COLLECTION OF CORAL REEF FISH FOR AQUARIA: GLOBAL TRADE, CONSERVATION ISSUES AND MANAGEMENT STRATEGIES

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PREFACE

This report is part of a long-term programme on the marine aquarium trade being carried out by the Marine Conservation Society (MCS), and also contributes to the work of the IUCN Species Survival Commission Coral Reef Fish Specialist Group.

One aim of the report is to provide technical background information to support an MCS guide called the *Responsible Marine Aquarist* which will be available later this year. The aim of the guide will be to encourage users of marine ornamental resources to be selective when they stock their tanks, and to try and choose appropriate species from well managed fisheries. Although this current report deals mainly with fish, the guide will also deal with invertebrates, recognizing that they are an important component of the trade, and that their collection also needs managing.

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CONTENTS

SUMMARY

The marine ornamental fish trade began as long ago as the 1930s, but it was not until the 1950s that it became firmly established on a commercial scale. By the 1970s it had expanded into a multi-million dollar industry, with fisheries operating all around the tropical world.

Currently about 45 countries supply the market. The most important suppliers are Indonesia and the Philippines, with Brazil, Maldives, Vietnam, Sri Lanka and Hawaii also supplying significant quantities. The main consumer markets are the United States, Europe and the Far East, especially Japan. The total import value of the specimens is calculated to be between US$ 28-44 million.

Total global annual catch could range from about 14 million to over 30 million fish. However, a number of assumptions that have been made in reaching these figures, so they should be treated with caution.

Marine aquaria can help to inform people about reef biodiversity and conservation, and the trade also provides jobs and economic benefits for supplying countries. However, there are a number of conservation and management issues connected with marine ornamental fisheries. Destructive methods of collection, including the use of cyanide, capture of species with low survival rates, high post-harvesting mortalities and the potential for over-exploitation are the most pressing concerns.

Over-collecting may threaten biodiversity at a local level. Of particular concern are the impacts of collecting on rare or endemic species and this requires further investigation. Stocks of target species need to be monitored on a country-by-country and reef-by-reef basis because of variability in abundance of particular species at different localities.

A few countries have effective ornamental fishery management plans in operation, others have poorly enforced regulations or no regulations at all. Considering the pressures currently faced by reefs it is important that ornamental fisheries are monitored and managed to ensure they are sustainable, and do not conflict with other economically important uses of coral reefs, especially tourism.

Conservation organisations, government agencies, public aquaria, aquarium hobbyists, scientists, and the aquarium trade itself are increasingly working together to try and address the problems and seek solutions. Several countries have fairly recently introduced controls because of environmental or conservation concerns and/or because of conflicts with other users of the same resource. This report discusses conservation issues and the steps being taken to manage the fisheries.

The following actions are recommended for improved management and conservation of resources:

- Collection and analysis of comprehensive and accurate data on exports, imports and domestic use of marine ornamental resources.

- Registration and licensing within all sectors of the industry, together with introduction of mandatory minimum standards and appropriate training and inspection schemes.

- Introduction of fishery log books to record species and numbers of individuals caught, collecting areas and time spent collecting. Compilation of the data and analysis to calculate and monitor catch per unit effort (CPUE) of a) all species combined and b) selected key species.

- Collaborative programmes between scientists and collectors to investigate resource base and use this information to combine with CPUE data to produce mutually-agreed quotas and exploitation guidelines.

- Designation of no-take areas to help conserve stocks of ornamental species and act as control sites to compare with areas where collecting occurs.

- Regulation of collecting effort by restricting the number of collectors.

- Protection of species with low population densities on a country-by-country basis.

- Cessation of trade in species that are known to have poor chances of survival until such time as husbandry problems have been solved.

- Development of mariculture in countries of origin to relieve pressure on wild stocks.

- Production of educational materials to support training, encourage better standards and promote public awareness of conservation and management issues associated with the marine aquarium trade.

INTRODUCTION

Sri Lanka was one of the first countries involved in the collection and export of tropical marine fish for the aquarium trade (Jonklaas, 1985). This began around 1930 and was run on a very small scale by professional collectors operating out of Colombo. Collections were made from passenger and cargo steamers and fish were stored in tanks on the boat's deck until they reached their final destinations. This trade expanded gradually during the 1950s as dealers began exporting fish by air.

In the 1950s, fish were being supplied from a number of other locations. For example, permits were first issued in Hawaii in 1953 (Walsh, 1999), and in the Philippines in 1957 (Fleras, 1984). Keeping marine aquaria was becoming increasingly popular and this was reflected in the demand for fish. For example, Hawaii issued 4 commercial fish collecting permits in 1968 and 65 in 1974 (Randall, 1987). In 1995 there were 167 permits and by 1998 the number had grown to 274 (Clark & Gulko, 1999). Concurrently, the harvest rose from 90,000 fish in 1973 to 422,823 in 1995 (Miyasaka, 1997).

In the early 1980s, the import value of marine fish and invertebrates for the aquarium trade was estimated to be between US$ 24-40 million annually, with over 40 countries supplying the market (Wood, 1985). Since that time, demand has fluctuated, and there has been an increase in the invertebrate side of the market (see p. 6). Overall, the value of the marine ornamental trade has apparently remained fairly stable in recent years (West, Tropical Marine Centre, UK, pers. comm 2000). This is substantiated by an examination of trade figures (see below).

Nearly all the tropical marine aquarium fish and invertebrate in trade are taken from on or around coral reefs. About 25 species are cultured on a commercial basis but the bulk of specimens, probably well over 98%, are taken from the wild (Moe, 1999). This raises conservation issues, and there has been a long-running debate about the positive and negative aspects of the trade. Coral reefs are valuable and important ecosystems that are threatened by pollution, destructive fishing, over-fishing, bleaching, tourism development and other stresses and activities. It is important that capture of reef animals for the aquarium trade does not add to the problems.

On the positive side, keeping marine tanks in the home, or visiting public aquaria can help educate the public about coral reefs and increase awareness of the need to conserve reef ecosystems. Aquarium fisheries typically target non-food species and are economically valuable, which should provide an incentive to conserve reef habitats. Although the economic importance of aquarium fisheries is tiny in comparison with food fisheries, the industry provides jobs and income for many people, particularly in supplying countries (e.g. in addition to collecting fish there are jobs involved in holding, packing and distributing them). Dufour (1997) concludes that for the Pacific Islands, if costs of transport and salaries can be controlled, an annual harvest of 100,000 fish could yield a turnover of US$ 200,000 and 10-20 permanent jobs.

On the negative side, the aquarium trade has raised concerns about the conservation of reef fish and their coral habitats. The main issues are possible over-exploitation of target species, secondary effects of this on reef communities, damaging methods of collection and high post-harvest mortalities. Collection needs to be properly managed, so that species are not over-exploited, and only those suitable for captivity are traded. Steps also need to be taken to ensure that reef habitats are not damaged during collection.

This report deals primarily with fish, but it is relevant to note the growing popularity of 'reef aquaria' which focus mainly on invertebrates rather than fish. For example, in the Philippines, approximately 20% of marine ornamental products (by volume) is reported to consist of invertebrates (Vallejo, 1997), and traders calculate that overall up to 30% (by value) of trade is currently taken up by invertebrates (West, pers. comm. 2000). In Florida State and adjacent Federal waters the economic importance of fish species landed for the marine ornamental trade fell from 54% in 1990 to 25% in 1998, with live rock and live sand averaging about 50% by value of landings (Lee *et al,* 1999). During this time, landings declined for more than half the fish groups but increased for most invertebrates.

OVERVIEW OF TRADE

Methods and sources of information

Some information on the marine ornamental trade was extracted from the relevant government export and/or import statistics, but unfortunately these trade categories are not always fully reported. Exports and imports of marine specimens may be combined with freshwater ones, or occasionally with other commodities, and the statistics do not always clarify whether the figures include invertebrates as well as fish.

Where records are available, exports and imports are generally registered either by value or weight rather than numbers of specimens. Value of exports is expressed as the fob cost (free-on-board = cost of goods without freight, packing and duties), while value of imports is the cif price (cost of livestock + carriage, insurance and freight). As a "rule of thumb" the cif value is double the fob value (OATA, 1999). When consignments are declared by weight, this includes water and packaging as well as the fish. Packaging methods vary, but in general fish livestock account for only about 1.5-3.0% of the total weight of the consignment (Davenport, Ornamental Aquatic Trade Association (OATA), pers. comm. 1998).

Trade in species included in the Convention on International Trade in Endangered Species (CITES) is monitored more rigorously, but no ornamental marine fish are currently listed, so no information can be obtained through this route. Giant clams (Tridacnidae) and hard corals are popular in the aquarium trade, and both these groups are listed in Appendix II of CITES, which means that permits have to be obtained and trade is monitored. Global trade in corals has been analysed recently (Green and Shirley, 1999) and is not dealt with in this report.

Additional details on trade in ornamental specimens and management of the fisheries were derived from published scientific papers, but most of the information has came from unpublished reports and knowledgeable contacts in the countries of origin. These sources are acknowledged in the text.

Much more detailed information on international trade will become available through a partnership between the Marine Aquarium Council (MAC) and the World Conservation Monitoring Centre (WCMC) which has created a central facility for assembling and analysing data on the international trade in marine aquarium organisms. This has been named the Global Marine Aquarium Database (GMAD) and the first report is scheduled to be produced during 2001.

Supplying countries and their relative importance

Ingredients for an economically successful fishery include access to popular species that can be supplied in high numbers as well as species not available from other sources. Proximity of the collecting sites to international air links is also important, especially in relation to providing fish that are not stressed as a result of many days spent in transit from the reef to the export facility.

Supplying countries are listed in Table 1. The most important suppliers are Indonesia and the Philippines, with Brazil, Maldives, Vietnam, Sri Lanka and Hawaii also supplying significant quantities.

	Relative Size of Fishery: Year 2000	Domestic use [D] or Export [E]	Summary Profile of Fishery [for further details and sources of information see appendix]
Western Atlantic and Caribbean			
USA: Florida	Large	D & E	Began in the 1970s. Currently about 100-125 full time collectors. 191,567 fish were collected in 1996. Florida also produces cultured marine fish.
Bahamas	Small	E	Exports mainly to the USA
Cuba	Small	E	Began in the late 1990s. Exports mainly to the USA
Dominican Republic	Medium	E	Exports mainly to the USA
Haiti	Medium	E	Exports mainly to the USA. Probably over 20 exporters
Puerto Rico	Large	E	Exports mainly to the USA. Began in the early 1970s. Suspended in 1999 but currently operating again at a lower level
Martinique	Small	E	Exports mainly to France
Barbados	Small	E	Exports only to the UK
Curacao	Medium	E	Exports mainly to Holland and Germany
Mexico	Small	D & E	Began in the late 1980s; prohibited in the mid-1990s but re-opened in Baja California.
Belize	Medium	E	Began in the 1970s. The fishery has not been expanded to its maximum potential because of environmental concerns.
Honduras	Small	E	Exports mainly to the USA
Colombia	Small	E	Exports mainly to the USA
Venezuela	Small	E	Exports mainly to the USA
Brazil	Large	E	Exports mainly to the USA, but also to Europe and other destinations. 23-25 wholesalers deal in marine fish.
Red Sea			
Egypt	Small	E	Began in 1984. Four export companies operating. Exports go mainly to the Far East and Europe. Numbers exported declined to 6,257 in 1998. 50 species are used.
Saudi Arabia	Small	E	Began in 1997. Possibly only two companies are currently active. In 1999, 14,058 fish were exported. 117 species of fish are used
Yemen	Small	E	Possibly as many as 5 companies are licensed to collect coral reef fish, and there are others operating without licences.
Arabian Gulf			
Bahrain	Small	E	One company is active. Exports go mainly to Japan and other Far East countries. Export value (local caught and re-exports) peaked at US$ 466,373 in 1994 and had declined to US$ 21,640 in 1999.
East Africa			
Djibouti	Small	E	One company is authorised to collect and export ornamental fish, but it is possible that the fishery is not currently operating
Kenya	Medium	E	Well established by the mid 1970s. 65 registered fish collectors operating in 2000, but possibly some unregistered. 4 export companies, with exports going mainly to Europe but also to the Far East and South Africa.. The numbers of fish and invertebrates exported have declined from 203,300 in 1995 to 24,493 in 1998. At least one third were invertebrates.
South Africa	Medium	D & E	
Indian Ocean			
Madagascar	Small	E	Recently started
Mauritius	Small	E	Two companies are operating. Exports go mainly to the Far East, South Africa, Reunion and Europe. 13,037 fish were collected in 1998.
Sri Lanka	Large	E	Well established by the 1960s. Currently around 1,000 full and part-time collectors are operating. Exports go to over 40 countries and export value is probably about US$ 1.5 million. Around 200 species of fish are used.

MALDIVES	Large	E	Began in 1979. Four companies operating in 2000. In 1999, 33% of fish were sent to Sri Lanka, the rest were exported directly to Europe, the Far East and the USA. In 1994 and 1996 more than 300,000 fish exported (fob value US$ 480,000); in 1999 167,000 were exported (value US$ 297,000). 100 species are used, with 20 species taking 75% of trade.
SOUTH-EAST ASIA –AUSTRALIA AREA			
COCOS KEELING	Small	E	Total allowable catch of 2,000 aquarium fish per annum
THAILAND	Large	E	Export had begun at least by the 1970s. From 1987-1990 exports from Phuket (one of the main collecting areas) were worth about 28-52 thousand US$ annually. Many fish are sent to Singapore for re-export or domestic use. Singapore imported 285,600 marine ornamental fish from Thailand in 1998.
VIETNAM	Large	E	Export probably began in the 1980s. A significant amount of stock probably goes to neighbouring countries for re-export. There are currently 100 full-time and 200 part-time collectors. Possibly about a million fish are collected annually.
TAIWAN	Small	D & E	Collecting is partly seasonal. Certain species are also cultured here.
HONG KONG	N/A	D & E	There is no collecting in Hong Kong waters. Marine fish are imported from neighbouring countries and used locally or re-exported.
PHILIPPINES	Very large	E	Exports began in 1957 and export value peaked in 1988 at about US$ 8 million. From 1990-1994 exports averaged US$ 6.76 million. In the early 1990s there were an estimated 2,500 collectors, and there are currently 34-37 companies actively exporting. It is estimated that about 6 million aquarium fish were exported in 1996. The fishery uses 386 species of coral reef fish belonging to79 families.
MALAYSIA	Small	D	Malaysia used to export marine aquarium fish, mainly via neighbouring countries for re-export, but export is no longer permitted. The quantities caught for the domestic market are unknown.
SINGAPORE	N/A	D & E	There is no collecting in Singapore waters. Marine fish are imported from neighbouring countries and used locally or re-exported.
INDONESIA	Very large	E	Export was established at least by the early 1970s and possibly earlier. It is now one of the major suppliers. Export value of marine ornamental fish in 1993 was US$ 5.5 million with stocks going mainly to USA and the Far East, also to Europe.
AUSTRALIA	Large	D & E	Commercial collection began in the 1970s. The number of collecting permits peaked at 160 in 1990 but had fallen to 63 in 1998, allowing about 180 collectors to operate. About 170,000 fish were collected in 1997, involving 150 species.
PACIFIC OCEAN			
JAPAN	Medium	D	Possibly also some export. 104 collectors operate in the Okinawa region.
BELAU (PALAU)	Medium	E	Export began in 1991. Single exporter and 5-15 full time collectors. About 100,000 fish and 40,000 invertebrates were exported in 1994, with a total value of US$ 200,000. The trade involves 200 species of fish and 100 species of invertebrate.
GUAM	Small	E	Exports go to Hawaii or California. There are two export companies, and between 5000-7000 fish are exported annually.
MARSHALL ISLANDS	Small?	E	Exports go mainly to the USA via Hawaii
HAWAII	Large	D & E	Commercial collection began in 1953. There are currently 274 permits and the value of organisms collected in the late 1990s was about US$ 0.8-0.9 million. The trade involves 103 species of fish.
NEW CALEDONIA	Small?	E	Recently re-started after a lapse of about 10 years
FIJI	Large	E	Collecting began in 1976. There are currently 5 export companies, exporting about 50 to 100,000 fish annually. There is a substantial trade in live corals.
TONGA	Small?	E	Single exporter
AMERICAN SAMOA	Small?	E	Single exporter with exports going mainly to the USA
COOK ISLANDS	Small	E	Collecting began in 1988. There are currently 6 full time and 3 part time collectors. 20,000 fish were exported in 1994.
COSTA RICA	Medium	E	In the early 1990s there were 40 authorised divers with around 143,000 exported annually. The trade involves 43 species of fish.

Table 1. Countries involved in collection and supply of marine ornamental fish

Relative size of fishery: Small: up to 50,000 fish exported annually, or export value less than US$100,000
Medium: 50,000 – 100,000 fish exported or export value up to about US150,000
Large: 100,000 – 200,000 fish exported, or export value up to about US$300,000
Very large: 200,000 + fish exported annually, or value over US$300,000

Estimating level of international trade

It should be possible to determine the level of international trade in marine ornamental fish from export and/or import data, but unfortunately these trade categories are not always fully reported. Exports and imports of marine specimens may be combined with freshwater ones, or occasionally with other commodities. When recorded separately they are generally registered either by value or weight rather than numbers of specimens. The statistics do not always clarify whether the figures include invertebrates as well as fish.

Imports

USA

The USA is a very important market for aquarium species. In 1992, 201 million ornamental fish were imported to the US at a value of US$ 44.7 million (Basleer, 1994). By volume only 4% (8 million fish) were marine, yet their value was 20% of the total (US$8.9 million) (Basleer, 1994). Imports to the US of 'live ornamental fish' peaked at US$ 54.3 million in 1995 and had fallen to US$ 45.1 million by 1998 (Bureau of Census data quoted in Milon *et al.* 1999). It is unclear if the proportion of marine to freshwater has remained the same.

European community countries

Other major importers are countries from the European Community. Imports of marine ornamental fish to Europe in 1992 were also worth US$ 8.9 million (Eurostat figures; see Table 2). In 1998, import (cif) value had risen to US$ 12.2 million.

Japan

Japan is known to import significant quantities of marine ornamental fish, as shown from the export statistics of several important suppliers. For example, exports from Indonesia to Japan in 1993 (calculated from data supplied by Directorat Jendral Perikanan, Departemen Pertanian, Jakarta) were worth approximately US$ 858,000. Exports from Singapore to Japan (source; external trade statistics of Singapore) between 1996 and 1998 were between Singapore $ 136,000 and S$ 157,000 annually (approximately US$ 76,000 – 88,000). Maldives export figures (Source: Maldives Customs Services, Compiled by Ministry of Fisheries, Agriculture and Marine Resources) show that the quantity going annually to Japan from 1997 to 1999 had an annual export value of between US$ 17,000 - 24 000. These three countries alone are supplying exports to Japan worth in the region of US$ 1 million (fob price), which is equivalent to at least US$ 2 million import (cif) value. Japan undoubtedly imports from many other countries, so the total import value could well be in the region of US $ 3 million.

Total

Adding import data for the US (1992), the EC (1998) and Japan (estimated total based on 1993-1999 data) gives a total import (cif) value of about US$ 24 million. There are many other countries also involved, so it is not unreasonable to conclude that the global import value could be in the region US$ 28 – 30 million.

Supplying country	Max & min annual import value for period 1992-1998 US$ 000	Import value 1992 US$ 000	Import value 1998 US$ 000
Indonesia	2108 - 5116	2108	4990
Philippines	1300 - 1746	1300	1746
USA: mainly Florida & Hawaii	920 - 1561	1089	1561
Sri Lanka	1145 - 1328	1193	1025
Singapore *	510 - 1829	1739	510
Kenya	338 - 497	451	497
Maldives	232 - 412	363	357
Brazil	26 - 304	69	302
Yemen	0 - 217	0	217
Egypt	116 - 221	117	177
Australia	58 - 154	84	117
Saudi Arabia	19 - 119	19	105
Fiji	26 - 78	26	78
Curacao	10 - 102	102	78
Eritraea	0 -73	0	73
Malaysia	4 - 56	4	56
Costa Rica	0 - 44	44	37
Cuba	2 - 37	0	37
Mauritius	0 - 31	0	30
Belize	2 - 27	18	27
Iran	0 - 46	0	20
Thailand	5 - 29	10	16
Dominican Republic	0 - 37	0	13
Barbados	11 - 36	34	11
Colombia	2 - 12	3	11
India	0 - 8	0	8
Haiti	0 -17	0	7
Hong Kong*	1 - 6	1	7
Solomon Islands	0 - 9	0	7
United Arab Emirates	0 - 5	3	5
Tanzania	0 - 4	0	4
Belau (Palau)	0 -2	0	2
Ethiopia	0 - 11	0	2
South Africa	0 - 2	4	2
Martinique	58 - 85	60	0
Bahrain	0 - 62	18	0
Djibouti	0 - 32	5	0
Guadeloupe	0 - 25	25	0
Israel	1 - 4	1	0
Japan	0 - 11	0	0
Madagascar	0 - 6	6	0
Marshall Islands	0 - 1	1	0
Taiwan	0 - 4	1	0
TOTAL		8,903	12,135

Table 2. Value of imports (cif – carriage, insurance and freight) of marine ornamental fish into European Community countries from 1992 – 1998 (source: Eurostat data). * Re-export (not a producer)

Exports

It is useful to try and check the estimated world import value against exports. Indonesia and the Philippines are known to be major suppliers of marine ornamental specimens. Indonesian Fisheries export statistics for 1993 give total exports of ornamental fish as 3,043 tonnes (including packaging), valued at US$ 8.5 million, with marine species amounting to 2,039 tonnes, valued at US$5.5 million (fob price). Export value for marine specimens from the Philippines averaged US$ 6.76 million annually from 1990-1994 (Bureau of Fisheries and Aquatic Resources [BFAR] statistics quoted in Vallejo, 1997).

Pacific countries (excluding Hawaii and Japan) were exporting ornamental fish with a value of US$ 1-1.5 million in the early 1990s (Pyle, 1993). In the latter part of the 1990s, reported value of all marine animals collected in Hawaii for marine aquariums ranged between US$800-$900 thousand annually (Miyasaka, 1997). Singapore is another major supplier to the world market, with exports of marine ornamental fish (representing re-exports from neighbouring countries) between 1996-1998 valued at an average of S$ 4.2 million annually, which is approximately US$ 2.3 million.

Adding export value for Indonesia (1993), Philippines (average 1990-1994), Pacific countries (early 1990s) Hawaii (late 1990s) and Singapore gives a total of about US$ 18.6. There are many other countries supplying smaller amounts, which must add up several million dollars perhaps bringing the total export value to about US$ 22 million.

Based on trade data (OATA, 1999), the import price is approximately double the export price. Thus if the export value is around US$ 22 million annually, the import value will be US$ 44 million annually, rather than the 28-30 million calculated above. The discrepancy between these two figures illustrates the difficulty in trying to come to accurate conclusions data from incomplete data.

Retail value of the trade in marine specimens is estimated to be between US$90-300 million (Wheeler, 1996; Biffar, 1997; Warmolts, 2000). The lower end of this scale fits reasonably well with estimated import value of between US$ 28-44, given that retail price is at least twice and possibly three times the import price.

Estimating numbers of specimens in trade

The Maldives and Singapore are amongst the relatively few countries that report exports and imports in terms of numbers of specimens being traded. Currently, there is no readily available information on total numbers of specimens traded at a global level, but it is possible to make very rough estimates based on the value of imports and exports.

The global import value of marine fish may be in the region of US $ 28-44 million (see above). If, according to Basleer (1994) and import value of $8.9 million represents about 8 million fish, then $ 28-44 million would represent around 25-40 million fish, based on an average import price of US $1.1.

Another way of estimating numbers in trade is to extrapolate from export value. Table 3 shows examples where both the number of fish and their export value has been recorded in official statistics. Calculation of the average unit price for a fish based on these large samples shows that the average export price/fish for these countries varies between US$ 1.08 – 1.99. If the global export value is US$ 22 million (see above), then this could represent between about 20 million and 11 million fish.

		Number of fish	Export (fob) value (US$)	Average export price/fish (US$)	Source
Eritrea	1997	103,813	112,798	1.08	Habte, 1997
Maldives	1997	262,641	481,000	1.83	Customs data, compiled by EPCS/ Ministry of Fisheries, Agriculture and Marine Resources, Maldives.
	1998	182,916	296,000	1.61	
	1999	167,000	297,000	1.70	
Singapore	1998	1,294,200	3,062,000	1.32	Singapore government statistics
Hawaii	1995	422,823	844,843	1.99	Miyasaka, 1997

Table 3. Average export price of marine ornamental fish based on large samples from four locations**.**

The two methods of calculating numbers in trade give significantly different results – from a top figure of 40 million, to a lower one of 11 million. The Ornamental Aquatic Trade Association (OATA, 2000) calculated that 10 million ornamental marine fish are imported annually throughout the world. Only when detailed records are kept will it be possible to find out which of all these figures is the more accurate.

Estimating total catch

Australia, the Cook Islands and the US State of Florida are examples of the relatively few areas where catch records are kept. Most other marine ornamental fisheries are not monitored in this way so the only way catch can be calculated is by adding numbers of fish exported + domestic sales + mortalities between harvest and export. Unfortunately, one or all of these components is generally unavailable.

As explained above, the estimates of numbers of specimens in trade ranges from 11-27 million. Information on domestic sales and mortalities is equally lacking, and only very rough estimates can be made. Japan, Taiwan, Australia, Florida, Hawaii and South Africa all have important domestic markets, and such markets are also growing in countries such as Malaysia, Indonesia and Singapore (Sankey, pers. comm. 1999). Probably several million fish are collected to supply these local demands.

On average, mortality after harvesting and up the time of importation may be around 8-10% (see page 30), which again represents several million fish. Thus total global annual catch could range from about 14 million to over 30 million individuals. However, given the number of assumptions that have been made, these figures should be treated with caution.

Value of fish through the chain

The amount paid to collectors reflects the desirability, availability and quality of the fish. However, it also depends on the number of links in the chain from collection to export. If the collector is also the exporter (a situation which occurs in some small ornamental fisheries), then he will receive the full export value of the fish. If he sells directly to the exporter he will receive perhaps half as much as the export price (see Table 4) but if he sells to a middleman then he may receive only one tenth of the export price (Baquero, International MarineLife Alliance, pers.comm. 2000). The low prices paid to collectors involved in chains (e.g. in the Philippines and Indonesia) is one of the reasons why collectors strive to increase their catch per unit effort and use cyanide (see p.29) as an aid in this process (Baquero, pers. comm. 2000). In the Pacific region, income of collectors is reported to be on a par, or above, the average salaries for the country (Pyle, 1993).

The value of fish based on the fob export price may be as low as US$0.10 for small, abundant species. Readily available, but more interesting specimens generally range from US$ 1to $5, whilst less common/more exotic species (e.g. ribbon eels, clown triggerfish, various butterflyfish, angelfish and groupers) vary between US$ 10-30. Rarities such as unusual hybrids or deep-water species may have an export price of hundreds or even thousands of dollars. Rare species and ones which are difficult to collect command the highest prices. For example, the masked or Hawaiian angelfish *Genicanthus personatus,* can fetch over $500 in Japan (Randall, 1987).

Export prices also vary between countries. For example, the bluehead angelfish *Pomacanthus xanthometopon* costs US$15 in Jakarta but US$25 in Manila (Vallejo, 1997). Higher prices will also be commanded for specimens from one particular area or supplier that consistently survive better than the same species originating form other areas.

The import price of specimens is the cif value. Generally the freight, packing and forwarding cost per unit are higher than the fob cost of the fish (Sankey, previously Tropical Marine Centre, pers. comm. 1999). This means that the import price will be at least double the export price.

In cases where there is a trade for both adults and juveniles of the same species, (for example certain angelfish and triggerfish), the import cost of adults is consistently greater than juveniles. This differential is due mainly to the freight costs which are set per kg. An adult requires proportionally more water, for example 3 - 6 litres/kg as against 1-2 litres/kg for a juvenile, and this boosts the cif (import) cost of large fish (Sankey, pers, comm, 1999).

Table 4 shows how the value of a specimen increases substantially at each step through the supply chain. In this example, the retail price of an emperor angelfish (*Pomacanthus imperator)* can be between 11 to 14 times the price paid to the collector, and this is in a situation where no middlemen are involved.

	Approximate prices (US$) paid for emperor angelfish *(Pomacanthus imperator*), based on unpublished data obtained by the author from Sri Lanka, and UK dealers lists, 1998.		Example of typical price structure for marine aquarium fish (Perino, 1990)
	small	large	
Price paid by dealer to collector	6	9	2.5 – 12.50
Export price (i.e. fob price of fish without freight costs)	12	24	25
Wholesale price (cif cost of fish plus profit margin]	33	64	50
Retail price (price paid by hobbyist to retailer)	66	124	100

Table 4. Example of price structure for marine ornamental fish.

Collectors that supply chains involving one or more middlemen usually get paid considerably less – for example in the Philippines they receive about one tenth of the fob export price (Baquero, International MarineLife Alliance, pers. comm. 2000). The industry maintains that a dollar received for fish on a remote beach can probably buy more goods than the same dollar in a northern economy (Davenport, Ornamental Aquatic Trade Association, pers. comm. 1999). However, there is concern about excessive profits being made by middlemen at the expense of the collectors (Baquero, pers. comm. 2000).

Fish families used for the aquarium trade

Many of the species collected for the marine aquarium trade are small, brightly coloured fish that survive well in captivity. There is also a demand for larger 'show' individuals and for 'curiosities' such as frogfish. Public aquaria with large tanks are also able to stock big fish such as sharks, groupers and moray eels.

Up to 1,000 species of fish from around 50 families are currently being traded. Typically, there is a high volume of trade in relatively low-price fish such as common species of gobies, wrasse, damselfish, anemonefish, butterflyfish and angelfish. This is supplemented by low volume trade in high value specimens such as clown triggers and various butterflyfish and angelfish. The high price reflects desirability, and the fact that, for one reason or another, most are difficult to catch in quantity.

	% of exports by number	**% of exports by value**	**Approximate selling price for each fish* $US**
Pomacentridae (damselfish & anemonefish)	29	13	0.7 – 2.5
Pomacanthidae (angelfish)	24	46	5.0 – 25.0
Chaetodontidae (butterflyfish)	11	10	2.0 – 8.0
Labridae (wrasse)	7	12	3.0 – 15.0
Blennidae and Gobiidae (blennies & gobies)	5	3	1.0 – 4.0
Balistidae & Monacanthidae (triggerfish & filefish)	4	2.5	2.0 – 12.0
Cirrhitidae (hawkfishes)	2	3	3.0 – 7.0
Serranidae (groupers and basslets)	2	1.5	2 - 10
Other varied	15	8	

Table 5. Data from Pyle (1993) showing the relative commercial importance of different fish families traded in the member countries of the Forum Fisheries Agency in the Pacific (excluding Hawaii, Guam and the Philippines). Percentage figures are rough estimates extrapolated from available data. *Price ranges exclude unusually high-priced, rare species.

Table 6 shows the relative importance of different families represented in the trade. Although a wide range of families is used, relatively few are consistently important. For example, in Queensland, Australia, more than 60% of all fish commercially harvested come from 5 families (Pomacentridae, Chaetodontidae, Pomacanthidae, Labridae, Gobiidae) (QFMA, 1999). These are also the most important groups in the Pacific fisheries (see Table 5).

		Approximate number of species in trade		
	FAMILY	**1-10**	**11-20**	**21+**
Sharks	Ginglymostomatidae Hemiscyllidae	x		
Rays	Dasyatidae	x		
Moray eels	Muraenidae	xx		
Snake eels	Ophichthidae	x		
Catfish	Plotosidae	x		
Cusk eel	Ophidiidae	x		
Frogfsh/anglerfish	Antennariidae	xx		
Soldierfish/squirrelfish	Holocentridae	x		
Flashlightfish	Anomalopidae	x		
Trumpetfish	Aulostomidae	x		
Cornetfish	Fistularidae	x		
Pipefish & seahorses	Syngnathidae		xx	
Lionfish, scorpionfish	Scorpaenidae		xx	
Grouper, rock cod, basses	Serranidae		xxx	
Anthias, fairy/flag basslet	Serranidae	xx		
Soapfish	Serranidae	xx		
Hamlets	Serranidae	xx		
Basslets; grammas	Grammatidae	xx		
Prettyfins	Plesiopidae	x		
Dottybacks; pygmy basslets	Pseudochromidae	xx		
Basslets	Grammatidae	xx		
Hawkfish	Cirrhitidae		xx	
Cardinalfish	Apogonidae		xx	
Big eyes	Priacanthidae	x		
Tilefish	Malacanthidae	x		
Remoras	Rachycentridae	x		
Trevally, jacks	Carangidae	x		
Remoras	Echeneididae	x		
Snappers	Lutjanidae	x		
Fusiliers	Caesionidae	x		
Bream, porgies	Sparidae	x		
Threadfin bream	Nemipteridae	x		
Drums	Sciaenidae	x		
Sweetlips; grunts	Haemulidae		xx	
Goatfish	Mullidae	x		
Sweepers	Pempheridae	x		
Stripey	Microcanthidae	x		
Batfish, spadefish	Ephippidae	x		
Butterflyfish	Chaetodontidae			xxx
Angelfish	Pomacanthidae			xxx
Clownfish	Pomacentridae		xxx	
Damselfish	Pomacentridae			xxx

Wrasse	Labridae			xxx
Parrotfish	Scaridae	xx		
Goatfish	Mullidae	x		
Grubfish	Pinguipedidae	x		
Jawfish	Opistognathidae	x		
Blennies	Blenniidae		xxx	
Gobies	Gobiidae			xxx
Dragonets	Callionymidae	xxx		
Dartfish	Microdesmidae	xxx		
Surgeonfish/tangs	Acanthuridae		xxx	
Moorish idol	Zancliidae	xx		
Rabbitfish	Siganidae	x		
flounder	Bothidae	x		
Triggerfish	Balistidae		xxx	
Filefish/leatherjackets	Monacanthidae	xxx		
Cowfish/trunkfish/boxfish	Ostraciidae		xxx	
Pufferfish	Tetradontidae		xxx	
Porcupinefish	Diodontidae	xx		

Table 6. Fish families represented in the marine ornamental trade.
Key to entries x = low level of trade; xx = moderate level of trade; xxx = high level of trade

Some species are collected only in very small numbers, perhaps because they are of marginal interest, or are difficult to catch or to keep alive. Typically, a handful of species make up the bulk of the fish collected. For example, in 1995, 90% of the harvest in Hawaii was focused on 7 species, with the yellow tang *Zebrasoma flavescens* taking 72% of the harvest (Division of Aquatic Resources unpublished data quoted in Tissot, 1999). In Costa Rica, Aguilar (1992) found that eight species were taking 81% of trade, and Graham (1996) reported that in Palau, 10 species made up 60% of exports.

Some examples of the top ten fishes exported from different areas are listed in Table 7. This shows that certain families are consistently well represented but that there is a notable difference in the most popular species from one country to another. Endemic species are particularly important in the aquarium trade as they are highly prized on international markets (QFMA, 1999). Many supplying countries have one or more 'rarities' that are in demand, for example Guam is currently the only source for the rusty angel (*Centropyge shepardi*) which is endemic to the southern Mariana islands and southern Japan (Tibbatts, Department of Agriculture, Guam, pers. comm. 2000). Similarly, Taiwan is a source of the blue-striped angelfish *Chaetodontoplus septentrionalis* (West and Thomson, Tropical Marine Centre, pers. comm. 2000), which is restricted to southern Japan, Taiwan and Hong Kong (Allen, 1981).

Another feature of the marine ornamental trade is that there is heavy reliance on juveniles, mainly because many young fish have more attractive colour patterns than the adults. An investigation of fish being offered for sale in Hong Kong revealed that out of 12,652 fish in 122 species, 56% fell within the juvenile size range (Chan and Sadovy, 1998). Male fish are sometimes selectively caught because they are more flamboyant than females or sub-adults. An example is the Indo-Pacific mandarin fish *Synchiropus spendidus* (Chan and Sadovy, 1998).

		Florida	Puerto Rico	Brazil	Eritrea	Saudi Arabia	Sri Lanka	Maldives	Hawaii	Costa Rica
FAMILY SYNGNATHIDAE										
Hippocampus erectus	Lined seahorse			6						
Hippocampus zosterae	Dwarf seahorse	2								
FAMILY SERRANIDAE										
Nemanthias carberryi	Threadfin anthias							5		
Pseudanthias evansi	Yellowback anthias							2		
Pseudanthias pulcherrimus	Resplendent anthias							4		
Pseudanthias squamipinnis	Scalefin anthias					3		1		
FAMILY GRAMMATIDAE										
Gramma braziliensis	Brazilian gramma			5						
Gramma loreto	Royal gramma		1							
FAMILY PSEUDOCHROMIDAE										
Pseudochromis fridmani	Orchid dottyback					4				
FAMILY APOGONIDAE										
Apogon sp	cardinalfish									5
FAMILY CIRRHITIDAE										
Oxycirrhites typus	Longnose hawkfish									3
Cirrhitichthys oxycephalus	Pixy hawkfish									6
FAMILY HAEMULIDAE										
Anisotremus virginicus	Porkfish	9								
FAMILY MULLIDAE										
Pseudopenaeus maculatus	Spotted goatfish			9						
FAMILY CHAETODONTIDAE										
Chaetodon auriga	Threadfin butterflyfish							6		
Chaetodon kleini	Klein's butterflyfish							9		
Chaetodon larvatus	Orange-face butterflyfish				8					
Chaetodon multicinctus	Multiband butterflyfish								6	
Chaetodon ocellatus	Spotfin butterflyfish			8						
Chaetodon paucifasciatus	Chevron butterflyfish					9				
Chaetodon semilarvatus	Golden butterflyfish				7					
Forcipiger flavissimus	Long-nosed butterflyfish								5	
FAMILY POMACANTHIDAE										
Centropyge argi	Pygmy angelfish	4								
Holocanthus bermudensis	Blue angelfish	3								
Holocanthus ciliaris	Queen angelfish			1						
Holacanthus tricolor	Rock beauty	1	3	7						
Chaetodontoplus mesoleucus	Vermiuculated angelfish*				9					
Holocanthus passer	King angelfish									1
Pomacanthus arcuatus	Gray angelfish	6		3						
Pomacantus asfur	Arabian angelfish				5	10				
Pomacanthus ciliaris	Queen angelfish	7								
Pomacanthus maculosus	Yellowbar angelfish				10					
Pomacanthus paru	French angelfish		5	2						
Pomacanthus zonipectus	Cortez zonipectus									2
FAMILY POMACENTRIDAE										
Amphiprion bicinctus	Red Sea clownfish					6				
Amphiprion clarkii	Clark's anemonefish						5			
Chromis cyanea	Blue chromis		10							
Chromis viridis	Blue-green chromis				1	1				
Dascyllus aruanus	Three-stripe damsel							7		
Dascyllus marginatus	Red Sea dascyllus				2	2				
Dascyllus trimaculatus	Three-spot dascyllus						2			
Neopomacentrus miryae	Miry's demoiselle				3					

FAMILY LABRIDAE										
Bodianus pulchellus	Spotfin hogfish	8	8							
Bodianus rufus	Spanish hogfish			10						
Halichoeres radiatus	Pudding wife		7							
Larabicus quadrilineatus	Fourline wrasse				4	5				
Labroides dimidiatus	Cleaner wrasse						1			
Thalassoma bifasciatum	Bluehead wrasse	10	6							
Thalassoma lucasanum										7
Thalassoma casanum										8
Thalassoma lunare	Crescent wrasse				6					
FAMILY OPISTOGNATHIDAE										
Opistognathus aurifrons	Yellowhead jawfish	5	2							
FAMILY BLENNIDAE										
Ecsenius bicolor	Bicolor blenny						4			
Ophioblennius atlanticus	Redlip blenny		9							
Nemateleotris decora	Elegant firefish							10		
FAMILY GOBIIDAE										
Gobiodon citrinus	Yellow coral goby							8		
FAMILY ZANCLIIDAE										
Zanclus canescens	Moorish idol								7	
FAMILY ACANTHURIDAE										
Zebrasoma flavescens	Yellow tang								1	
Zebrasoma veliferum	Sailfin tang									
Zebrasoma xanthurum	Purple tang					8				
Acanthurus achilles	Achilles tang								3	
Acanthurus bahianus	Ocean surgeonfish			4						
Acanthurus leucosternon	Powder blue surgeon						3	3		
Acanthurus sohal	Red Sea surgeonfish					7				
Ctenochaetus strigosus	Goldring bristletooth								2	
Naso lituratus	Orangespine unicornfish								4	
FAMILY BALISTIDAE										
Balistes vetula	Queen triggerfish		4							
FAMILY DIODONTIDAE										
Diodon hystrix	Porcupinefish									4

* listed as *Chaetodon mesoleucus*

Table 7. 'Top-ten' species of fish on the export lists of nine supplying countries. [Entries 1 – 10 signify position in list for each country. Hawaii: top 7 only].

Sources of information

Florida: Derived from catch data provided by Florida Marine Fisheries Commission
Puerto Rico: Sadovy, 1992
Brazil: Monteiro-Neto *et al.* 2000
Eritrea: Habte, 1997
Saudi Arabia: Abdul-Ghani and Gazzaz, 2000.
Sri Lanka: Wood & Rajasuriya, 1999
Maldives: data for 1997 compiled and supplied by Marine Research Centre, Ministry of Fisheries, Agriculture and Marine Resources, Maldives.
Hawaii: unpublished data from the Division of Aquatic Resources, Hawaii, quoted in Tissot, 1999.
Costa Rica (Pacific coast): Aguilar, 1992.

Collection and Onward Transport

Collection and export

Ornamental fish can be collected by snorkelling, but it is more common to use scuba or hookah gear (compressed air delivered through a line from a boat). If fishermen unintentionally catch ornamental species in their traps they may contact aquarium dealers, as they get a better price for them than selling the fish for food.

Collectors may be part-time or full-time, self-employed or employed by a dealer or exporter. Whilst many marine ornamental fishing operations involve local collectors, some companies bring in collectors from elsewhere. For example, collectors from the Philippines have operated recently in Eritraea (Daw *et al.* 1998), and also in Yemen (Kemp, University of York, pers. comm. 2000). Whilst this may be a good option for the businesses (e.g. in terms of having experienced collectors), the use of foreigners has been questioned because it deprives local people of jobs. Also, outsiders may have fewer incentives to act as stewards of the reef resources on which the trade depends.

Collectors are usually paid on a piece-rate basis, and specimens vary greatly in value. Some of the most desirable species occur in fairly deep water. For example, in both the Cook Islands (Bertram, 1996) and Hawaii (pers. obs), collectors go to 70m in search of deep-water angelfish and butterflyfish. This can be dangerous because unless collectors take proper precautions they risk decompression sickness from doing multiple deep dives.

Market forces drive the collection of ornamental reef fish. Importers often request particular species and some fish (e.g. cleaner wrasse, anemonefish) are constantly in demand. These are always targeted because dealers can virtually guarantee a sale. On the other hand, if dealers find themselves left with species that they can't sell, they generally instruct their collectors not to bring in any more.

Collecting methods

The ability to collect efficiently without damaging either fish or the reef requires considerable skill and experience. Collectors pick up basic methods by watching others, then improve their skills through practise. A number of techniques are used, and collectors may also develop special methods for particular species. For example, lines with tiny barbless hooks may be used to catch species that are particularly difficult to trap (Sankey, previously Tropical Marine Centre, pers. Comm., 1998; QFMA, 1999). In Sri Lanka, some collectors use specially made small, tubular nets for capturing species that live in shallow burrows. The mouth of the net is placed over the entrance to the burrow, and the fish are 'tickled' out of their refuge using a fine rod. As they emerge into the net, the mouth is closed with a drawstring (Wood & Rajasuriya, 1999).

Nets are essential tools for collectors, and collectors also usually also have some form of 'tickler stick' to persuade fish out of their refuge. Hand nets and barrier nets are most commonly used, and these are usually made from nylon mono-filament. Mesh sizes range from about 3-28mm, and the mouth of the hand, or dip net may vary from 10cm to 50cm. In Sri Lanka and the Maldives most collectors capture the bulk of their specimens with a combination of large and small hand nets (Wood, 1985).

Barrier or fence nets are widely used in Australia (Couchman & Beumer, 1992) and the Pacific (Pyle, 1993). They are generally set out in a V-shape, or arranged strategically around reefs or rocks. They are weighted along the bottom with lead or chain and buoyed along the top with small floats. Large barrier nets are about 10-30m long and 1-2m high, and need a pair of divers to set them out. They are primarily used to catch surgeonfish and wrasse (Pyle, 1993). In Australia, there is a limit of 80 metres for the combined length of joined fence nets. Small barrier nets are about 5m long, 0.5m to 1m high, and are generally set by a single diver. The basic idea in using barrier nets is to persuade the target fish into the barrier, then scoop them out using a hand net.

A few collectors in Hawaii use a seine-like net which is less than 2m long, weighted at the bottom and has a wooden pole at each end (Randall, 1987). The collector sets one pole down then encircles the fish with the other. This is particularly effective for catching certain species, such as the firefish *Nemateleotris magnifica* (Randall, 1987). In Sri Lanka, a small 'underwater' cast net (the 'moxy net') was popular, especially with snorkellers, but its use is no longer permiited (Rajasuriya, National Aquatic Resources Agency, Sri Lanka, pers. comm. 2000) because of the damage that can be caused during deployment. It is about 1m in diameter, with a float on the top and weights around the perimeter to hold it in position. The collector drapes the net over corals or other hiding places then flushes the fish out by banging on the coral with a stick (Wood, 1985).

A completely different method of obtaining aquarium specimens from the wild has been developed recently. This involves collection of larvae at the end of their planktonic phase, just before they settle on the reef (Dufour *et al.* 1999). Animals collected at this stage are less stressed than adults because they are still vagrants and not yet adapted to coral reef habitats (Dufour *et al.* 1999). Thus survival rates are improved, provided the techniques of mass rearing a large number of larval species at different sizes can be achieved (Dufour *et al.* 1999). This method of supplying the trade has been tested in French Polynesia.

Catch per unit effort

Relatively few aquarium fisheries are monitored for catch per unit effort, but those that have been show fairly similar results. In the Cook Islands, CPUE has been monitored since the fishery began, and between 1989 - 1994 remained fairly constant, with the average number of fish caught per scuba dive tank between about eight and twelve (Bertram, 1996). Assuming that 3 dives are made, this would amount 24 – 36 fish/day.

CPUE has also been monitored in Australia, and has increased from about 20 fish/diver day between 1988-1991 to about 45 fish/diver day from 1995-1997 (QFMA, 1999). It is not known whether this increase is due to differences in reporting or data entry, or whether it reflects more efficient harvesting through increased diving skills and technology (QFMA, 1999).

Wood (1985) gives details of the catch of three collectors during two dives off the east coast of Sri Lanka. Each worked on his own and collected both fish and invertebrates. Collectors here make 3 or 4 dives/day, so extrapolating from the figures in Table 8, may collect in the region of 30-50 fish/day.

	Anemonefish & damselfish		Butterflyfish		Other fish species		shrimps		Other invertebrates		Total catch at 17m & 13m	
Site	17m	13m	17m	13m	17m	13m	17m	13m	17m	13m	Fish	Inverts
Diver A	6	6	0	1	1	2	12	0	0	0	16	12
Diver B	1	25	0	2	1	0	17	0	0	0	29	17
Diver C	0	11	1	2	3	1	0	0	0	3	18	3

Table 8. Example of catches made by three collectors in Sri Lanka (data from Wood, 1985).

Use of chemicals

In some countries collectors use chemicals which temporarily stun the fish and so make them easier to catch. The extent of use and impacts of these chemicals is discussed further under Conservation Issues (p.29). Cyanide (despite being illegal) and quinaldine are the commonest ones used. Both are used to catch fish that take refuge in holes or amongst corals.

Collectors usually obtain cyanide in the form of sodium cyanide tablets, which they grind up, dissolve in seawater, then put in plastic squirt bottles. Quinaldine is usually sold in liquid form but is also available as an expensive water-soluble powder, quinaldine sulphate. It is dissolved in acetone, ethyl alcohol or isopropyl alcohol and diluted with water in a squirt bottle (Randall, 1987).

Transfer to holding tanks and onward transportation

As specimens are caught they are transferred into polythene bags or plastic containers. Usually collectors carry several so that they can to keep specimens separate if necessary. Fish with swim bladders need to be brought to the surface very slowly to prevent the bladder from bursting. In parts of the Pacific, collectors use a plastic 'holding cage' to store their fish. This has holes in it and a spring-controlled trap door to put the fish through. When it is ready to be lifted, the cage is brought up very slowly and the fish are able to 'decompress'. This usually takes several hours, or even days for very sensitive species (Randall, 1987).

Collectors often avoid this wait by bringing the fish to the surface straight away and then piercing the swim bladder so that the gas is released. This technique is widely used and when done by an experienced collector using the needle of a hypodermic syringe, it can be very safe and does not appear to stress the fish (Pyle, 1993). However, if collectors are not well practiced or if they use an ordinary needle rather than a hypodermic, damage can easily be inflicted.

At the surface, fish are transferred into plastic tubs or holding tanks on the boat, then taken to the shore. Generally, they are caught and brought to shore on the same day, although in countries such as Indonesia and the Philippines, where collecting grounds may be very isolated, it can be several days before the fish are landed (Baquero, 1995). Once ashore, the fish are either placed in holding tanks or taken immediately for export. An increasing poor practice in some countries is to store the fish in polythene bags for several days with daily water and oxygen changes (Sankey, previously Tropical Marine Centre, UK, pers. comm. 1999).

Some export companies are tiny, with just a few dozen tanks and two or three people involved in caring for the stock and organising the packing. Others have hundreds of tanks and employ a large workforce. Some exporters of marine fish also deal in freshwater and brackish water specimens.

No standards have yet been set for holding tanks or filtration systems that are used in the aquarium fish trade. These vary considerably and it is beyond the scope of this review to describe them in detail. They range from simple, open pools with flow-through water systems, to glass and concrete tanks with aerated seawater. Many use some form of under-gravel filtration system, but some have moved on to a central filtration system, which involves protein skimmers, ultraviolet sterilisers and oxygenation units. The latter is expensive to install, but provides excellent conditions for the fish. Water quality is constantly controlled and monitored, and diseases virtually eliminated. The central filtration system suits large-scale operations, but is often beyond the reach of small companies. Even large export companies may require foreign investment to develop these systems.

Great efforts are made to minimise mortalities, and different countries and companies develop their own 'best' methods for keeping stock. Aggressive species are isolated in small, perforated plastic containers within the main tanks, or in specially designed systems with numerous small compartments. Sometimes spines are clipped so that the fish do not injure others or pierce the bag in which they will be placed for onward transit. Most fish are not fed for at least 48 hours prior to packing. This ensures their guts are empty and they will not foul their bags. Every animal is individually packed, usually in two bags but sometimes in three or even four. This ensures that if the inner bags are holed, the outer ones will retain water. Generally the bags have 25-50% water and the rest either oxygen or air/oxygen mixture (Sankey, pers. comm. 1999). Aggressive species are held in opaque bags, or bags wrapped in paper, which stops them trying to fight. The bags are packed into large styrofoam boxes, and fish can remain healthy in this condition for up to about 48 hours. The number of specimens per box depends on species and size. For example there may be less than ten, or more than sixty.

CONSERVATION ISSUES

The aquarium trade has raised concerns about the conservation of reef fish and their coral habitats. The main issues are possible over-exploitation of target species, secondary effects of this on reef communities, damaging methods of collection and high post-harvest mortalities.

Impacts on populations of target species

Most traders maintain that collecting for the aquarium trade has no noticeable impact on reef fish populations, that individuals are soon replaced, and that losses are minuscule in comparison with natural mortality. In a regional context, where the resource base is large and the fishery relatively small, this is probably true. Records from the Cook Islands Aquarium Fish Ltd., showed that with all species pooled, catch per unit effort (CPUE) remained constant from 1990-1994. This suggests resources are sustainable within current levels of exploitation (Bertram, 1996).

Australia is also able to sustain its fishery without a decline in CPUE (QFMA, 1999). The Great Barrier Reef (GBR) contains more than 2000 reefs and shoals. The immensity of this available habitat and the interconnectivity of fish populations provides a large element of insurance against adverse effects of the ornamental fishery (QFMA, 1999). The total annual harvest of about 200,000 ornamental fish from the GBR can be put into perspective by considering that a single coral reef of average size may support 10 million fish (perimeter of 100 km; average density of 3 fish/m^2) (QFMA, 1999). However, important points are that not all of these fish will be equally available or equally attractive to the industry and that the effects of collecting have to be viewed not in terms of their global impact but their potential to deplete particular species or locations (QFMA, 1999).

There is no doubt that aquarium fish collectors are particularly effective at catching target species. They can catch species such as lionfish that normally have few predators because they are aggressive or venomous (Wood, 1985). They can also remove fish from ‘safe’ refuges, for example, anemonefish can be very easily captured from their anemones. A sensible harvesting practice in Australia is to leave at least one anemonefish in the host anemone. This enables new recruits to use odour to locate and join groups of the same species, so ensuring the population is maintained (QFMA, 1999). Collectors used to be allowed to take the anemone as well as the fish, but this is no longer permitted (QFMA, 1999).

Up to 1,000 species of reef or reef-associated fish are collected for the ornamental market. Many are geographically widespread while others have restricted distributions. The abundance of a species may vary considerably within its range, as may its level of exploitation. Thus a rare but geographically widespread species may be more vulnerable to over-collecting than an abundant, endemic one. In general it has proved difficult to assess the impacts of fish collecting. Species need to be considered independently, but detailed information is lacking for most.

In Australia, there is anecdotal information from tourism interests, other recreational users, the public and other management agencies that indicates high fishing effort in Moreton Bay and reefs offshore from Cairns may be causing, or may eventually cause, localised depletion of aquarium fish stocks in these regions. This information has not been validated by independent scientific surveys or other research information, but the Authority is sufficiently concerned to be considering constraints on fishing effort (QFMA, 1999).

A number of other reports, some of which are anecdotal, suggest that the aquarium trade has caused noticeable declines in fish populations. Noyes (1976) described intensive collecting of young angelfish in accessible areas along the Fort Lauderdale coast in Florida. He reported that these fish were much rarer than they used to be, although he noted there were times of year when more were present. Lubbock and Polunin (1975) reported that certain once common butterflyfish had become rare in Trincomalee Bay, Sri Lanka. They also felt that populations of anemonefish had been over-collected along stretches of the Kenya coast. Samoilys (1988) noted that 'a report from a collector with 20 years experience on the Kenya coast indicates that the angelfish *Pomacanthus maculosus* and *P. chrysurus* are threatened due to over-collecting'.

Albaladejo and Corpuz (1984) carried out surveys in some of the collecting areas in the Philippines and discovered that numbers of certain desirable aquarium species (e.g. butterflyfish, angelfish and triggerfish) were unusually low. Also in the Philippines, Rubec (1987) reported that the angelfish *Centropyge bispinosus* and emperor angelfish *Pomacanthus imperator* had disappeared from the Balinao reefs, while the blue tang *Paracanthurus hepatus* had become rare. All these species were targeted by aquarium collectors, and had previously been common. In Indonesia intensive collecting for the aquarium trade selectively depleted several species in the Seribu islands and around eastern Java (Soegiarto and Polunin, 1982).

Research in Hawaii has produced contradictory results. A two-year study in the late 1970s on the impacts of collecting yellow tang *Zebrasoma flavescens* (one of the most heavily exploited species), suggested that populations were not adversely affected (Taylor and Nolan, 1978). On the other hand, Pfeffer and Tribble (1985) concluded that heavy collecting in Hawaii may have caused local depletions. They blamed a combination of this, and hurricane damage, for causing a temporary collapse in the aquarium industry. Randall presented another view on Hawaii's ornamental fish trade (Randall 1987). He believed that populations of the top ten aquarium fish traded in Hawaii were "enormous", and the take by aquarium collectors "negligible". Collectors were reported to move around the reefs, knowing that in a few months they could return to sites and find them replenished.

However, a recent study (Tissot and Hallacher 1999) has shown that collection of fish for the aquarium trade causes declines in populations. Monitoring of 23 sites along the 230 km Kona coastline of the Big Island of Hawaii showed that eight of the ten species targeted by aquarium collectors were significantly reduced in abundance at impact (collecting) sites relative to control areas. The magnitude of the overall percent decline at impact sites ranged between 57% percent in *Acanthurus achilles* to 38% in *Chaetodon multicinctus.* It is relevant to note that a decline of 48% was found in the pygmy angelfish *Centropyge potteri,* reported previously by Randall (1987) to be abundant despite being heavily collected.

In general, endemic species or those with restricted geographic distributions will be more vulnerable to over-exploitation than more widely distributed species. However, the abundance of the species concerned, and the level of exploitation to which it is subjected will also influence its vulnerability. So too will recruitment patterns for that particular species – sometimes populations may be sustained by only infrequent influxes of juveniles, which makes the vulnerability of the species more pronounced.

An example where an endemic species suffered from over-collecting for the aquarium trade was in the Revillagigedo Archipelago off Mexico's Pacific coast. In the early 1990s the clarion angelfish, *Holacanthus clarionensis*, was subjected to heavy, mostly 'pirate' collecting, from people coming over from the USA in 'sport fishing boats'. At least 1,000 individuals were being taken by each boat, and fish numbers had decreased by up to 95% in some areas (Almenara-Roldan & Ketchum, 1994).

In Australia, anecdotal information suggests that populations of two species of angelfish with a very restricted Indo-Pacific distribution may be depleted (QFMA, 1999). These are the scribbled angelfish, *Chaetodontoplus duboulayi,* and black angelfish, *Chaetodontoplus personifer*, both of which are popular amongst aquarists. The information has not been validated by scientific surveys, but concerns have been raised by commercial aquarium fish collectors, many of whom are long-term participants in the fishery and have observed these apparent fluctuations (QFMA, 1999).

There are conflicting reports about the effects of collecting on the Banggi cardinalfish *Apogon kauderni.* This species is found off the Banggai islands (Allen and Steene, 1995), and is much in demand as an aquarium specimen. According to trade contacts this species is found in great abundance in its distributed area, but there is a lack of accurate information on its status in the wild and on the numbers being collected. Several research programmes are now underway to try and clarify the situation and make management recommendations (Vagelli, New Jersey State Aquarium pers. comm. 2000).

High price may be an indication that a species is rare and therefore vulnerable to over-collecting, but this is not necessary the case. For example Tinker's butterflyfish, *Chaetodon tinkeri*, has a restricted range, occurring only in the Marshall, Johnston and Hawaiian Islands (Myers, 1989) and in the mid-1980s was considered a rarity and had a wholesale price of around $30 (Randall, 1987). However, the high price for this species is more likely to be connected to the difficulty in collecting it, because it occurs at depths of 27 to 135 m (Lieske and Myers, 1994). Thus although it may be thought of as a fairly rare species, much of the population probably lives in deep water so it may be more common than it appears (Allen 1981).

On balance, the fact that juveniles are preferred to adults (except for smaller species such as gobies, blennies and dottybacks) probably reduces the risk of over-exploitation, because it means that breeding adults are left on the reef. However, if juveniles are consistently, heavily exploited then numbers of breeding adults may be reduced, and rates of population renewal cut. Juveniles of some species can be especially vulnerable to over-collection, because when fish are newly-settled their escape responses are poor, and they are much easier to catch (Wood, 1985).

In conclusion, there is currently no evidence of any species collected for the marine ornamental trade being at risk of global extinction, but there is evidence of local depletions. If an 'ornamental' species is gradually depleted throughout more and more of its range the situation could become serious, especially for species with narrow distributions or low population density. Abundance is influenced by many factors (e.g. food supply, pressure from predators, availability of breeding sites, recruitment success etc.), and while a species might be common and able to sustain harvesting in one area this might not be true elsewhere. Fish populations on 'upstream' reefs will be less resilient to harvesting than those on 'downstream' reefs that receive strong and/or regular recruitment (QFMA, 1999).

The selective nature of ornamental fisheries means that a species under heavy collecting pressure could be totally removed from certain localities. Stocks of ornamental species therefore need to be monitored and managed on a country-by-country and reef-by-reef basis because of variability in abundance of particular species at different localities. Collection of rare and/or endemic species needs to be especially carefully controlled. Field surveys and investigation of catch and effort are needed to monitor the impact of collecting and devise appropriate controls.

Effects of ornamental fishery on ecological processes

What are the implications of aquarium collecting on the wider reef community? For example, it is well known that removal of herbivorous fish such as parrotfish and surgeonfish can lead to an increase in algal cover on the reef. Algae grow very rapidly and in the absence of grazers may spread over the reef, to the detriment of the slower-growing, reef building corals. Several herbivorous tangs and damselfish are collected for the ornamental trade, but at present there is no evidence to suggest that they are being removed in large enough numbers to have an impact on the reef. The only study to look at this issue was carried out recently in Hawaii (Tissot and Hallacher, 1999). The three most heavily collected species (*Zebrasoma flavescens, Ctenochaetus strigosus* and *Acanthurus achilles)* are all herbivorous, and all showed significant reduction in abundance at the collecting sites. However, there was no difference in the abundance of macro-algae between collecting and control sites, suggesting that reductions in herbivory due to harvesting of these species were not having a significant effect on algal abundance (Tissot and Hallacher, 1999).

The species that have stimulated the most discussion and speculation in relation to the ornamental fishery are the cleaner wrasses, whose 'clients' include virtually every species of reef fish, and even turtles. The two main groups of fish that have adopted cleaning as a way of life are gobies and wrasse. Gobies are particularly active in the Caribbean, and wrasse in the Indo-Pacific, although juvenile wrasse such as the bluehead wrasse (*Thalassoma bifasciatum*) and spotfin hogfish (*Bodianus pulchellus*) in the Caribbean also engage in cleaning activities. Several juvenile angelfish and butterflyfish are known to act as cleaners (e.g. juvenile grey angelfish, *Pomacanthus arcuatus* and French angelfish *P. paru*), and it is possible that other juvenile fish also feed in this way. Many of these species are popular aquarium species, with the cleaner wrasse *Labroides dimidiatus* being collected in large numbers. For example, at least 20,000 are exported annually from Sri Lanka (Wood and Rajasuriya, 1999). Cleaner wrasse play an important role in helping to maintain the health of reef fish, but nothing is known about the impact of collecting them for the aquarium trade.

Damaging collecting methods

Collectors sometimes inadvertently break coral whilst attempting to corner a fish or stop it escaping. Barrier nets may be come entangled on the reef, and corals are then broken in order to free them. Corals and rocks may be deliberately overturned or broken in order to flush fish out into the open so that they can be picked off with hand nets. This has been reported to take place in Komodo, Indonesia, following use of cyanide to stun target species such as juvenile angelfish (Pet, Nature Conservancy, pers. comm, 1999).

Collectors sometimes also bang on the coral, and break it, while trying to persuade fish to enter their net. Branching corals that provide a refuge for small fish are sometimes broken off in order that the fish can be removed. For example, in the Cook Islands, the red hawkfish *Neocirrhites armatus* is collected using a technique called ‘coral notching’ which involves removal of branches from the coral *Pocillopora* to extract the fish (Passfield and Evans, 1991). Randall (1987) reports that in Hawaii the same species of hawkfish together with damselfishes of the genera *Dascyllus* and *Chromis* may be caught in this way. The industry in the Cook Islands maintain that the damaged coral regrows and that, when planted, the broken branches produce additional coral heads (Bertram, 1996).

There is no doubt that collection of fish once they have retreated into corals (especially branching species) is difficult and can easily result in the coral being either deliberately or accidentally damaged. In countries such as the Hawaiian Islands and Sri Lanka there are many rocky rather than coral areas that support the species required. For example, in Hawaii, adult pygmy angelfish

Centropyge potteri are generally collected on rocky reefs, in rubble areas or on ledges (Allen, 1981). This is easier for the collector and also reduces damage. Many of the fish collected in Sri Lanka are also taken from rocky areas (Wood, 1996), and again this reduces damage to coral reefs.
It has been reported that fish stunned during the process of taking food fish using explosives such as dynamite may be diverted into the ornamental trade (Randall, 1987), but there are no other validated reports of this practice being used in the aquarium industry. The use of dynamite in reef areas is extremely damaging, reducing coral to rubble and killing many juvenile fish. It destroys habitats of value to the ornamental fishery and would not be condoned by the vast majority of collectors.

In conclusion, it is known that collection of reef fish for the ornamental market can damage corals and so lead to reef degradation. However, the amount of damage done has not been quantified. Often reefs that are exploited for the aquarium trade are also used for other purposes and even where research has been carried out it is difficult to determine the impact of collectors alone.

Use of cyanide and other narcotics

Many fish retreat down their burrows, into coral or amongst rocks when collectors try to get close to them, and are difficult to catch with nets. If attempts are made to extract them, the fish and the corals may both be damaged. Collectors use tranquillisers or anesthetics to make capture easier, and to increase their catch per unit effort.

The use of **cyanide** in the capture of aquarium fish is well documented. It began in the Philippines in the 1960s and is now firmly entrenched (Noyes, 1976; Rubec, 1988; Barber & Pratt, 1997; McAllister *et al.* 1999). Investigations during the 1980s revealed that about 80-90% of fish exported from the Philippines had been captured using sodium cyanide (Rubec 1986, 1988). This percentage is thought to have declined following the re-training of collectors to use nets, but within the last decade, the use of cyanide has spread to Indonesia (Barber & Pratt, 1997), and is also probably used in Thailand (Satapoomin, Phuket Marine Biological Center. pers. comm. 2000). There is also a report of its use in Yemen (Abdallah, 2000).

Cyanide is a toxic chemical with a narcotising effect at low doses (Ireland and Robertson, 1974). The aim is to subject the fish to a sublethal dose, catch it while it is dazed and then transfer it quickly to clean water. In practise it is impossible to give precise doses, and there is unknown but possibly heavy mortality to 'target' fish in the field (Randall, 1987). Rubec (1988) reported that only 10% of fish that emerge from cyanide-treated refuges are collected. The rest are left to die. Many more are entombed with resulting high wastage, and other animals (e.g. shrimps and crabs) living in these micro-habitats may also be killed. Yet another problem is that species of no value to the ornamental trade and too small to be edible, are discarded during the collecting process.

In addition to wastage and damage *in-situ*, there is further wastage because fish that are captured with cyanide often die. Perino (1990) reported that 5-25% of fish collected with chemicals die within hours of capture, and 20-40% more after that. Often death may not occur until the fish have reached the hobbyist, and the aquarist may assume it is his/her fault rather than connect the death with previous exposure to cyanide. Hanawa *et al.* (1998) examined the effects of cyanide exposure on the pomacentrid *Dascyllus aruanus,* and concluded that 'environmentally relevant exposures of cyanide can adversely affect fish and this effect can be measured 2.5 weeks post-exposure'. The combined effects of cyanide and stress (for example from handling) not only increased mortality, but also placed an appreciable metabolic load on the fish, as indicated by elevated oxygen consumption rates.

Death following exposure to cyanide has been reported to be due to liver damage (Dempster and Donaldson, 1974). However, Sankey (previously Tropical Marine Centre, pers. comm. 1999) believes that most of the postcollection mortality is due to effects on the central nervous system caused by anoxia when the fish is subjected to cyanide on capture. These effects manifest themselves in many ways over days or weeks (Sankey. pers. comm. 1999). Cyanide also has an effect on corals at the collecting sites. Experiments with *Pocillopora damicornis* have shown that high doses of cyanide kill the coral, medium doses cause discolouration/bleaching due to loss of symbiotic zooxanthellae and low doses result in loss of zooxanthellae but not in sufficient amounts to cause discolouration (Jones, 1997). Corals can recover from bleaching but this may take 6 - 12 months (Jones, 1995) and in the meantime the growth rate and reproductive output of the coral is reduced (Goreau & MacFarlane, 1990; Szmant & Gassman, 1990). The estimated cyanide concentration in a collector's squirt bottle is about 20 parts per thousand, (Johannes & Riepen, 1995) which is sufficient, even when diluted, to result in significant loss of zooxanthellae (Jones, 1997).

In the late 1980s there were reported to be about 1,500 aquarium fish collectors using cyanide in the Philippines (Rubec, 1988). McAllister (1988) estimated that at least 150,000 kg of cyanide was being used annually. An active collector douses about 50 coral heads a day for 225 days of the year and on this basis it was calculated that over 33 million coral heads were being sprayed with cyanide each year (Rubec, 1988). According to Rubec *et al.* (2000), many of the 300 collectors based on Olango Island (off the east coast of Cebu) are third generation cyanide users and they have destroyed the coral reefs for over 300 miles in every direction.

The use of cyanide is universally outlawed for the capture both of aquarium and food fishes, but enforcing regulations is difficult. It continues to be used because it is easy to obtain, inexpensive and makes fish catching easier. Even though some collectors have been re-trained to use nets, the amount of cyanide being used is still substantial, and damage continues to be inflicted on fish and other reef life. Another possible effect of drug use is that, because it makes capture easier and is effective in removing fish from refuges, it may make overfishing more likely.

Quinaldine is another narcotic associated with the ornamental industry. It is fairly widely used in Florida and some other countries, but is banned in others (e.g. Hawaii). It is reported to be less dangerous than cyanide, but capable of killing fish during collection when concentrations are high or exposure time is long (Randall, 1987). Alternatively, latent damage may cause death some days later.

Corals and other reef organisms may also be damaged or killed, not only from the effects of the quinaldine itself but from the acetone or alcohol solvents (Randall, 1987; Jaap and Wheaton, 1996). Jaap and Wheaton (1996) found that some corals bleached from application of quinaldine to their tissues. They also found that small cryptic animals were stupefied by quinaldine and were very easy prey for the blueheads that trailed them during the experiments.

Bleach, formalin and gasoline were reported to be used occasionally to catch aquarium fish in Puerto Rico in the early 1990s, (Sadovy, 1992), but the extent to which they are used elsewhere is not known. Like quinaldine, they are toxic substances capable of damaging fish and other reef organisms.

The possibility of using clove oil as a fish anaesthetic and replacement for cyanide has been discussed by Erdmann (1999). Recent studies have shown that it is highly effective, cost-efficient and safe in the laboratory, and Erdmann recommends that further research should be carried out to verify the eco-friendliness of clove oil for use in wild capture.

Introduction of exotic species

Introduction of aquarium fish species to areas where they are not native is discussed by Randall (1987). He points out that the problem is far more acute with freshwater fishes than marine, but that even in the marine environment, introductions can be disastrous. Randall cites two species introduced into Hawaiian waters through the food industry. These are the mullet *Valamugil engeli* (introduced accidentally) and the blue-lined snapper *Lutjanus kasmira* (introduced intentionally), both of which had increased in numbers, probably at the expense of more commercially important species.

Randall (1987) reports cases of aquarists who admitted to releasing exotic species into waters out of their normal range, and this is apparently still happening, possibly when specimens outgrow their tanks. Three Pacific batfish (*Platax* spp) have been tracked in the Florida Keys since 1994 and in 2000 divers collected two and transferred them to the New England Aquarium to help educate people about the possible dangers of alien species becoming established [ENS, 2000]. For example, they may be superior competitors to native fish, prey on valuable species or introduce diseases or parasites that adversely affect local marine life. Some hobbyists enjoy keeping interesting species such as the crown-of-thorns starfish, which if it was released and became established in the western Atlantic, could cause untold damage to reefs.

Post-harvesting mortalities

The marine aquarium hobby requires healthy live fish (and invertebrates) with reasonable life expectancy. Premature deaths are to be avoided for a number of reasons. Firstly, every fish that dies prematurely puts extra pressure on natural resources because replacements are then required to meet the demand. Secondly, most people agree that it is not ethical to trade in live animals unless their health and welfare can be assured. Premature/unexpected mortalities give the trade a poor image. Thirdly, there are sound economic reasons why mortalities should be avoided, for example:

- Mortalities immediately after capture and before arrival at the dealer's premises represent wasted fishing effort for collectors and a loss of income (assuming the collectors are paid for each live fish passed to the dealer).
- Mortalities in holding tanks prior to export are a financial loss for the exporter.
- Mortalities during transit and prior to sale represent further financial losses to the industry.
- Poor rates of survival in home or public aquaria are expensive and disappointing for the hobbyist.

There are many factors that lead to mortalities, including physical damage and use of chemicals such as sodium cyanide during collection, inferior water quality in tanks and during transit (e.g. due to build-up of ammonia), poor handling, and disease and stress at all stages. Some specimens die prematurely because they belong to species that are impossible or difficult to keep, even when maintained under ideal conditions by experienced aquarists. Others fail to survive because they have been collected when too small. Although juvenile fish are popular in the trade, if too young they may be difficult to maintain.

Accurate figures of the numbers that die prematurely are not available, but various estimates have been made. Research on trade between Sri Lanka and the UK (Wood, 1985) indicated that in the mid 1980s there was about 15% mortality during and immediately after collection and before export, 10% mortality in transit to the UK and a further 5% in holding facilities (importers and retailers). Sadovy (1992) in a study of the Puerto Rican industry, estimated mortalities from the time of capture to the time of export to vary within a range of 10-20%, depending on capture, handling and shipping methods, the level of skill of collectors and conditions of holding facilities.

It is clearly difficult to put a 'global' figure on the percentage of premature post-harvesting mortalities because there is considerable variation in handling and treatment of fish. For example, Baquero (1995) describes the stressful journey of ornamental marine fish in the Philippines, where it may take several days for the bagged specimens to reach the exporters facilities, during which time they may be subjected to water of very poor quality. Vallejo (1997) estimated mortality rates of 30-40% in holding facilities in the Philippines. Furthermore, a telephone survey carried out in 1997 by the International Marinelife Alliance (IMA) showed that of over 300 US aquarium fish dealers, mortality at the retail level of marine fish from the Philippines varied between 30-60% in the first three days after arrival (Rubec *et al.* 2000).

In contrast, Pyle (1993) reports average pre-shipment mortalities in most of the Pacific to be as low as 1-2%, which includes those that are released back into the sea because they are sub-standard. Cyanide is not used in this region, and middlemen are generally not involved. Fish are subjected to much less stress as a result, and mortalities during shipment from this region were reported to average 5-10% in the early 1990s (Pyle, 1993).

Mortalities cost money at all stages and for this reason alone, dealers make efforts to reduce losses. High-tech equipment and first class treatment for the fish, both of which reduce mortality, also cost money. Many of the export facilities in the less prosperous supplying countries, and some of the smaller retail establishments in importing countries cannot afford to invest in sophisticated and costly equipment. Facilities may occasionally be so sub-standard that only a small percentage of harvested specimens survive.

Fortunately, there are an increasing number of facilities with advanced, state-of-the-art filtration systems and stock management which keep mortalities down to a fraction of 1% (Sankey, Tropical Marine Centre, pers. comm, 1998). For example, holding facilities of one of the newly-opened (but short-lived) companies in Eritraea used a sophisticated closed system of filtered, UV-treated circulated seawater and guaranteed live delivery of all stocks (Daw *et al.* 1998). About 1-2% of collected fish were returned to the sea because they were unhealthy or imperfect, but mortalities during transit and holding were claimed to be very low. Many other reputable suppliers from around the world guarantee live delivery of all stock, and this type of approach helps to ensure high standards are maintained.

There may, however, be a problem when specimens are transferred to hobbyists tanks because conventional under-gravel biological filtration systems are still used by many hobbyists, and these do not provide water of such high quality. However, mini versions of the more advanced systems and use of protein-skimmers to maintain water quality are becoming much more commonplace. Another problem is that turnover of specimens in importers and retailers tanks is often rapid, which means that the fish may not be settled and feeding. Potential problems are then transferred to the hobbyist, with associated risks of high rates of mortality. A preliminary survey carried out in the UK, involving over 200 specimens, showed that half the fish had died within 6 months and nearly 70% within a year, but others were still living after 4 years (Wood, 1985). The extent of mortalities may depend to a considerable extent on the knowledge and expertise of individual hobbyists and the amount of information they are given before setting up their tanks (Dakin, consultant aquarist, pers. comm. 2000). Also, as indicated by the high mortalities at the retail level of marine fish from the Philippines (see above) it depends on the previous treatment of the stock.

MANAGEMENT OBJECTIVES AND PROGRESS

Aims of management

Marine ornamental fisheries need to be managed to ensure they are biologically sustainable and integrated with other resource uses. In a wider context, the industry needs to reduce post-harvesting mortalities and stop collection of species unsuited to captive life. Finally, socio-economic issues have to be addressed, particularly to ensure that trade is fair and equitable.

Biological sustainability
Conservation issues have already been discussed in the precious section. Management strategies need to ensure that stocks of harvested species are renewed at the same or a greater rate than they are removed. Habitat damage (for example from ecologically unsound collecting methods) needs to be kept to an absolute minimum and care taken that ecological processes are not disrupted.

Integration with other resource uses
Ornamental fisheries may clash with a number of other activities, but in particular with one of the fastest growing, economically important reef-based activities - recreational diving. This dichotomy of interests is a fundamental problem that managers have to deal with. As with other fisheries, the 'exotic' reef fish and invertebrates collected for the ornamental trade are not owned by anyone, but are part of a shared natural heritage. People in both the supplying and consuming countries have different perceptions about who has the right to use these resources.

Reduction of post-harvesting mortalities
Capture and transport of fish, and their maintenance in captivity requires skilful handling and high standards of husbandry to ensure the stock is kept in good condition. Post-harvesting mortalities place extra (unnecessary) demands on the resource. Management of the trade has to include strategies to reduce mortalities of harvested species, and ensure that those species unsuited for life in captivity are not collected or marketed.

Equality and fair trade
Socio-economic aspects need to be addressed as part of the overall management of marine aquarium fisheries. In particular, it is important that collectors (who tend in most countries to be the least privileged of all sectors within the industry) are treated fairly and given incentives to protect and manage their own resources. Development of culturing facilities should be encouraged in the country of origin of the species concerned.

These management aims can be achieved in various ways – for example through research, monitoring, training, use of non-damaging collecting methods and adoption of strategies for controlling catch, such as reserves, quotas, closed seasons etc. There are also a number of possibilities for enhancing the fishery, such as mariculture and construction of artificial reefs. However, both of these may in themselves have environmental or social impacts.

Management of marine aquarium fisheries is undoubtedly more complex in some countries than others. For example, in the Philippines and Indonesia there are thousands of collectors spread over wide areas, hundreds of middlemen and numerous exporting companies. These factors, together with lack of resources, have made monitoring and control of the trade extremely difficult. In contrast, the Cook Islands fishery employs 6 full-time and 3 part-time collectors and there is only a single company, operating from one island (Bertram, 1996).

Currently, a reasonable proportion of countries that have marine ornamental fisheries also have some form of regulations and management strategies on paper (see Appendix) but these are not necessarily enforced, and in most cases it is not known if they are effective in conserving resources.

Although collection of coral reef specimens for the aquarium trade is widespread, some governments (e.g. Oman, Wilson, pers. comm. 1999) have turned down applications for ornamental fisheries to be started. A number of existing fisheries appear to have closed down for commercial reasons, and several countries have fairly recently introduced controls because of environmental or conservation concerns and/or because of conflicts with other users of the same resource. In Jamaica, the Natural Resources Conservation Authority stopped issuing permits to export marine aquarium fish in 1990 because it considered that the Jamaican marine system was stressed and overfished and because there was a severe lack of funding to conduct surveys (Johnston, Natural Resources Conservation Authority, Jamaica, pers. comm. 2000).

In 1999, the government of Mozambique introduced a 2-year ban on trade in ornamental fish and live corals in order to give time for management guidelines to be formulated (Whittington *et al.* 2000). This move was made because coral and ornamental fish had reportedly been harvested wastefully and traded fraudulently, against a background of poor legal enforcement. A similar move has been made in Puerto Rico (Lilyestrom, Department of Natural & Environmental Resources, PR pers. comm. 2000). Closure of the fishery was considered in the Philippines, where use of cyanide persists. A proposal to close the fishery was put forward in 1997 by the Department of Natural Resources, who sought radical action as a showcase for International Year of the Reef, but this was not taken further.

Multi-sectoral approach to management

Whatever the scale of the problems to be addressed, it is important that all those with an interest in the trade in marine ornamental fish are involved in its management. This includes the industry itself (collectors, exporters, importers, retailers), local and /or government managers of coral reefs resources and those who depend on the same resource (e.g. the tourist industry/recreational divers). Consumers (private hobbyists and public aquaria) and the general public also have important roles to play.

The extent to which these different sectors and representatives are currently involved in management varies. The main role of industry groups such as fishery co-operatives, exporters associations and trade organisations is to promote business and ensure it is profitable. However, their industry relies on continuing access to ornamental resources, and for this reason alone many of those involved in trade support conservation initiatives.

Several ways in which the different sectors are working together to improve management are mentioned in the following pages. The US state of Hawaii (Walsh, 1999) and the State of Queensland in Australia (QFMA, 1999) are examples of collecting areas where there has been public debate in the production of management plans for the ornamental fishery.

Management of collecting operations may be led by government fishery authorities, but to succeed needs to closely involve the collectors. One approach is to encourage Territorial Use Rights Fisheries (TURFs) whereby the fishing rights of specific areas are allocated to particular communities (Christy, 1982). The advantages and disadvantages of these types of management system have been discussed elsewhere (Lock, 1986, Ruddle and Johannes, 1990, Medley *et al.* 1993).

Sometimes the most effective strategy is to empower the local community by giving them legal rights – for example to exclude outside fishermen. In the Pacific Ocean, reef fisheries have a tradition of management under Customary Marine Tenure systems, in which local families control the fishing rights on reefs close to their villages. Village Fisheries by-laws which have legal recognition are a way of enabling local communities to develop conservation strategies for their own resources (Fa'asili & Kelekolo, 1999).

Conservation measures

A number of measures can be taken to reduce or control collecting effort and conserve stocks of ornamental species. These include options such as limiting access to the fishery, establishing fishing reserves, and setting quotas and size limits.

The ecologically sound approach to resource use embodies the 'precautionary' principle, which advocates that exploitation is carried out only if it can be shown that it will not be detrimental. However, in many countries, collection started up and continued without any knowledge of the impact it was having. The lack of scientific data to back up management initiatives is one of the main problems besetting the industry.

The need for research

Both for a proposed ornamental fishery, or one that is already underway, data need to be collected on the biology, population dynamics, recruitment and conservation importance of the species involved. Particular attention needs to be given to rare or endemic species that are targeted for the trade. Monitoring programmes then need to be established to investigate the effects of collection and the effectiveness of management strategies. It is important that this is done on a country-by-country basis, but it has to be admitted that, due to the wide diversity of species used, this is a daunting task.

Scientific assessments have been made in a number of countries either before permission is granted to begin collecting, or as a monitoring and assessment exercise on fisheries that are already established. In some cases population densities of individual species have been made from which crude estimates of maximum sustainable yields have been calculated (e.g. Edwards and Sheppard, 1987). This type of work has enabled recommendations to be made in countries such as Sri Lanka (Wood, 1985; Wood & Rajasuriya, 1999), Djibouti (Barratt and Medley, 1988), the Maldives (Edwards and Shepherd, 1992) and Puerto Rico (Sadovy, 1992). Research on juvenile recruitment, population densities and community structure of aquarium species is being carried out in the Bay of California, Mexico (Almenara-Roldan & Ketchum, 1994).

The extent to which governments have established mechanisms for monitoring and recording catches of ornamental species varies, but often the only statistics maintained are those of exports. These do not provide information on levels of exploitation on particular reefs or areas within the country and often may not be species-specific. A more effective way of monitoring the fishery, collecting species-specific data and detecting signs of over-exploitation (i.e. declining catch/unit effort) is to collect data on catch. Pro-forma daily log books in which collectors record their catch (including fish that subsequently die) are an ideal solution. These are in use in Australia, Palau, Cook Islands and the Maldives, and a pilot scheme is in operation in Sri Lanka. Fish landings from the Florida Keys National Marine Sanctuary are also being collected (Haskell, Florida Keys National Marine Sanctuary, pers. comm, 1997).

Probably the greatest store of knowledge is held by the collectors themselves. Experienced collectors have an intimate knowledge of the resource on which their livelihoods depend and could contribute a great deal to the scientific base of information needed for management. Every effort should be made to harness this knowledge in joint ventures between collectors, reef scientists and managers.

Limiting collecting effort

One way this can be achieved is to allow only a limited number of collectors to operate, using a specified type of gear. An example of this type of approach is in Australia. Initially the number of permits was allowed to rise in line with increasing market demand (Couchman & Beumer, 1992) and the number of collectors in the fishery jumped from 30 in 1986 to 160 in 1990, followed by a gradual reduction. In 1992 only 76 permits were issued, and in 1997 it was reduced to 62 (QFMA, 1999). Restrictions on net size help to ensure that the smaller number of collectors do not simply expand their effort to increase the catch. The aim is to monitor the fishery while fishing effort is kept constant.

Palau also regulates entry into the marine aquarium fishery by limiting the number of permits (no more than 20 permits issued in any given year) and attaching them to individual fishermen rather than vessels or companies (Graham, 1996).

A novel way of limiting collecting exists in Curacao. The airline company (KLM) is very strict in accepting shipments because of bad experiences in the past. They will only accept shipments from two established exporters, and therefore indirectly effectively limit the amount of harvesting taking place (Pors, CARMABI Foundation, pers. comm. 2000).

Establishment of quotas

Quotas can be set either on numbers of fish captured or exported. Species-specific quotas are much more effective in conservation terms. Overall quotas may simply encourage collectors to take the most valuable species, and do not necessarily ensure protection of stocks of the most vulnerable ones. Several countries have quotas in operation. In the two examples below, the Maldives system is likely to be more effective in conserving resources because it is based on scientific research.

In the Maldives, based on a study by Edwards (1988), a blanket quota of 100,000 fish was set for 1988 and 1989. Species-based quotas were also set for certain species that were thought to be over-exploited or were close to maximum sustainable levels of exploitation. Potential yields for certain collected species were subsequently estimated, and further proposals made to prevent localised over-exploitation (Edwards and Shepherd, 1992). In the mid-1990s the quotas that had been set were reported not to have been properly implemented by Customs, largely due to lack of co-ordination among the responsible authorities, and it was recommended that a review of the quotas should be undertaken (Adam, 1995). A few changes have been made, for example a reduction from 20,000 yellow coral gobies (*Gobiodon citrinus*) in 1996 to 17,500 in 1999 (source: Marine Research Centre, Maldives), but most quotas remain the same. The smallest numbers are 50 specimens for the two-spined angelfish *Centropyge bispinosus* and each of two species of long fins (*Calloplesiops altivelis* and *Plesiops coeruleolineatus*). The largest quota is 40,000 specimens of the Indian damsel *Pomacentrus indicus.* Starting from January 2000, the Marine Research Centre has been getting copies of all the proforma invoices from Customs, so that proper checks can be made on exports in future (Zaha, Marine Research Centre Maldives, pers. Comm.. 2000).

In Brazil there is a resolution from the national environment agency IBAMA (Instituto do Meio Ambiente e dos Recursos Naturais Renováveis) that limits to 5,000 the total number of fishes per species sold by any wholesaler per year. No scientific work has been conducted to establish this quota and little or nothing is known about species populations (Monteiro-Neto *et al.* 2000). Some species are endemic (e.g. *Gramma brasiliensis*), or have limited distribution, and their populations may be at risk (Monteiro-Neto *et al.* 2000).

Quotas could have an important role to play in management of aquarium fisheries. However, restrictions on numbers of specimens that can be collected or exported will be effective only if they are based on scientific research and are species-specific so that they ensure conservation of vulnerable species. In most cases, insufficient work has been carried out to decide on appropriate quotas (from a conservation point-of-view).

Restricted access/fishery reserves

In many countries there is open access to ornamental fish stocks, except in marine parks or sanctuaries, where collecting is prohibited or restricted to certain zones. Where fishery reserves have been set up they are usually for food fish, but recently several have been established as a means of regulating aquarium fisheries. For example, in Hawaii, nine marine reserves (fishery replenishment areas) have been established where, from 1999, aquarium collecting has been prohibited.

The advantages of fishery reserves (Roberts and Polunin, 1993; Russ and Alcala, 1994) are accepted in some countries, but in others there is a fear that because the 'best' areas will be set aside, the livelihoods of the fish collectors (and other fishermen) will be affected. Education and consultation is needed in order to promote the concept of reserves (Roberts and Hawkins, 2000) and emphasise their potential benefits in:

- maintaining a sector of the fish population from exploitation
- providing undisturbed spawning grounds for these species.
- boosting recruitment to adjacent fished areas through larval dispersal
- reducing conflict with other resource users - in particular recreational divers

It is possible that fishery reserves could be run by the collectors themselves. Unfortunately, the countries currently supplying a major proportion of marine ornamental fish (e.g. Indonesia, Philippines, Brazil) do not have a history of traditional conservation management of marine resources, such as is practised in many of the Pacific islands (mainly to manage edible species). However, a number of community-based management schemes are now in operation, especially in the Philippines, (e.g. on San Salvador Island (Christie *et al.*, 1994). Experience shows that locally-run reserves can be extremely effective not only in conserving the resource, but increasing awareness and understanding of conservation and management issues and the importance of individual and group responsibility in taking care of the environment.

In conclusion, establishment of reserves to help in management of ornamental resources is a key tool which needs to be further developed. More research is required to identify the most appropriate sites. For example, it is important to set-aside 'upstream' sites as reserves in order to maximise their usefulness in exporting fish larvae to other (fished) areas.

Temporary closures/closed seasons

Temporary closure could be particularly relevant for the ornamental fishery, where immature fish are often targeted. If collecting is stopped for a period this would allow juveniles to grow beyond the size at which they are collected for the ornamental trade. Some of these individuals can be expected to reach maturity and so contribute recruits to the population.

As far as is known this approach is not formally in operation in any of the collecting areas. However, in Sri Lanka the monsoons force a closed season on the ornamental fishery. In effect, the east coast is closed from April to October and the west coast from May to November. It is likely that this resting period allows time for at least some of the juveniles to progress through to a size at which they are no longer targeted (Wood, 1985).

In Hawaii, the collectors move to other reef sites if one locality receives heavy fishing effort (Randall, 1987). 'They know they can return to previous sites in a few months and see the reefs replenished. This is from a combination of fishes moving from adjacent sectors into vacated territories and from the settling out of late postlarval stage of fishes from the plankton' (Randall, 1987).

For this approach to work, more needs to be known about the breeding cycles of the targeted species, the time(s) of year that recruitment takes place and subsequent growth rates of the new recruits.

Restrictions on rare and/or endemic species

'Rarity' of a species may be 'natural' or caused by human activities which have a direct or indirect effect on the species concerned. Whatever the reason for low populations, these species need special attention. Species endemic to single islands or reef systems are clearly most at risk from global extinction, whilst the vulnerability of other species varies from one locality to another.

Many countries are involved in collecting ornamental species, and in most cases it is not possible to advocate general rules for particular species. Decisions about which species need protecting have to be decided on a country-by-country basis. Regulations can seldom be applied universally because a species that is rare in one locality may be common or abundant in another. For example, butterflyfish such as *Chaetodon lunula* and *C. falcula* and the angelfish *Pygoplites diacanthus* are rare around the coast of Sri Lanka, and therefore collection inadvisable, whilst in the adjacent Maldives, populations are relatively high, and therefore sustainable collection feasible. Some of these species are now protected in Sri Lanka (with agreement of the collectors/exporters) and others have been selected for 'observation' because their populations are considered to be low (Wood and Rajasuriya, 1996).

The dwarf angelfish *Centropyge multispinis* is one of these rare, protected species in Sri Lanka (Wood & Rajasuriya, 1996). Yet it is reasonably common in the Maldives and can be exported in numbers up to 10,000 annually (source Marine Research Centre, Maldives). Similarly, in Mozambique this species was abundant on all reefs surveyed and so could form the basis for the ornamental trade (Whittington *et al.* 1999).

In Australia, seahorses, seadragons and pipefish (Syngnathidae) and ghost pipefish (Solenostomidae) are now protected because they are considered to be rare and/or threatened with over-exploitation. Under new legislation, exports require permits from January 1998, and these will be granted only for animals derived from approved captive-breeding programmes or management plans.

Currently, none of the fish used for the marine ornamental industry is listed in the Convention on International Trade in Endangered Species (CITES). However, seahorses are on Annex D of the EU Wildlife Trade regulations, thus imposing a trade monitoring requirement. A few endemic species of interest to the aquatic trade (e.g. various toadfish, seahorses, pipefish and butterflyfish) have been proposed as possible candidates for inclusion in the IUCN Red List of Threatened Animals (Hudson & Mace, 1996).

Restrictions on size

Size limits may help in two ways. Firstly by ensuring that a reasonable proportion of the stock reaches maturity and secondly by reducing wastage as a result of high losses in captivity at this vulnerable stage. To some extent, size regulations are self-imposed by the industry because of the difficulty of keeping very small juveniles alive.

The OVI-Haribon PMP project in the Philippines promotes a system of harvesting fish of the correct size (Vallejo, 1997) and in particular stopping the export of juveniles smaller than 2cm. It is difficult to keep these small fish alive in captivity due to their dietary requirements and low resistance to stress.

One of the few ornamental fisheries to have detailed regulations concerning size of specimens that can be taken is that in the State of Florida, USA. The State has a comprehensive set of regulations (The Marine Life Rule) covering both recreational and commercial ornamental fisheries. This lists all ‘ornamental’ species as ‘restricted’ species, and stipulates maximum and minimum sizes that can be collected (Florida Keys National Marine Sanctuary Regulations, Final Rule, 1997).

Improving collecting techniques

It is important that the apparatus and methods used to catch fish causes minimal wastage and damage to both stock and habitat. Collectors generally pick up their techniques from watching others, and from experience. This can result in the learning of both good and bad practices. In some cases, collectors may not be fully aware of the implications of some of their activities - such as removing coral to obtain fish and using toxic ‘anesthetics’. One way of improving the situation is to stipulate the methods that can be used during collection and ensure that collectors are trained and adhere to these regulations. In the Cook Islands, as a result of complaints by divers about indiscriminate destruction of the reef habitat, the exporting company dismissed collectors who were frequently causing damage (Bertram, 1996). They also no longer allowed inexperienced collectors to take species which required ‘coral notching’ (removal of branches from the middle of the coral colony) to gain access to resident fish.

Better standards are probably achieved where collectors have responsibility. For example, in Sri Lanka and a number of other countries, dealers will only accept fish that are in good condition (pers. obs). They inspect each specimen brought in by collectors and refuse to accept those that are damaged. The damaged specimens are either kept by the collector in his own tank in the hope that they will recover, or are returned to the sea. In either case their chances of survival may not be great, but an important point is that the collector is not paid for these fish. This is a strong incentive for collectors to catch and handle fish with great care. Otherwise their own time and effort is wasted.

An enduring problem is the use of cyanide as an 'anesthetic'. It is outlawed in all countries that supply the ornamental market, but is still widely used in the Philippines and Indonesia. Over the past decade there have been concerted efforts to try and curb the use of cyanide, especially in the Philippines where it was estimated that in the mid-1980s over 80% of all fish were collected using cyanide (Rubec, 1988). In 1990 the Haribon Foundation and International Marine Life Alliance (IMA) launched the Netsman Project, and this was followed by the Cyanide Fishing Reform Programme (CFRP) and Destructive Fishing Reform Initiative (DFRI). In the latter part of the 1990s about 1,500 aquarium fish collectors were trained in the use of barrier nets (Rubec *et al.* 2000). A similar programme has also been initiated in Indonesia, for fishermen in Northern Sulawesi (Barber & Pratt, 1997).

The reform package in the Philippines includes public information, village-based education progammes, training on coral-friendly fishing methods and alternative livelihood programmes. A co-operative was set up to enable net-trained collectors to market their fish overseas, and a "Cyanide Detection Test" (CDT) put into operation. This is intended as an enforcement tool against cyanide use in both the food and aquarium industry and is seen as a vital component of the reform programme. If fish are found to contain cyanide the shipment is confiscated, and the owners and collectors arrested and prosecuted

Over 32,000 marine fish have been tested at the six cyanide detection test laboratories since 1993 (Rubec *et al.* 2000). This is only a tiny proportion of the total exported (possibly about 30 million between 1993-1998). Of those sampled, there has been a marked drop in the proportion of aquarium fish tested with cyanide residues present from over 80% in 1993, 47% in 1996 to 20% in 1998 (Rubec *et al.* 2000). However this does not necessarily prove that cyanide use has been reduced to the same extent or that damage to fish has been reduced. Fish are damaged by being subjected to cyanide (see p 29), but the amount of cyanide that is actually absorbed is very little, and may be at such low levels as to be undetectable through the CDT (Sankey, pers. comm. 1999). Under the current system of testing for cyanide, concentrations below 0.2ppm are considered negative (Baquero, International MarineLife Alliance, pers. comm. 2000).

Despite the training, many collectors have been slow to switch to nets or have reverted to cyanide after the net-training programme. For example about 30% of collectors trained by IMA reverted to the use of cyanide, although at a reduced rate (Anon, 1998). Part of the problem is that cyanide is widely (and legitimately) used in various industrial processes and is very easily diverted to fish collectors. A more crucial factor is that collectors have come to rely on cyanide to catch the numbers and species they need in order to make a living (Rubec *et al*. 2000). They can earn more money using cyanide because they can catch as many as three times more fish (Rubec *et al.* 2000). The fishing reform programme would be much more likely to succeed if collectors were provided with a good economic incentive (Baquero, pers. comm. 2000; Rubec *et al.* 2000) and all sectors in the industry were willing to pay more for net-caught fish (Rubec *et al.* 2000).

Resolving socio-economic issues

Some of the poor practices that persist within the fishery are due to the economics of the trade and the way collecting operations are organised. The main problems arise where there is a long chain between the collector and the exporter, such as in the Philippines and Indonesia. In these cases the collectors, who are the least privileged of all sectors within the industry, are paid significantly less for each fish than collectors who work in a short chain. According to Rubec *et al.* (2000), about 85% of the price paid by Manila exporters goes to the middlemen and only 15% to the collectors.

Collectors have little say in the way that the industry operates, and have to respond to the instructions of the middlemen because there is no other way that they can sell their fish and make a living (Baquero, International MarineLife Alliance, pers. comm. 2000). The consequence of low prices is that collectors in these countries are forced to try and maximise their catch to provide enough for their families subsistence. This often leads to the use of unsustainable or damaging collecting methods such as the use of cyanide. The problem is compounded by the fact that some of the middlemen are cyanide pushers who will buy fish only from collectors to whom they have sold cyanide (Baquero, IMA, pers. comm. 2000). When collectors are told by the middlemen 'I'll buy your fish if you buy my cyanide', they have little alternative but to agree.

It is clear that socio-economic aspects are of fundamental importance and need to be addressed as part of the overall management of marine aquarium fisheries. In particular, it is vital that collectors are treated fairly and given incentives to protect and manage the resources on which their livelihoods depend.

Resolving conflicts with other resource uses

The most likely conflicts are with reef tourism and, to a much lesser extent, food fisheries. Fish watching and fish collecting are generally not compatible activities. Reef tourism has grown enormously in popularity in recent years, with more and more areas being visited, and may bring in significantly greater revenues than the aquarium fish industry.

Dive tourism relies on the same resource as the ornamental fishery - plentiful numbers and diversity of colourful, coral reef fish, corals and invertebrates. Apart from the possibility of fish numbers being reduced, fish may be more wary and unapproachable on reefs where collecting takes place. This has led to conflicts in places such as the Maldives, where 'house reefs' associated with tourist resorts are protected, but popular boat dive sites are sometimes used by collectors (Adam, 1995). Some of these sites are now designated as marine protected areas, which has reduced conflicts to some extent.

There may also be conflicts with food fisheries. A number of species of value to the ornamental market are also used as food fish (e.g. sweetlips, groupers). In Hawaii, the goldring surgeonfish *Ctenochaetus strigosus*, caught as a juvenile for the aquarium trade (the second most heavily collected species), is also caught when larger by subsistence fishermen (Clark & Gulko, 1999). Generally, juveniles rather than adults are taken for the aquarium trade, but it can be argued that this ultimately reduces the numbers available to the food fishing sector. It may be necessary to separate or restrict the two activities if it is felt that they are incompatible. In Australia, capture of many species of wrasse, grouper and other food fishes for the aquarium trade is prohibited (QFMA, 1999), and in the Maldives the baitfish *Chromis viridis* cannot be taken for the aquarium trade. However, taken overall, very few of the desirable aquarium species are juveniles of commercial food fish.

Concerns from other sectors can be useful in precipitating conservation action. In Palau, widespread public concern about the potentially negative impacts of the aquarium fishery led to the formulation of regulations on the taking and export of fish for aquarium purposes (Marine Protection Act 1994: Regulations on the Collection of Marine Resources for Aquaria and Research) (Fa'asili & Kelekolo, 1999).

In Hawaii, the ornamental fishery has been the subject of controversy and conflict since the early 1970s, principally regarding the Kona coast of the island of Hawaii (Walsh, 1999). Despite numerous discussions and informal agreements between the industry and dive tour operators, it was not until 1998 that the state legislature passed a bill to improve the management of fishery resources in west Hawaii. A major thrust of the bill, which became Act 306, was to improve management of the aquarium industry by protecting a minimum of 30% of the west Hawaii coastline through the establishment of Fish Replenishment Areas (FRAs) – marine reserves where aquarium fish collecting is prohibited.

Local fishermen and tour operators in Mozambique were concerned that the ornamental industry was having a major detrimental effect on the coral reefs of the area. These concerns were formalised by the local community and tourism association of Inhambane and led to a paper highlighting the situation and calling for a number of regulatory measures to be introduced (Rodrigues and Motta, 1998). In response to these concerns, in February 1999, the Ministry of Agriculture and Fisheries published a nationwide directive ordering an immediate two-year moratorium on the trade in ornamental fish and invertebrates (Whittington *et al,* 2000).

Licensing

Licensing can provide a way of monitoring and regulating aquarium fisheries and improving standards within the industry. It can, for example, be an effective tool for controlling fishing effort. The number of licences or permits issued should be based on scientific evaluations of the resource, and be non-transferable and subject to review before being renewed on a yearly basis. Different types of permit are needed for collectors, exporters, importers and retailers, and these should specify the conditions that have to be met before a permit can be issued. Voluntary guidelines can also be used to promote good practise, but being optional can be ignored. As discussed in Wood (1985), conditions on licenses should seek to ensure that traders:

- Keep records of fish caught, bought and sold, and have these records available for scrutiny.
- Maintain well-run facilities with minimal losses.
- Adhere to specified standards regarding packaging and transport, in order to minimise stress and mortalities.
- Deal only with other accredited operators (e.g. obtain fish from licensed collectors; import fish from licensed exporters and so on).
- Abide by international and/or national conservation and welfare legislation.
- Do not deal in fish whose chances of survival are low.

Licensing of collectors provides an opportunity for managers to control or limit fishing activities, collect catch data and ensure that only trained collectors are allowed to operate. Conditions can be applied to the licence or permit which demand that the licence-holder maintains certain standards and/or levels of catch, adheres to a reporting system and has properly equipped holding tanks. The success of licensing depends on how strictly the conditions are applied and how much use is made of information obtained. Like marine parks, paper licensing can be a meaningless exercise unless it has a purpose and is followed through.

Several of the large supplying countries do not currently licence their collectors (e.g. Vietnam, Sri Lanka). This means that anyone can become a collector without any official ‘stamp of approval’. In other countries permits are in operation but with varying degrees of effectiveness. In Indonesia permits for capture and export are required, but control has been reported as lax (Kvalvagnaes, 1980). Similarly in Kenya, collectors are meant to be licensed, but some may operate even though they don’t have a permit (McClanahan, Wildlife Conservation Society, pers. comm, 2000). Collectors are also licensed in the Philippines and various restrictions apply, but enforcement of regulations is difficult.

In Brazil, permits to collect have to be obtained from the Federal Environmental Agency (IBAMA) but authorisation is apparently given for large numbers of individual species without any assessment of the impact this might have (de Moura, Universidade de So Paulo, pers. comm. 1998). However, in a number of countries collectors have to be licensed and the conditions attached to the permit are rigorous. For example, in Florida, collectors operate under State legislation ('*Marine Life Rule*'), and in Fiji and Australia they have to hold permits to operate, and strict controls are in place.

As with licensing of collectors, there is variation in the extent to which dealer's premises are licensed. Some do not have to be licensed. Many are licensed but not inspected. Others are licensed and subjected to quite rigorous checks. Some companies involved in the marine ornamental trade attain high standards voluntarily, by dealing only in 'net-caught' specimens and avoiding species that do not survive well in captivity.

Voluntary guidelines and Certification

In theory, statutory controls should provide a solution to many of the problems associated with the marine aquarium trade, but in practice they do not always work. Countries such as the Philippines and Indonesia licence their collectors and ban the use of cyanide, yet these `paper' restrictions have little effect on the way the trade operates. A co-operative, educational scheme such as the *Cyanide Reform Fishing Programme* that promotes best practise by involving collectors in the management of reef resources is much more likely to be effective.

Guidelines and best practice have to be introduced at all stages from reef to consumer and are more effective if there are market incentives to encourage proper collection and handling practices. There are various initiatives and innovations within the industry that help to improve standards. Some companies take a firm stance over issues such as use of cyanide and deal only in 'genuine net caught' specimens. The industry can also play an important role in supporting conservation initiatives and promoting best practise. Ornamental Fish International (the trade organisation representing the industry for the import and export of ornamental specimens) has a Code of Ethics, and the UK-based Ornamental Aquatic Trade Association (OATA) has a code of conduct for its members.

The buying public can also make a difference. Wood (1992) discussed the feasibility of introducing some form of 'green' or 'eco-label' to enable consumers to choose suitable specimens coming from sustainable fisheries. Most marine aquarium fish are destined for developed countries where people have access to information about conservation, and are in a position to exert considerable influence. For example, the Philippines share of the marine ornamental fish market declined in the mid 1980s because of the poor reputation the country gained by its continued use of cyanide to catch aquarium fish. Buyers and hobbyists in importing countries preferred to go to sources of supply where fish have been caught in a way that did not damage either the fish or the reef.

Wood (1992) suggested that particular species or specimens offered for sale should be given a 'green label' only if they met the following criteria:

- Chances of survival in captivity are high
- Collection is not altering the ecology of the reef (for example due to removal of `key' species).
- The collecting technique itself is not causing damage to the reef (or any other) habitat and/or the specimens (for example through the use of sodium cyanide to stun the fish).

- Collection is not causing either localised or more widespread declines in the populations of target species.
- Collection is not contravening local or national legislation.
- The specimens originate from a fishery where management plans or conservation measures are operating.

In the US, the world's largest market for ornamental species, there have been a number of initiatives to improve standards. In 1995 the American Marinelife Dealers Association (AMDA) was established. This is a trade association that represents over 100 retail and wholesale operators. The main aims of AMDA are to promote responsible marine aquarium keeping, and to develop standards for collection, handling, shipment, holding and selling of specimens (Tullock, 1996).

An independent body known as the Marine Aquarium Council (MAC; originally the Marine Aquarium Fish Council) was established in 1996 to promote this type of approach. A cross section of organisations is involved in this initiative, representing the aquarium trade, conservation organisations, public aquaria, hobbyists and scientists. The aim of the MAC is to establish standards, oversee environmental certification and promote conservation education. One of the intentions is to create the market incentives to encourage the utilisation of best management practices in the aquarium industry, and ensure that collection, handling, and sale of marine organisms from coral reefs is ecologically sustainable, socially beneficial, and economically viable (Holthus, 1999).

The scope and purpose of the MAC standards is as follows (Holthus, 2001).

Standards for Ecosystem Management
Scope: Ecosystem and fishery management and conservation of the collection area.
Purpose: To verify that the collection area is managed according to principles of ecosystem management in order to ensure ecosystem integrity and the sustainable use of the marine aquarium fishery.

Standards for Collection and Fishing
Scope: Fish, coral, live rock, other coral reef organisms, and associated harvesting and related activities, e.g. field handling and holding practices.
Purpose: To verify that the collection, fishing, and pre-exporter handling, packaging and transport of marine aquarium organisms ensures the ecosystem integrity of the collection area, sustainable use of the marine aquarium fishery, and optimal health of the harvested organisms.

Standards for Handling and Transport
Scope: Holding, husbandry, packing, transport, etc. at wholesale, retail and all other branches of the marine aquarium industry.
Purpose: To verify that the husbandry, handling, packing and transport of marine aquarium organisms ensures the optimal health of the organisms.

The first MAC-IMA Partnership Project (Holthus, 2001) will work to ensure a critical mass of collection areas and collectors in the Philippines have the potential to comply with MAC Core Standards by:

- identifying pilot program collectors and collection sites,
- assessing the collector's collection and husbandry skills,
- developing a training program in collection, handling and collection area management based on MAC standards,
- evaluating collectors ability to meet MAC standards.

A Trade Advisory Group (TAG) has also been established within the American Zoo and Aquarium Association (AZA). This aims to identify and define the problems associated with the trade in live marine organisms, and to provide recommendations and educational information that will reduce fish and invertebrate mortality. One of its specific goals is to develop a list of "difficult" species that would enable institutions developing new displays to chose species that are already known to prosper in public aquariums.

Whether or not traders and consumers will respond positively to voluntary eco-labelling and certification schemes is unknown. There is no doubt that many people are concerned enough to take a stance, but industry support is also needed. In 1997, through the OVI-Haribon project '*Eco-marketing and Fair Trade for PMP Aquarium Fish Collectors'*, it became possible for importers to obtain certified net-caught ornamental species from the Philippines (Baquero, 1997). However, the export venture failed, partly because it did not get the full industry support but also because it was unable to compete with exporters in the Philippines who could supply non-certified fish at a cheaper price (Baquero, International MarineLife Alliance, pers. comm. 2000). Rubec *et al.* (2000) emphasise that much of the blame for the continuing use of cyanide is the refusal of middlemen, exporters and buyers to pay more for net-caught fish.

Mariculture

Pressure can be taken off wild populations by supplying tank-bred, rather than wild-caught, fish (and invertebrates) for the aquarium market. It might also be possible to raise protected species and to develop hybrids (much as has been done in the freshwater ornamental industry).

Marine fish have always been more difficult to raise successfully in captivity than freshwater or brackish ones. Few spawn spontaneously in marine aquaria, although some can be induced to do so with injections of pituitary hormone (Randall, 1987). The task of rearing those with pelagic eggs and larvae is extremely difficult, and there is more chance of success with species that have demersal eggs. Careful attention has to be paid to diet, which requires research into the correct type/mix of microalgae and zooplankton. Foods enriched with essential elements are proving to be the key to success in many cases. Once the larvae have metamorphosed, mortality drops and the juveniles are usually relatively hardy (Sankey, pers. comm. 1999).

Over 100 species of marine fish have been bred in captivity in many countries, but of these, relatively few have been bred in commercial quantities (Dawes, 1999). Commercial culture began in 1972 but only about 25 species have so far fulfilled the three main requirements for commercial culture: high value, high demand and relative ease of culture in large numbers (Moe, 1999). The mainstay of this trade are anemonefish (*Amphiprion* spp and *Premnas biaculeatus*). Others that are being hatchery reared on a commercial basis include several gobies (*Gobiosoma, Gobiodon, Amblygobius*), dottybacks (*Pseudochromis* spp), jawfish (*Opisthognathus*) and basslets (*Gramma* ssp).

Research into mariculture is continuing, in an attempt to increase the range of species that can be cultivated on a commercial basis. A joint programme of research in the Pacific has selected the yellow tang (*Zebrasoma flavescens*), flame angel (*Centropyge loriculus*) and clown coris (*Coris gaimard*) as model species representative of a wide ecological range, and is also investigating the possibility of cultivating popular invertebrates such as the feather-duster worm *Sabellastarte scantijosephi* (Lee, 1999).

There have already been some notable advances in culturing some of the more challenging species. For example, a tropical fish company in Taiwan has succeeded, after a four-year programme, to breed from and raise young of the yellow-banded angelfish *Pomacanthus maculosus* and the Arabian angel *P. asfur* in potentially commercial numbers (Dawes, 1999).

A number of issues have to be considered and resolved before mariculture operations are developed. In the first instance, there are implications for the collectors whose livelihoods could be affected by a switch from wild-caught to cultured animals. There is also the possibility that if the trade becomes more reliant on cultured specimens, less attention might be paid to conserving the habitat in which they occur in the wild (McAllister, 1999).

Finally, there is the crucial question of where mariculture facilties should be established. At present, much of the technological expertise is in the more prosperous consumer countries, and there are many companies investing in mariculture enterprises. Commercial culture is concentrated in the United States (especially Florida and Hawaii), Europe and Taiwan, with virtually none in the countries where stocks originate. Establishment of mariculture facilities away from the countries of origin deprives these nations of income and puts people out of jobs. It could also be in breach of the Convention on Biological Diversity which seeks to promote the fair and equitable sharing of benefits arising from the use of wildlife resources. In the context of trade in ornamental species, source countries would be deprived of benefits if genetic resources were taken for breeding and sale elsewhere. Technology should be transferred to developing countries to enable them to set up their own facilities for culturing fish that have come from their own reefs. It is relevant to note that the Convention has been ratified by over 170 countries, with the notable exception of the United States.

Artificial reefs

The use of artificial reefs to enhance marine ornamental fisheries has potential, but as far as is known, none has yet been set up specifically for this purpose. The reef would have to be carefully sited ‘downstream’ from a ‘donor’ reef, in order that it received a plentiful supply of larvae. It would also need to be a reasonable size in order to provide sufficient diversity and abundance of specimens.

There has been success with the ‘cultivation’ of living rock. This in essence relies on the same mechanisms as an artificial reef - i.e. placing artificial structures on the seabed and allowing them to become colonised through natural recruitment. In the case of ‘living rock’ pieces of ‘seed rock’ are placed in suitable areas on the seabed where recruitment occurs. After about six months the rocks with their attendant algae and invertebrates are harvested. A number of companies in Florida, where collection of natural living rock is prohibited, are now using this method.

However, although artificial reefs could have a role to play in boosting the availability of supplies, it has been pointed out that they should not be seen as a quick-fix solution to solving the many problems occurring on coral reefs (McAllister, 1999). They may even create more problems than they solve, for example by altering movement of sediments and interfering with other coastal processes.

CONCLUSIONS AND RECOMMENDATIONS

Considering the many pressures currently faced by reefs it is vital that uses of the reef entailing extraction of living resources are carefully managed, but currently only a relatively small number of countries have comprehensive regulations that are rigorously enforced. Collection of ornamental specimens may have an impact on populations of the targeted species; also on other species and on ecological processes in the habitats where fishing occurs. The fishing methods themselves may also have an impact. Ornamental fisheries need to be investigated and monitored, and strategies formulated to ensure they are regulated and managed on a sustainable basis. Socio-economic as well as biological and ecological issues have to be addressed in this process. The following are seen as key areas for action:

Accurate data are needed for management purposes. It is recommended that country management authorities introduce log books and export forms for use by collectors and dealers to record details of collection sites, time spent collecting, species and numbers collected and exported. Currently this type of information is difficult to obtain in most countries

Experienced collectors have an intimate knowledge of the resource on which their livelihoods depend and can contribute a great deal to the scientific base of information needed for management. Every effort should be made to harness this knowledge in joint ventures between collectors, reef scientists and managers.

Minimum standards need to be introduced to all sectors of the industry to ensure that specimens are collected, held, packaged and transported in a way that keeps stress and mortalities at the lowest possible levels. Certification provides one way of regulating the industry, and can be used for collectors, dealers, exporters, importers and retailers. Only those that meet the standards would be given a permit to operate. Voluntary guidelines and standards can also be used to promote best practice.

Training programmes should be undertaken to ensure that collectors use non-destructive collecting techniques, adhere to regulations and guidelines, follow ‘environmental’ standards, and are fully informed of heath and safety aspects of their operations (particularly in relation to decompression sickness). Efforts should continue to bring about an end to the use of cyanide which damages both the fish and the reef. This can be done through a combination of training, education, community-based resource management and strict enforcement of regulations.

Production and circulation of educational materials and guidelines to collectors, exporters, importers, retailers, aquarium keepers and the general public is important. This material should highlight reef conservation and management issues and best husbandry techniques for reef specimens.

Measures to conserve stocks should include designation of key areas as fishery reserves. These are accepted in some countries, but in others there is a fear that because the ‘best’ areas will be set aside, the livelihoods of the fish collectors (and other fishermen) will be affected. Education and consultation are essential to promote the concept of reserves and emphasise their potential benefits.

Other measures could include regulation of fishing effort. This can be done by restricting the number of collectors (e.g. through a permit or licence system).

Species with low population densities should be protected from commercial exploitation. For most species this is best done on a country-by-country basis, because of the variations in 'natural' populations in different localities throughout the range of a species. Consideration should be given to setting quotas for the numbers of fish that can be exported from particular countries – preferably on a species-specific basis. It may also be appropriate to introduce regulations on size.

It would be useful to carry out co-ordinated research into husbandry of difficult species at recognised centres of excellence, but the hobbyist trade should cease in species whose chances of survival in captivity are already known to be low.

Consideration should be given to taking pressure off wild stocks by developing mariculture projects in countries where the species originate. Currently, captive breeding of marine ornamental species on a commercial scale is limited to a small percentage of species that are easily reared and in high demand, but there is considerable potential now that more companies are interested in research and development.

Construction of artificial reefs may be of benefit, by providing additional habitat for settlement and growth of coral reef species, which could then be harvested for the ornamental trade.

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