years of operation the facility would remain in debt[190]. The main reasons included high start-up costs, high operating costs and fairly low returns in comparison with wild-caught products. This may be true of newly set-up farming operations. On the other hand, should established exporters develop farming as a side activity, costs would be greatly reduced, as they would only have to bear the expense of the equipment in the grow-out facilities and labour costs. With time it is then expected that cultured corals would become the main source of exports. Non-governmental organizations are likely to play an important role in encouraging and securing potential initial funding (with governments and foreign aid as the most probable source) to kick-start farming activities and provide local community members with the required training.

An example of a successful coral mariculture initiative comes from the Solomon Islands where a group of 25 women have been growing about 12 different species of hard corals and a few species of soft corals. Small nubbings of live coral are attached to concrete discs, placed in trays and left to grow in carefully chosen sites for four to six months until the fragments have reached a marketable size. By providing the country's main exporting company with a regular supply of cultured pieces this small group of women is earning a regular income[192].

Fish

In recent years there has been an increased focus on supplying aquarium fishes through closed system culturing. Although to date virtually all marine ornamentals are wild caught (breeding and rearing marine species only accounts for 1 to 2 per cent of the trade at present) and efforts to develop captive cultivation have been limited, there is increasing pressure to develop reliable and sustainable hatchery procedures for the captive breeding of many reef fish species.

Although not exhaustive, Table 15 lists some of the main species for which breeding and farming has been mastered, some of those for which production and marketing are presenting difficulties, and some of those which have not yet been bred and reared but for which research projects have been developed[xx].

Aquaculture can be an environmentally sound way to increase the supply of such organisms, by helping reduce pressure on wild fish populations and producing juvenile and market-size fish of a wide variety of species year round. Furthermore, rearing aquarium fish in closed systems is likely to lead to the production of hardier species, which fare better in captivity and survive longer[21, 47, 196]. To date it has proved successful for a few fish species[197]. It is hoped that much of the market demand for the more popular ornamentals such as clownfish, yellow tangs and angelfish may eventually be satisfied by cultured fish, once culture technologies have been established successfully[198]. However, in reality, most marine ornamental aquaculture remains comparatively problematic, both from a technical and a socio-economic point of view[199]. Attempts at closing life cycles, i.e. spawning, rearing and mating, repeatedly in closed systems have proved technically challenging for most species (except for species within the Pomacentridae family[200], as for example *Amphiprion* spp.) and existing mariculture projects have been developed on a relatively small scale[37]. Blennies, gobies and members of the Pomacentridae family are relatively easy to rear in captivity as they attach or deposit their eggs on or in various substrates and, for species such as the clownfish, can be conditioned to spawn voluntarily by manipulation of day length and water temperature[201]. Most other fish

Table 15: Main species bred for the marine aquarium trade

1 = commercially available; 2 = production and marketing difficult; 3 = subject of research

Amblyeleotris randalli	1	*Gobiosoma evelynae*	1	*Calloplesiops altivelis*	3
Amblygobius phalaena	1	*Gobiosoma louisae*	1	*Centropyge potteri*	3
Amblygobius rainfordi	1	*Gobiosoma multifasciatum*	1	*Chaetodon lunula*	3
Amphiprion akallopisos	1	*Gobiosoma oceanops*	1	*Chaetodon miliaris*	3
Amphiprion akindynos	1	*Gobiosoma randalli*	1	*Chromis cyanea*	3
Amphiprion allardi	1	*Lythrypnus dalli*	1	*Chrysiptera parasema**	3
Amphiprion biaculeatus	1	*Hippocampus barbouri*	1	*Dascyllus albisella*	3
Amphiprion clarkii	1	*Pseudochromis aldabraensis*	1	*Dascyllus aruanus*	3
Amphiprion ephippium	1	*Pseudochromis dutoiti*	1	*Diodon* spp.	3
Amphiprion frenatus	1	*Pseudochromis flavivertex*	1	*Equetus acuminatus*	3
Amphiprion melanopus	1	*Pseudochromis fridmani*	1	*Equetus lanceolatus*	3
Amphiprion ocellaris	1	*Pseudochromis sankeyi*	1	*Equetus punctatus*	3
Amphiprion percula	1	*Pseudochromis splendens*	1	*Forcipiger flavissimus*	3
Amphiprion perideraion	1	*Pseudochromis steenii*	1	*Gramma loreto*	3
Amphiprion polymnus	1	*Pterapogon kauderni*	1	*Hippocampus erectus*	3
Amphiprion rubrocinctus	1	*Amphiprion bicinctus*	2	*Hypoplectrus unicolor*	3
Amphiprion sandaracinos	1	*Amphiprion chrysopterus*	2	*Hypsypops rubicundus*	3
Cypho purpurascens	1	*Amphiprion polymnus*	2	*Microspathodon chrysurus*	3
Dascyllus trimaculatus	1	*Gobiosoma xanthiprora*	2	*Opistognathus aurifrons*	3
Doryrhamphus excisus excisus	1	*Abidefduf abdominalis*	3	*Pomacanthus arcuatus*	3
Elacatinus puncticulatus	1	*Anisotremus virginicus*	3	*Pomacanthus paru*	3
Gobiodon citrinus	1	*Apogon* spp.	3	*Synchiropus splendidus*	3
Gobiodon okinawae	1	*Bodianus rufus*	3	*Zebrasoma flavescens*	3

Source: Oliver[39]; Ogawa and Brown[47]; Oceans, Reefs and Aquariums[236]; Tropical Marine Centre[237]; and data taken from GMAD

*Successfully reared very recently[200]

species such as angelfishes and butterflyfishes are known as broadcast spawners, i.e. they spread their eggs freely in the water column, and are therefore more difficult to culture in captivity; they also usually require hormone treatment to induce spawning. To date, the greatest obstacle to successful tank breeding of ornamental reef fish is rearing larvae beyond the sixth to eighth day of development, a time typically associated with failure to initiate larval feeding[47]. This is often due to larval feeds being too large or not meeting the nutritional requirements of fish larvae. Once the larvae transform into small juveniles, they are weaned onto semi-natural diets and various prepared rations and can be transported and sold[201]. Beside technical challenges, the high price commanded by some cultured aquarium fishes compared to those wild caught often undermines their economic viability[37].

The increasing use of mariculture to supply coral, other invertebrates and fish to the marine ornamental trade raises its own suite of issues. Firstly, should rearing facilities be established mainly in developed countries, as the trend so far seems to indicate[xxi]. Relations between the different players involved in the marine ornamental trade may be altered, possibly depriving local fishers of employment and losing the community- and national-level benefits the trade provided[203, 204]. This would be contrary to the first article of the Convention on Biological Diversity ratified by 170 countries[205] (but not the United States), the objectives of which are: 'the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over these resources and to technologies, by appropriate funding.' Development of facilities in source countries has the potential to raise the standards among rural communities and provide income opportunities for a great number of households due to its ability to generate considerable income per unit area, with high export earnings[5]. Furthermore, setting up hatcheries in source countries would also reduce the risk associated with escapes and, by extension, the risk of introducing exotic species.

A relatively recent type of mariculture whereby fish larvae are captured via means of light traps[206, 207] or crest nets (shaped like funnels and placed on the reef edges) has been raising much interest. Not only would it provide local communities with the benefit of such activities and/or provide them with an alternative

Captive breeding of seahorses

In light of expressed concerns of overexploitation of seahorse populations, the possibilities for captive breeding are of great interest and a number of captive breeding projects have been set up around the world. The Seahorse Trust[202] reports that it has bred 18 species of seahorse with varying levels of success; for example, it has bred six generations of *Hippocampus capensis* with a 90 per cent success rate, compared to only two *H. comes* (pictured) out of many broods. In addition, the Tropical Marine Centre in the United Kingdom has captive breeding facilities and breeds seahorses, e.g. *H. barbouri*. However, it is only if aquaculture is developed as an alternative livelihood for fishers in source countries that it can be highlighted as having great potential for integrating conservation and sustainable development objectives[167]. Results of a recent protocol developed for culturing *H. kuda*, one of the most heavily exploited species for the aquarium trade, in the source countries are encouraging. They indicate that *H. kuda* grows rapidly from birth to 14 weeks and showed highest survival rates when fed *Artemia* (brine shrimp, a commonly available feed for aquarium fish) enriched with a locally available crustacean, *Acetes* spp.[167].

Cleaner shrimps

In GMAD eight species under the genus *Lysmata* and four species under the genus *Stenopus* were identified as being traded as marine ornamentals: *L. debelius* (fire/blood/scarlet cleaner shrimp), *L. grabhami* (Atlantic white-striped cleaner shrimp), *L. amboinensis* (Indo-Pacific white-striped cleaner shrimp), *L. wurdemanni* (peppermint shrimp), *L. intermedia*, *L. multicissa*, *L. rathbunae* (peppermint shrimp), *L. californica* (peppermint/red rock shrimp), *S. cyanoscelis* (golden banded shrimp), *S. hispidus* (yellow-banded coral shrimp), *S. tenuirostris* (blue-banded coral shrimp) and *S. zanzibaricus* (gold-banded coral shrimp). They are hardy species and their maintenance as adults in aquaria is fairly straightforward, although they are sensitive to sudden changes in aquarium conditions. These species feed mainly on parasites and diseased skin, hence their common name 'cleaner shrimp', as well as any missed food items, a beneficial function to aquaria as it relieves pressure on filtration systems[212]. Although suited to maintenance in aquarium captivity and of benefit to the health of fish maintained in a tank, their removal from coral reefs may lead to a reduction in reef diversity because of their natural ecosystem role of removing parasites from reef fishes and animals. However, in recent years efforts have been made to develop aquaculture protocols for marine ornamental shrimps, especially species of *Lysmata* (cleaner shrimp) and *Stenopus* (banded coral shrimp) to reduce wild specimen collection[213]. Many companies have commercially raised the peppermint shrimp *L. wurdemanni*, and rearing protocols for it and other related species, including *L. debelius*, are available[214-216]. The largest bottleneck for commercial production is their relatively long and variable larval durations[217]. Thus, most research efforts have focused on identifying appropriate broodstock and larval diets to reduce larval durations and increase the aquaculture potential for these species, which are among the most popular invertebrates in the marine aquarium trade[217]. Due to these constraints, the vast majority of traded specimens are still being collected from the wild. LeRoy Creswell, of the Harbor Branch Oceanographic Institution, and Junda Lin, Florida Institute of Technology, have set up a private company Oceans, Reefs, and Aquaria Inc., which is commercially producing, and marketing, peppermint shrimp as tank-reared ornamentals[218]. They are also engaged in pilot production of the gold-banded coral shrimp. In the United Kingdom, the primary producer of captive raised invertebrates is the Tropical Marine Centre, which is actively breeding *L. debelius*, *L. amboinensis* and *L. californica*.

The main importers of ornamental shrimps should work together with the main exporters to adopt sustainable procedures and develop the necessary technology for rearing the most important species in trade. Developing this expertise in developing countries with optimal climate conditions and low production costs would allow for more effective conservation programmes to be implemented whilst generating a valuable source of revenue[219].

A banded coral shrimp, *Stenopus hispidus*.

Banded coral shrimps collected for the trade.

livelihood but it might also relieve some of the fishing pressure on coral reefs. The two groups pioneering this technique are researcher Vincent Dufour (under a programme called AquaFish Technology) and his team based in the Pacific, and members of ICLARM–The World Fish Center, based in the Solomon Islands and the British Virgin Islands. Considering that the vast majority of fish larvae die after having settled onto the reef (10 per cent survival rate), removing them prior to the high mortality rate fish populations suffer at recruitment would guarantee minimal fishing impact[208]. Species farmed this way and exported from French Polynesia to France showed promising growth rates, were more gregarious, accepted a wider variety of food and were less sensitive to stress than wild-caught individuals of the same species[209]. The research group based in the eastern Caribbean region has also developed a floating mesh cage system in which larvae can be grown out by providing them with a constant supply of plankton-rich water[210]. The plankton pump uses a single light at night and utilizes an airlift pump during the day. With an average price of US$0.5 per fish, by trading 50 individuals grown out using this system, members of fishing communities in Southeast Asia, for example, could be provided with a livelihood[211]. On the downside this larval collection technique depends on inputs of fish larvae, which are typically unpredictable in space and time as well as in species composition – not all larvae caught may be suitable for rearing, or in demand for trade.

Invertebrates

Since technical constraints regarding the spawning of mature giant clams and raising of larvae and juveniles were overcome in the 1980s, interest in giant clam culture and population management has increased considerably[84]. Giant clam mariculture has several advantages: the animals require no artificial feeding, rearing techniques are relatively simple and the setting up of facilities requires little capital investment and can involve local community members. Furthermore, unlike many other forms of mariculture it does not require broodstock to be continuously captured from the wild and hence the impact on wild stocks is minimal.

James Cook University in Australia, the Micronesian Mariculture Demonstration Centre (MMDC) in Palau and the Coastal Aquaculture Centre (CAC) in the Solomon Islands[80] have developed pioneering research activities on clam mariculture. In the 1980s, scientists from Australia, the Philippines and a range of Pacific Islands nations (e.g. Kiribati, Fiji, the Solomon Islands and Palau) teamed up to further develop advanced giant clam mariculture technologies[220].

The initial interest in culturing giant clams came from concerns related to the decline, and in some cases extinction, of wild stocks throughout their range, due partly to increasing pressure on coastal systems as a result of settlement expansion, pollution and improved harvesting efficiency. Hatcheries were initially developed to reseed depleted reefs and with the aim of growing clams as a food source to relieve pressure on wild populations[81], provide employment and earn foreign exchange[80]. Nowadays, giant clams are also reared specifically for sale as aquarium species with government and commercial hatcheries in most tropical Pacific nations and island groups where giant clams are known to occur. These hatcheries are having commercial success because the giant clams can be sold at smaller sizes and thus the loss rate experienced due to predation on cultured stocks is reduced[80]. In fact giant clam farms developed for subsistence purposes showed poor economic viability[82]. Any conservation efforts for invertebrates other than clams and cleaner shrimps would be constrained by the near uniform lack of information on key life history characteristics.

MANAGEMENT INITIATIVES FOR THE TRADE

Marine ornamental fisheries, if managed sustainably and integrated with other resource uses, have the potential to provide many people in source countries with a stable source of income and thus a livelihood. Countries like the Solomon Islands and Vanuatu have no specific management plans for the ornamental marine industry[221]. On the other hand countries such as Fiji, Palau and Australia have policies regulating collection of reef organisms[6]. Unfortunately, these often exist only on paper, are not enforced and were rarely implemented on the basis of rigorous scientific baseline studies or monitoring activities and so in most cases might not be effective at actually conserving populations.

When addressing issues relating to the management of ornamental fisheries, it is important to involve all parties concerned. This includes collectors, wholesalers, governments, hobbyists, scientists and members of industries who might have a resource conflict with aquarium collectors (e.g. the tourist industry)[6]. One of the most promising and effective strategies is to allow local communities to manage and control their fisheries. A number of islands in the Pacific Ocean, where local village communities have legal rights to particular reef areas, are successful examples of such a system[222].

Overall it is also important to highlight the need for further research on the biology, population dynamics, recruitment and conservation importance of species involved in the marine ornamental trade, with a particular focus on rare or endemic species and species that show poor survival in aquarium conditions. A survey of the distribution and abundance of target species, including an assessment of the exploitable area, is also crucial when attempting to set quotas or develop a management plan for resources harvested for the aquarium trade.

In a similar manner as for many conventional commercial food fisheries, measures such as limiting access to the fishery, establishing reserves and setting quotas have been suggested as direct ways for controlling aquarium fisheries and ensuring their sustainable development. In all of these instances, scientific data such as the biology, population dynamics and recruitment patterns of traded species need to be collected. However, to date, such scientific information has been lacking. Catch data to species level is also important when attempting to assess the effects of collection, developing management strategies and assessing their efficacy.

Limited access to the fishery

A licensing system, such as the one operating in Australia, the Cook Islands, Palau and a number of other Pacific Island countries, whereby collection effort is regulated through a limited number of permits being issued each year, offers a good way of monitoring the industry[6]. In addition, Australia has introduced restrictions on net size to ensure a limited number of permits is not offset by greater fishing effort[6]. The number of permits to be issued should be based on scientific studies estimating the resource base and sustainable harvest quotas, be non-transferable, subject to review on a regular basis and clearly state the conditions under which fishing is authorized. The licensing system in Florida, where collectors operate under state legislation, and in Fiji, where conditions attached to operators' licences are severe, stands in contrast to schemes in place in countries such as Indonesia where permits are issued but enforcement and control is difficult[6].

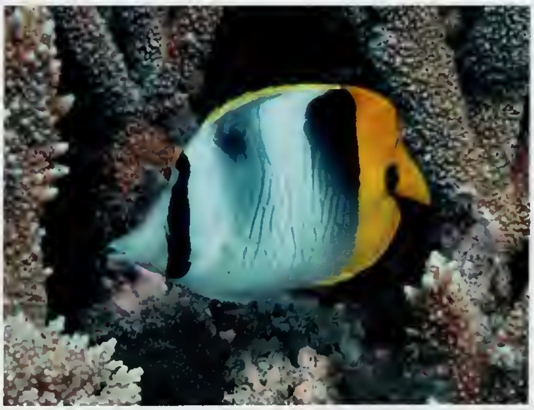
Quotas

Limiting the number of fish being exported from any source country is another way of reducing or limiting collecting pressure. Quotas are only likely to be effective if based on rigorous scientific research and implemented at a species-specific level[6]. Although relatively simple and easily enforced, general quotas are not advisable as they may simply encourage collectors to focus collection on the most valuable species, hence not ensuring protection of stocks overall and least so of vulnerable species[6]. Species-specific quotas such as those stipulated for butterflyfishes, angelfishes and giant Caribbean anemones under the Florida Administrative Code[43] ensure that collection activities are maintained at sustainable levels and that a healthy population remains on the reef. Unfortunately, the difficulties of a species-specific quota system lie in identifying species to which such a system should apply, which requires detailed knowledge of their life histories, recruitment patterns, the aereal extent of exploitation as well as species densities on the reef[90]. This is compounded by the fact that such quotas need to be developed on a country-by-country basis[6].

Although there is no specific requirement within the text of CITES to establish quotas to limit the trade in listed species, the use of export quotas has become an effective tool for the regulation of international trade. Export quotas are usually set by each member state individually, but they can also be set by the Conference of the Parties, and they generally relate to a calendar year (1 January to 31 December). Before any Party can issue a permit to allow export of specimens of species in Annex II, the scientific authority of the state must advise that the proposed export will not be detrimental to the survival of the species (the so-called non-detriment finding). In order to help make sure that export quotas are not exceeded, export permits should indicate the number of specimens already exported in the current year and the quota for the species concerned[223].

Indonesia has implemented a quota system for the collection of stony corals based on available information on rates of growth, recruitment, distribution and abundance of coral species[7]. The management plan for coral harvesting also includes a system of rotational harvests including no-take zones. However, in practice, quotas for coral species are based on very limited data, making it difficult to determine whether there is any basis for regarding these quotas as sustainable. As a result of this, the EU expressed concern at the potential

Lined butterflyfish, *Chaetodon lineolatus*.



Eritrean butterflyfish, *Chaetodon paucifasciatus*.

Grape/bubble coral, *Plerogyra* spp.

unsustainability of current export volumes and its CITES Scientific Review Group has temporarily banned the import of a number of coral species into the EU until Indonesia can demonstrate that collection according to the set quotas is indeed not contributing to reef degradation.

Size limits

Size limits are another useful tool in managing aquarium fisheries. The marine ornamental fish trade tends to be highly selective in favour of juveniles due to their distinctive coloration, low transport cost for exporters and optimal size to fit in a home aquarium. However, the young of some popular fish species are easily stressed and hence may suffer high mortality during holding and transport[6]. Setting minimum size limits such as those encouraged by an Ocean Voice International–Haribon Foundation project in the Philippines[118] would help ensure that stock is not unnecessarily wasted[224]. Maximum size limits are equally important to ensure that sufficient numbers of breeding adults remain on the reef. At the recent Nineteenth Meeting of the Animals Committee (18-21 August 2003) the decision of 'a universal minimum permissible size of 10 cm (height) [...] for all seahorses in international trade, [...] to allow animals to reproduce before being caught' was adopted.

The State of Florida has an exemplary regulation system stipulating minimum and maximum sizes for a number of ornamental fish species. According to the Florida Administrative Code butterflyfishes and several species of angelfishes (grey, French, queen and rock beauty), for example, are subject to both a minimum and a maximum length restriction[43]. Maximum length limits are also specified for gobies, jawfish and the Spanish hogfish[43].

Maximum size restrictions for the collection of coral pieces are important to ensure that mature colonies are not removed from the reef. Such restrictions would be particularly useful for species of coral which tend to develop particularly large colonies. The Indonesian authorities have stipulated maximum size limits of 15 cm and 25 cm for slow-growing species such as *Plerogyra* and *Catalaphyllia* and fast-growing species such as *Acropora* respectively[224]. Removing primarily small specimens is also likely to reduce damage to the reef habitat structure.

A study of *Pocillopora verrucosa* in the Philippines showed that maximum sustainable yield could be calculated using information on distribution and abundance as well as growth rate and rates of mortality and recruitment[225]. The minimum size that should be allowed at harvest was calculated to be 18 cm in height, equivalent to six years old.

Marine reserves

A potential solution to the localized depletion and habitat degradation that may result from extensive and unmonitored collection of marine ornamentals is the creation of marine reserves, areas where fishing is prohibited or controlled. Marine reserves have often been recommended, and suggested as useful tools in managing marine fisheries (usually food fisheries), for they have been shown to increase fish abundance[226-230] and protect ecosystems from habitat destruction due to fishing[231, 232]. Hence, they could also, if set up and managed appropriately, prove to be a valuable tool for managing aquarium fisheries[6, 13, 20, 224]. Australia, for example, has developed an effective management strategy whereby coral reef habitats have been divided into zones for different uses, which include no-take areas[74]. Selected collection areas, representing less than 1 per cent of the reefs in a region, have been established for licensed collectors to harvest coral for the aquarium trade[74]. Government statistics show that despite collectors harvesting 45-50 tonnes of coral per year for 20 years, no noticeable impact on the resource has been observed[74].

Reef fish assemblages and patterns of distribution of fish are influenced by the associated reef habitat, which provides food and shelter to a large number of organisms. The greater the complexity of the reef structure the greater the available fish biomass and the more diverse fish assemblages will be[233]. Therefore, in order to be effective at protecting the wide range of fish species of interest to the marine aquarium trade, marine reserves need to include a great diversity of habitats, i.e. have structural complexity[18]. The limited home range size and high level of habitat specificity associated with marine ornamental fish seem to indicate that marine reserves should be effective tools at managing ornamental fish populations.

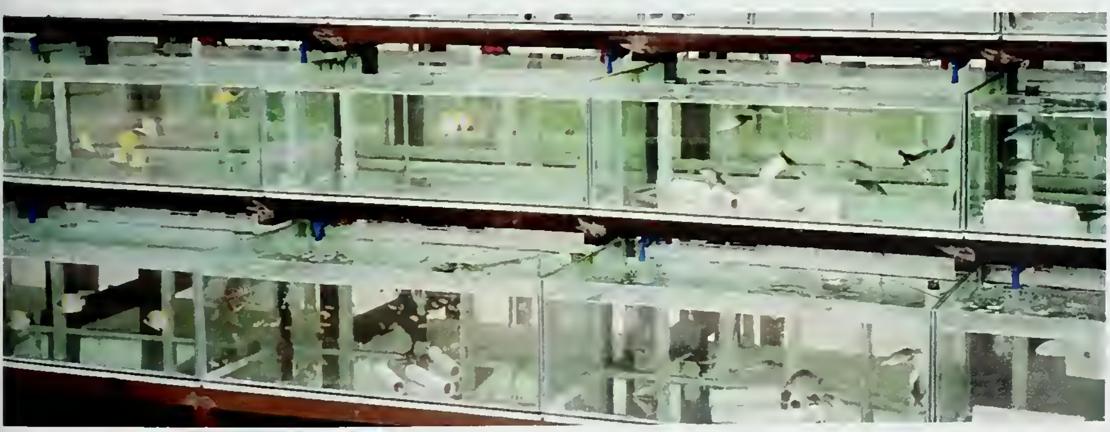
Management decisions (e.g. location for reserves) should involve participation by all stakeholders, with appropriate consultation with scientists and fishers at the local and national levels, so as to minimize conflict and optimize benefits[55, 234, 235]. Marine reserves are likely to be most successful at ensuring the sustainable use of local resources as well as increasing awareness and understanding of conservation and management issues if implemented by the collectors and relevant members of the community themselves, a process often referred to as community-based management. By giving community members a sense of ownership of their resources, they will more likely guard these against destructive uses[17, 30].

Traditional management under customary marine tenure (CMT) presents a unique set of conditions for the successful implementation of marine reserves. CMT plays a key role in the overall social, economic and cultural aspects of societies in the Pacific Islands[222]. In the Pacific basin, although CMT comes under a range of different organizational concepts, and has in part been eroded because of colonialism, the local community is often the exclusive owner of marine resources, managing coastal fisheries and habitats[222]. The essence of CMT structures is based on the idea that the more responsibility is left to local communities for the control of local resources, the less governments will have to be implicated in legal, conservation and social issues, and the greater the sense of responsibility members will have towards the sustainable use and conservation of marine resources and habitats. However, their effectiveness is likely to be dependent on how such systems adapt to changing socio-economic conditions.

Temporary closures

Temporary closures are often cited as an alternative to the implementation of reserves. This approach is commonly used to protect species during reproductive phases to ensure there is sufficient recruitment to sustain the population. Although not in operation specifically for the aquarium trade at present, such closed seasons could allow juvenile fish to grow to a size unsuitable for aquarium collection thus making sure that a healthy stock of adult fish is maintained on the reefs[6]. These adults in turn would contribute recruits and help maintain healthy population levels despite irregular and stochastic recruitment events. It is important to note that temporary closures are only likely to be effective if implemented at the right time and at the right location[224].

Holding tanks at a marine aquarium wholesaler.



Conclusions and recommendations

On the journey from 'reef to retail'.

Given the wide range of threats facing coral reefs, with reefs in Southeast Asia – the most important source of the majority of animals in the marine ornamental trade – particularly at risk, it is becoming increasingly important that harvesting of marine organisms for the aquarium trade is appropriately managed in order not to further compound these problems. However, to date only a relatively small number of countries have put in place comprehensive regulations to control the collection of marine ornamentals. The highly selective nature of these fisheries increases their impact on populations of targeted species. They may also, directly through the use of destructive fishing practices or indirectly through the removal of key species (e.g. cleaner fish/shrimp), impact other species and ecological processes in the habitats where fishing for the aquarium trade occurs.

Most of the restrictions that regulate the trade to date have been put in place despite a lack of information on the population status and life characteristics of the targeted species. More accurate trade data, and much more specific information on particular life history characteristics such as recruitment and growth rates, should be collected to establish quotas and maximum sustainable yields, as well as to help in the development of frameworks to manage the collection of reef organisms for trade on a sustainable basis. Certification schemes and associated operational standards for the industry need to be further developed and more widely applied to make certain that fish are collected, handled and transported in a manner that minimizes stress to the animals right through the process from 'reef to retail'. Raising awareness through the circulation of information materials about these standards and the steps that consumers can take to help ensure animals are being collected in a way that is sustainable should also be promoted. The purchasing power that hobbyists possess is undoubtedly the single most important market force in the marine aquarium industry. If sufficient numbers of informed consumers demand fish that have been caught using sustainable techniques it is likely that this will have important positive repercussions on fishing methods globally. In source countries, and particularly in Southeast Asia, steps need to be taken to reform policies, strengthen institutions (e.g. mount public awareness campaigns in the media and schools) and develop pro-active training programmes to encourage collectors to use non-destructive methods.

Species that are unsuited to life in aquaria or exhibit low population densities, restricted ranges, or life history traits that make them particularly vulnerable to collection, should receive special attention to reduce the risks of overexploitation.

The designation of marine reserves, establishment of quotas and size limits in addition to measures to limit access to the fishery are examples of ways in which population stocks of marine ornamentals could be both conserved and managed so as to provide sustainable livelihoods for low-income coastal populations. It is important that management decisions, such as the location of reserves, involve the participation of all stakeholders, including appropriate consultation with scientists and fishermen at the local and national levels. In this way, conflicts can be minimized and benefits optimized.

Finally, further research into mariculture technologies is needed in order to take pressure off wild stocks and increase the cost effectiveness of facilities. Such projects should develop as an alternative livelihood for fishing communities in source countries, thereby integrating conservation and sustainable development objectives.

Endnotes

i. The marine aquarium trade is composed of: saltwater fish, corals (stony and soft) and invertebrates (e.g. shrimps, small clams) that can be kept in an aquarium. Fish make up about 85 per cent of the trade by value.

ii. Process by which a product is labelled, making it possible for the consumer to choose products that are environmentally friendly and have been collected in a sustainable way.

iii. CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. CITES is an international agreement to which States (countries) adhere voluntarily. States that have agreed to be bound by the Convention ('joined' CITES) are known as Parties. Although CITES is legally binding on the Parties – in other words they have to implement the Convention – it does not take the place of national laws. Rather it provides a framework to be respected by each Party, which has to adopt its own domestic legislation to ensure that CITES is implemented at the national level. Further information on CITES and its Appendices can be found at http://www.cites.org/

iv. Further information on live animal transport can be found at http://www.iata.org/cargooperations/liveanimals/index

v. For more information visit http://www.aata-animaltransport.org/

vi. The MAC Core Standards Interpretation Document can be found at: http://www.aquariumcouncil.org/docs/library/1/10-01-02_MAC_Core_Standards_Interpretation.pdf

vii. Further details on EU wildlife trade regulations can be found at: http://europa.eu.int/comm/environment/cites/home_en.htm or http://www.eu-wildlifetrade.org/

viii. Japan's data are based on exporters' reports for 1997 and years 1999-2001 as Japan's Annual Reports for 1999-2001 are not available and Japan did not report any coral imports for 1997.

ix. Canada's data are based on exporters' reports for 1997 and 2000 – there were no coral imports reported in 1997 and Canada's 2000 Annual Report is unavailable.

x. Republic of Korea's data for 2001 are based on exporters' reports as its 2001 report is unavailable.

xi. The EU comprises Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

xii. The author, through a MAC representative, approached John Brandt, an experienced aquarium hobbyist, for an alternative opinion. In answer to the question, 'What constitutes an unsuitable species?', and in response to a request to derive species lists fitting that criterion, he replied:

'The experiences of aquarium hobbyists and professional aquarists have shown that some species of animals are unsuitable for captivity. Though there may be a variety of causes, the underlying factor with these animals is that they cannot consistently be maintained in aquariums successfully. Unsuitability is a culturally derived category. Most aquarists agree that a failure to thrive in captivity is a fundamental characteristic of an unsuitable species. Some aquarists regard species that can reach a large adult size as being unsuitable. There is also a common sentiment that truly unsuitable species should not be collected for the aquarium trade.

'The most frequent reason that an animal cannot acclimatize to captive care is that its dietary needs cannot be met. Many reef species are obligatory feeders (e.g. Butterflyfishes[42, 173]), meaning that they eat only one or few types of foods in the wild. When placed in aquariums they may refuse to eat prepared foods or if they begin eating they may experience malnutrition over time. Unsuitability is characterized by high rates of mortality and greatly reduced lifespans. Occasionally individuals can be found that have acclimatized to captivity, but rarely can any particular factor be attributed to their success.

'The factors for unsuitability in lists A (highly unsuitable species) and B (generally unsuitable species) only involve failure to thrive in captivity; not potential size, toxicity or any other factors that may make a species unsuitable.

'These compiled lists and their criteria do not represent a highly formalized approach to the issue. Much dialogue between hobbyists, professional aquarists and scientists on this topic should occur before any official regulations, policies or legislation be enacted from these lists.'

xiii. Coral that has a mutualistic relationship with zooxanthellae (small algae) and, hence, grows only in sunlit waters.

xiv. Loss of the coral's zooxanthellae.

xv. Recruitment is an integral part of fish population dynamics, because the survival of juveniles ultimately dictates the abundance of adult populations. In order to survive, juveniles must overcome competition, predation and habitat availability[124]. Typically, researchers define recruitment as the survival of individuals that settle as larvae out of the plankton to reef habitat.

xvi. An organism that has an intimate association with one or more organisms of a different species.

xvii. Two notable exceptions to the rule:
Acanthochromis polyacanthus: This species of damselfish incubates its eggs in a small crevice for two weeks. Once the eggs hatch they do not disperse with ocean currents but instead shoal near the bottom;
Pterapogon kauderni: In this species the male retains the free embryos in his oral cavity for several days and so there is a complete lack of a planktonic phase.

xviii. Main countries of destination given by the database were the Netherlands and the United States.

xix. This section is based on the MAC website and Holthus[113].

xx. More detailed information on cultured fish and invertebrates can be found under the breeders' registry: http://www.breeders-registry.gen.ca.us/

xxi. Currently, the most important farms are based in the Bahamas (Aqualife Research), the United States (ORA Farms and Dynasty Marine Associates in Florida and C-Quest in Puerto Rico) and the UK (Tropical Marine Centre in London).

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From **Ocean** to **Aquarium**

The global trade in marine ornamental species

From Ocean to Aquarium is the product of a collaboration between UNEP-WCMC, the Marine Aquarium Council (MAC) and the industry itself. It is the first of its kind, examining issues surrounding the trade of live coral, fish and invertebrates for the marine aquarium trade, and presenting a comprehensive and independent synthesis of related information.

With the total value of the trade amounting to as much as US$330 million a year and an estimated 2 million people worldwide keeping marine aquaria, the industry plays a significant role in both source and destination countries.

Tropical coral reefs are the most important source of specimens for the aquarium trade – mainly fish, including seahorses, the corals themselves, and others such as anemones, starfish and giant clams. Almost all marine aquarium species are taken from the wild, with few examples of captive breeding. Most originate from Southeast Asia, particularly Indonesia.

From Ocean to Aquarium presents a brief overview of how the trade functions and the impacts it has on coral reefs, as well as on the human communities that derive an income from trading in marine ornamental species. It describes, for example, the effects of destructive harvesting techniques such as the use of cyanide, and the risks certain species face of over-collection to satisfy the demands of aquarium hobbyists. However, it also highlights the measures that can be taken to ensure the sustainable collection of organisms, minimizing the impacts on coral reefs while maximizing the income for coastal communities.

It is with this in mind that organizations are working together to ensure the future for coral reefs, their animals and the aquarium trade.

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