WCMC Biodiversity Series No. 10

The Global Trade in Corals

Edmund Green and Francis Shirley

WORLD CONSERVATION MONITORING CENTRE

WCMC – World Conservation Press

1999

The World Conservation Monitoring Centre, based in Cambridge, UK, is a joint venture between three partners in the World Conservation Strategy and its successor Caring for the Earth: IUCN – The World Conservation Union, UNEP – United Nations Environment Programme, and WWF – World Wide Fund for Nature. The Centre provides information services on the conservation and sustainable use of species and ecosystems and supports others in the development of their own information systems.

WORLD CONSERVATION MONITORING CENTRE

Published by: WCMC – World Conservation Press, Cambridge, UK.

ISBN: 1 899628 14 2

Citation: Green, E.P. and Shirley, F. 1999. *The Global Trade in Corals* .World Conservation Monitoring Centre. World Conservation Press, Cambridge UK. vii + 60 pp.

Cover design by: Michael Edwards

Printed by: Victoire Press, Cambridge.

Available from: World Conservation Monitoring Centre
219 Huntingdon Road, Cambridge, CB3 0DL, UK
Tel: +44 1223 277314; Fax: +44 1223 277136
Email: info@wcmc.org.uk: http://www.wcmc.org.uk/

CONTENTS

ACKNOWLEDGEMENTS

1. EXECUTIVE SUMMARY 1

2. MONITORING THE INTERNATIONAL TRADE IN CORAL 3

3. METHODS USED IN THIS STUDY 7

4. THIRTEEN YEARS OF INTERNATIONAL TRADE IN HARD CORAL 11

5. THE LIVE CORAL TRADE 23

6. THE TRADE IN BLACK CORAL 33

7. IS CITES AN EFFECTIVE TOOL FOR MONITORING TRADE IN CORAL? 35

8. THE IMPACT OF TRADE ON CORAL REEFS 41

9. THE ECONOMICS OF THE LIVE CORAL TRADE 43

10. THE SUSTAINABILITY OF THE LIVE CORAL TRADE 53

11. CONCLUSIONS 63

REFERENCES 67

LIST OF TABLES

Table 1. European imports of coral are recorded under a single category 3

Table 2. A stylised CITES record for coral 4

Table 3. The number of coral transactions in the CITES Trade Database where Import Quantity was recorded at a different value to the Export Quantity 8

Table 4. Trade links between the top ten coral importing and the top ten exporting nations 13

Table 5. Coral imports to different regions 14

Table 6. Trade links between coral importing and exporting regions 17

Table 7. Taxonomy and general ecology of corals in trade 19

Table 8. The weight and linear dimensions of pieces of live coral in the UK and USA aquarium trade 24

Table 9. The mean weights and dimensions of pieces of live coral in the aquarium trade 25

Table 10. Selected results of a survey of 683 aquarists 28

Table 11. The growth rates of species of 10 genera of commonly traded coral 29

Table 12. Trade links between the ten largest importers and exporters of black coral 33

Table 13. The number of coral species per genus recorded in the CITES Trade Database compared with the number of coral species per genus listed in CITES Appendix II 35

Table 14. The 1999 free-on-board prices of single pieces of live coral from Indonesia 43

Table 15. The value to exporting nations of different genera of the live coral trade 45

Table 16. The average retail prices in US dollars for 805 pieces of live coral from seven retail outlets in the USA in 1999 47

Table 17. The retail prices in pounds sterling of 73 pieces of live coral in the UK in 1999 48

Table 18. Characteristics of some common aquarium corals, summarised from Fossa and Nilsen (1998b). 54

Table 19 The mortality of Schleractinia corals in aquaria 55

Table 20. The viability in aquaria of some coral species which may be propagated by fragmentation 57

Table 21. The retail price of cultured corals from two USA suppliers surveyed in 1999 59

Table 22 Indonesian coral export quotas (number of pieces) for 1997 Compared to the number of pieces traded, as calculated from the CITES database, and the quotas set for 1999 61

LIST OF FIGURES

Figure 1. Ten nations imported 98% of the coral recorded under CITES, 1985-1997 11

Figure 2. Ten nations exported 94% of the coral recorded under CITES, 1985-1997 12

Figure 3. The quantity of coral exported from the Philippines and Indonesia 12

Figure 4. Trends in the global trade in coral as recorded under CITES, 1985-1997 15

Figure 5. Trends in the amount of coral exported from the major exporting nations 16

Figure 6. Exports of coral recorded under CITES expressed as tonnes per $1000km^2$ of coral reef 17

Figure 7. The most frequently traded genera of coral recorded under CITES 1985-1997 18

Figure 8. The relative amounts of the ten most frequently traded genera in the live and dead coral trade as recorded under CITES 1985-1997 23

Figure 9. The trend in live coral trade 1985-1997 26

Figure 10. The annual variation in the global trade in black coral 34

Figure 11. The value of the international trade in live coral in terms of the revenue in 1997 US dollars accruing to exporting nations 46

Figure 12. Size-frequency distribution of corals in the live trade 49

Figure 13. The retail value in 1997 US dollars of the international live coral trade between 1985 and 1997 50

Figure 14. Schematic representation of the economics of the live coral trade 51

Figure 15. Cumulative imports of live corals to the USA, as recorded by CITES 1985-1997 56

LIST OF BOXES

BOX 1 THE ILLEGAL TRADE IN CORALS 31

BOX 2 PRACTICAL ASPECTS OF IDENTIFYING CORAL SPECIES 37

BOX 3 PRACTICAL ASPECTS OF IDENTIFYING CORAL GENERA 38

ACKNOWLEDGEMENTS

We would like to thank Teresa Mulliken of TRAFFIC International and Tim Inskipp of the World Conservation Monitoring Centre for their efforts in reviewing a manuscript. The assistance of the following people in compiling Table 7 is gratefully acknowledged:

Stephen Cairns
Department of Invertebrate Zoology
Smithsonian Institution
Washington D. C. 20560-0163
USA

Brian Rosen
Department of Palaeontology
The Natural History Museum
Cromwell Road
London
SW7 5BD
UK

Douglas Fenner
Australian Institute of Marine Science
PMB No 3
Townsville MC
Queensland 4810
Australia

The assistance of the following people is gratefully acknowledged:

Jaime Baquero, Ocean Voice International
John Caldwell, CITES Trade Database Manager, WCMC
Bruce Carlson and Charles Delbeek, Waikiki Aquarium
Chris Collins, Geological Conservation Unit, University of Cambridge
Heather Cross, WCMC
Keith Davenport, Ornamental Aquarium Trade Association
Svein Fossa, Akvariekonsulenten
Vin Fleming, CITES Advisor, Joint Nature Conservation Committee
Chantal Hagen, Marine and Coastal Programme, WCMC
Helen Hendry, Department of Zoology, University of Cambridge
John Jarvis, Coral Conservation Group
Stephanie Pendry, TRAFFIC International
Phil Shane, Quality Marine Limited, USA
Kristian Teleki, Cambridge Coastal Research Unit, University of Cambridge
Paul West and Derek Thompson, Tropical Marine Centre

“Whereas today the average aquarium uses sterile white corals, it is entirely possible that the aquarium of tomorrow will contain nothing but living corals and fish”

R.P.L. Straughan, *The Marine Collector’s Guide*. 1973

1. EXECUTIVE SUMMARY

Trade in more than 2000 species of coral is monitored by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Records for black corals (from 1982-1997) and stony corals (from 1985-1997) were analysed in the first global assessment of the legal trade in coral: 70 nations imported a total of 19,262t (or 34,600,000 pieces) from 120 exporting nations over this period, with the USA accounting for more than 56% by weight of the global trade, compared with 15% for the EU. Historically the Philippines was a major exporter (19% by weight) but since the late 1980s has been superseded by Indonesia. Taiwan (4.5t per $1000km^2$) and China (3.0t per $1000km^2$) exported more coral per unit area of reef than any other nations, although the majority of this trade occurred in the 1980s and today both are minor exporters. In recent years Fiji and the Solomon Islands have become increasingly important coral trading nations. Regional trade links demonstrate that for the period 1985-1997 South-East Asian exports were an order of magnitude greater than those from the Pacific, and two orders of magnitude higher than the Caribbean and Indian Ocean. Globally the trade in coral peaked in the early 1990s but has since declined to levels comparable with the mid 1980s (approximately 1000t per year).

Many trade records identified taxa at levels higher than species, such as Anthipatharia spp. or Scleractinia spp. The majority only identified genus: overall a total of 119 recognised Scleractinian genera. There is a clear failure to record items to species level as required under the Convention. This probably reflects practical difficulties in coral taxonomy and identification. The practical aspects of identifying specimens to species, and the problems that non-specialists have in using existing guides, were tested experimentally.

Dead corals, mainly the skeletons of genera with predominantly branching growth forms, accounted for more than 90% of the trade up to the early 1990s, but since then there has been a large increase in the amount of live coral traded. Colourful species with large polyps (e.g. *Euphyllia* spp., *Goniopora* spp., *Catalaphyllia* spp., *Trachyphyllia* spp. and *Heliofungia* spp.) dominate the live trade in contrast to the trade in dead coral which selects *Fungia* spp., *Pocillopora* spp., *Porites* spp. and *Acropora* spp. The quantity of corals traded live has increased tenfold from 1985 to constitute more than half of the global trade in 1997, between 600-700t.

Measurements of live coral pieces in trade suggest the typical size to be 10 x 6cm in cross section, 6 cm in height and weighing about 200g. When assessed against published data on growth rates of different corals these dimensions suggest that a typical live coral in the aquarium trade is at least three years old. Some species of coral can be expected to survive in home aquaria for many years, certainly more than three, but the husbandry of other species is more difficult and mortality occurs in less. In the latter case the amount of coral being collected cannot be sustained by reproduction and growth. However in comparison to other extractive and destructive impacts on coral reefs, such as mining and dynamite fishing, the effects of collecting live coral for the aquarium trade are very small.

An economic analysis, using data on the cost of corals at point of export and the retail price in the market place, estimated that the exporting nations generated approximately US$5 million (1999 US$) in revenue from the live coral trade in 1997. This trade was worth approximately US$50 million in retail sales (1999 US$). Coral collectors earned between US$105,000 - 792,000 (1999 US$) in income, depending on assumptions made on the price they received per piece of coral.

2. MONITORING THE INTERNATIONAL TRADE IN CORAL

Early accounts of the coral trade were specific to certain countries (e.g. the Philippines, McManus 1980) or were constrained by the availability of suitable data (e.g. Wells, 1985). Export and import data have been available from customs authorities in some countries for many years, but corals are often combined with shells and other derivatives such as cuttle bone in these statistics (Table 1). While customs data were useful in highlighting some aspects of the trade, these constraints prevented analyses in an international context until corals were listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Table 1. European imports of coral are recorded under a single category

Year	Quantity (t)
1997	14.9
1996	11.1
1995	6.1
1994	6.1
1993	4.4
1992	59.2
1991	65.3
1990	68.2
1989	60.7
1988	46.1
1987	48.2
1986	45.1
1985	42.3
1984	34.4
1983	31.3
1982	30.9
1981	31.2

Notes:
EU trade is recorded under the code 050800 00 which is defined as '*coral and similar materials, unworked or simply prepared but not otherwise worked, shells and cuttle bone, unworked or simply prepared but not cut to shape; waste and powder thereof*'.

The amounts of coral being traded in the late 1990s are much lower than in the 1980s but it is impossible to determine under this recording system how much coral, as opposed to shells *etc.*, is being imported. Worked (i.e. carved) coral is recorded under a separate category (code 960190 10) which is defined as '*worked ivory, bone, tortoise shell, horn, coral, mother of pearl and other animal carving material and articles of these materials*'. Data taken from Eurostat, European Union external trade statistics.

Each party to the Convention is required to designate one or more management authorities to be responsible for administering the convention, and one or more scientific authorities to provide advice on technical issues, including assessments of the threat to species that international trade poses (Armstrong and Crawford, 1998). Shipments of coral involving parties to the Convention must be accompanied by a CITES permit which is issued by the national CITES management authority. Parties to CITES importing or exporting living or dead coral material are then obliged to produce annual reports summarising and specifying the quantity of trade in each listed species. These data have been produced since CITES came into force in 1975 and are compiled in the CITES Trade Database managed by the World Conservation Monitoring Centre on behalf of the CITES Secretariat (WCMC, 1996). A stylised record from this database is shown in Table 2.

Table 2. A stylised CITES record for coral

Year	Taxon	Importing Nation	Exporting Nation	Origin	Quantity		Unit		Term		Purpose		Source	
					I	E	I	E	I	E	I	E	I	E
1992	*Favia fragum*	Hungary	France	Cuba	2	2	kg	kg	live	live	zoo	zoo	wild	wild

Notes:
Year = date of transaction.
Taxon = coral species.
Importing Nation = the declared country of destination.
Exporting Nation = the declared country from which the specimen(s) were consigned.
Origin = country of origin where trade in a re-exported specimen(s) is reported.
Quantity = numerical amount of specimen(s) reported as imports (and recorded in Units).
Unit = unit of quantity, either weight or number of specimens.
Term = descriptions of specimen(s) traded. Recorded terms for corals are carvings, derivatives, extract, live, pieces and scientific specimens.
Purpose = purpose of the transaction. Recorded purposes for corals are commercial trade, bio-medical research, circuses and travelling exhibitions, personal, zoos, scientific and educational.
Source = source of the specimen. Recorded sources for corals are specimens taken from the wild, animals bred in captivity, confiscated specimens and pre-convention specimens.
I and E = For each transaction Quantity, Unit, Term, Purpose and Source are all recorded at the point of import (I) and export (E).

The CITES Trade Database provides records of the international trade in coral between 1982 and 1997. However limitations in the data must be acknowledged:

(i) Taxonomy: CITES requires that specimens be recorded at the species level. Coral taxonomy is a highly specialised subject requiring experience and expertise. Accurate identification of species may require considerable time and effort. Undoubtedly mis-classification occurs in compiling CITES permits for corals and species data cannot be considered reliable.

(ii) Units: quantity is recorded either as weight or pieces, making comparisons between different shipments difficult.

(iii) Some countries (e.g. Indonesia in the years 1985-1996, see Edwards and Nash (1992), but not 1997) report on the basis of permits issued, not on actual items traded, thereby over-estimating trade if not all permits are used.

(iv) Export permits may be issued in one year but used in another so that the transaction is reported in separate years by exporting and importing nations. This serves to over-estimate trade volumes as there is no way of knowing whether an export transaction in one year is the same shipment as an import transaction in the following year.

Nevertheless the CITES Trade Database is a unique and invaluable mechanism for monitoring international trade in marine species (Wells and Barzdo, 1991). It is undoubtedly the best source of data for an analysis of the global trade in corals.

A HISTORY OF CORAL WITHIN CITES

In total 143 nations are parties to CITES. The Convention prohibits all international commercial trade in species, listed in Appendix I, which are in serious threat of extinction. However regulated trade is permitted in species, listed in Appendix II of the convention, which are vulnerable to exploitation but not yet at risk of extinction. All species of black coral (Antipatharia) were listed in CITES Appendix II on 6th June 1981 as a result of a proposal put forward by the UK government on behalf of the Government of the British Virgin Islands (an overseas territory of the UK). The commercial harvest of corals for the jewellery trade, then valued at US$500 million per year, was the principal reason for this inclusion. In response to a proposal from Australia the second addition of corals to CITES was made during the fifth meeting of the parties and resulted in 17 genera of hard coral being listed in Appendix II on 1st August 1985. These genera were within the orders Athecata, Coenothecalia, Stolonifera and Scleractinia. However this partial listing did not include all the species being traded, and as a result failed to either regulate or monitor trade because of the difficulties associated with identifying listed and non-listed species, many of which look very similar. Israel was concerned that corals collected illegally within its territorial waters of the Red Sea were being traded under the guise of imported corals and so proposed the listing of all coral species in 1990. All remaining species of hard coral (including the Order Milleporina and 23 genera in the Order Stylasterina) were added on 18th January 1990. There are presently no species of coral listed in Appendix I but more than 2000 in Appendix II.

In an attempt to improve the documentation and standardise the reporting of the international trade in corals the USA developed a resolution (CITES Notification to the Parties No. 788) for discussion at the tenth meeting of the Conference of the Parties to CITES (CoP10), which took place from 9-20th June 1997 in Harare, Zimbabwe. This resolution proposed that: (i) reports of trade in specimens of coral transported in water should record the number of pieces traded; (ii) reports of trade in coral specimens other than specimens of coral transported in water should record the weight in kilograms; (iii) specimens of readily recognisable coral gravel and 'living rock' (also known as 'live rock') in trade be reported at the level of order (Scleractinia), where 'living rock' is defined as pieces of scleractinian coral to which are attached live specimens of invertebrate species not included in the appendices. The aquarium industry opposed this resolution out of a concern that part (iii) would bring about a large increase in the amount of items that had to be recorded (e.g. the small pieces of rock to which soft corals and anemones are attached) and in so doing would restrict trade to only those nations with the capacity to manage the extra reporting load. The resolution failed to attract support at CoP10 from nations other than the USA, and was withdrawn.

THE PHILIPPINE AND INDONESIAN TRADE IN CORALS

Studies of the trade in coral originating in the Philippines (Mulliken and Nash, 1993) and Indonesia (Bentley, 1998) used CITES data from 1986-1989 and 1985-1995 respectively. Mulliken and Nash (1993) describe how the Philippines was a major source of corals in international trade for at least three decades, exporting more than 13,000t. The collection of corals for the coral trade there is believed to have caused localised damage and altered the species composition of some reefs (Wells 1981). Legal measures were taken to stop the collection and export of coral in 1973, 1977 and 1980. However, trade continued and customs data show that the USA imported an average of 350t annually between 1981-1985. The export ban was also temporarily lifted in 1986 and again in 1992 to allow traders to clear stocks, but there have been repeated problems of Philippine coral being illegally imported into the USA and EU (Mulliken and Nash, 1993; Best, 1997). Bentley (1998) used CITES data to identify the major importers of Indonesian corals, and compared the trade to other destructive and extractive reef practices. However, this report is the first global analysis of the coral trade which uses all CITES records from the period 1985-1997 to assess the trade in corals in an international context.

3. METHODS USED IN THIS STUDY

A NOTE ON THE CITES TRADE DATABASE

In order to understand the recording of trade data in the CITES Trade Database, and the analyses in this report, it is necessary to clarify the differences between (i) a database record, (ii) a CITES permit, (iii) a shipment of coral, and (iv) a database output.

(i) A database record is a unique combination of date, taxon, importing and exporting nation, origin, quantity, unit, term, purpose and source (see Table 2 for definitions).

(ii) A single CITES permit, in the case of corals, is usually a list of different species going from country X to country Y. Each combination of date, taxon, importing and exporting nation, origin, quantity, unit, term, purpose and source is entered into the CITES Trade Database as a separate record. Most countries, with the notable exception of Indonesia, do not allow more than about five species to be listed on a single CITES permit.

(iii) Theoretically a CITES export permit and a CITES import permit is needed to allow the passage of a shipment of coral. The number of CITES permits issued should therefore be twice the number of shipments made, but this is not the case as many countries do not issue or require import permits.

(iv) The CITES Trade Database contains 316,606 records of coral trade for the period 1982-1997. In an attempt to facilitate the analysis of these data records are combined in database outputs. This means that all records of e.g. wild caught, live *Pocillopora damicornis* originating in Indonesia, being exported from Singapore to the USA for commercial purposes and recorded in kilograms in 1994 are combined as a single entity in the output.

The database records may be analysed individually to determine, for example, the proportion by number which are completed to species level. Given the huge number of individual database records this was only performed for 1997 data (38,077 records). The database outputs may be analysed to determine, for example, the amount of coral by weight which was traded between any two countries. This was performed for all database outputs for the period 1982-1997, where appropriate.

THE RATIONALE FOR ANALYSING TAXONOMIC DATA AT THE GENUS LEVEL

Coral trade data were extracted from the CITES Trade Database. Species were identified in just 2% of 1997 database records, presumably reflecting practical problems with coral identification and taxonomy. Coral was typically recorded to genus (83% in 1997) or simply as higher (suprageneric) levels such as Pectiniidae (a Family) or in most cases simply as Scleractinia spp. (15% in 1997). Therefore all analyses were conducted at the generic level. In the majority of trade (95% by weight) Quantity, Unit, Term, Purpose and Source were not recorded on both import and export permits. Where both import and export fields had been completed transaction data were excluded from analysis if the Import Quantity had been recorded at a different value to the Export Quantity (these constituted only 4% by weight of the trade, Table 3).

Table 3. The number of outputs from the CITES Trade Database where the Import Quantity was recorded at a different value to the Export Quantity

Year	# IQ ≠ EQ	n	%
1985	5	137	3.6
1986	27	372	7.3
1987	11	363	3.0
1988	8	329	2.4
1989	0	356	0.0
1990	19	975	1.9
1991	20	991	2.0
1992	69	1594	4.3
1993	13	1609	0.8
1994	6	1900	0.3
1995	99	1949	5.1
1996	140	2397	5.8
1997	125	2235	5.5
Total	542	15,018	3.6

Notes:
N = total number of database outputs for each year, % = the percentage of database outputs for which # IQ≠ EQ in that year.

CONVERTING BETWEEN UNITS OF WEIGHT AND NUMERICAL UNITS

Trade in coral is recorded either in numerical units (number of pieces) or units of weight (Table 2). A conversion factor, the weight of a 'typical' piece of coral in trade, was needed to analyse numerical and weight records in conjunction. The Amendments to Appendices I and II of CITES (Anon., 1989) noted that US Custom Service statistics, which are recorded by weight, and US Fish and Wildlife Service Statistics, which are recorded as 'items', appear to indicate the average weight of a piece of coral to be 1kg, and the average size 50cm. By comparison Kirkby (1992) noted that 2,387,179 pieces of dead coral weighing 544t, were imported into the USA between January 1991 and April 1992. The mean weight of these pieces would therefore have been 228g. However, Kirkby's data are inconsistent because he also noted that 627,884 pieces of live coral, weighing eight tonnes, were imported over the same period, at an average weight of just 13g per piece. This is clearly too low. Instead values of 0.5kg per piece of massive coral and 0.25kg per piece of branching corals, as defined in the Amendments to Appendices I and II of CITES (Anon., 1989), were used here to express each transaction in both weight and numerical units. These figures were derived from '*weighing a small quantity of dead corals*' (Anon., 1989). An intermediate conversion value of 0.375kg per piece of coral was used for those genera whose species could not be described as either predominantly massive or branching in their growth forms. One weakness of these conversion values is the assumption that it is possible to generalise for pieces of coral from many different genera, which were collected for many different purposes, from many different locations. However, the purpose of this study was to obtain an overall understanding of the global trade in coral, and this acknowledged disadvantage was outweighed by the ability to combine transactions recorded in units of weight with transactions recorded in numerical units. A conversion value also solves the problem of expressing trade in units which are meaningful in terms of management (i.e. quantitative kilograms not qualitative 'pieces') which prevented the authors of the most extensive study of coral trade to date from assessing its effects (O'Brien Shoup and Gaski, 1995).

A conversion factor was not available for black corals, and therefore transactions recorded in units of weight have to be treated separately from transactions recorded in numerical units making it difficult to draw conclusions about the total trade. These species are mainly collected for jewellery and have been listed under Appendix II since 1982. For these two reasons black coral data were analysed separately from hard corals.

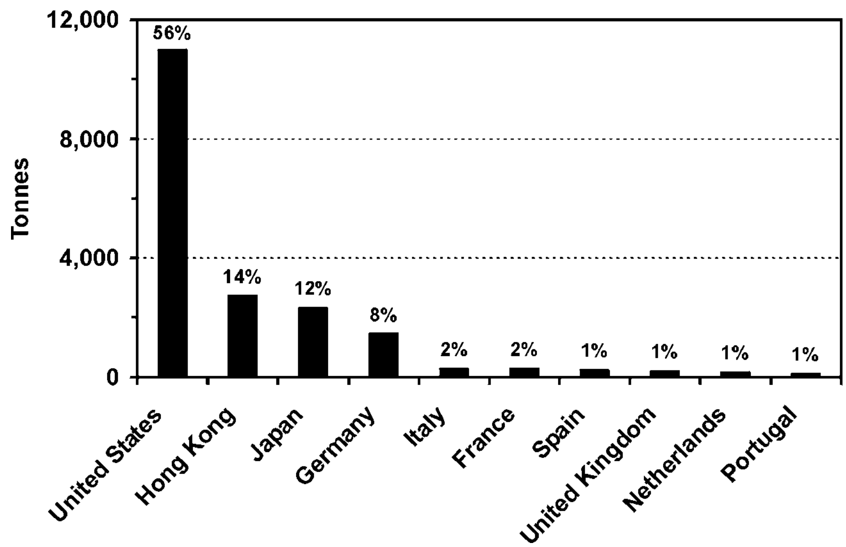
THE RE-EXPORT OF CORALS

Describing the international coral trade is complicated by the re-export of material. Coral may be imported from its country of origin, then exported to another importing nation. Records indicate that a total of 3165t (16%) of coral was traded in this way with the majority of the re-export recorded as occurring through Hong Kong and the USA. Hong Kong re-exported 1650t most going to Japan, 1059t, and to the USA, 528t. Thus 60% of Hong's Kong gross exports was coral imported from elsewhere (all but 5t were from China). In fact given the small area of reef in Hong Kong it is perhaps surprising that this proportion is not higher. The USA re-exported 1173t of coral, 11% of its gross imports, to 19 different nations. Although this coral originated from 15 different nations the data are skewed by very large amounts of coral originating from Indonesia and Fiji which were re-exported to Canada and Denmark. In the analyses described here re-exported coral was treated as an import of the second importing nation, not the first. In other words, figures given here are net imports and do not include coral which was recorded as being re-exported to a third party. Of course re-export may have occurred and been recorded as a separate transaction, and the third party may in turn re-export to a fourth party, but there is no way of quantifying these occurrences with CITES data.

4. THIRTEEN YEARS OF INTERNATIONAL TRADE IN HARD CORAL

Seventy nations imported a total of 19,262t (34,600,000 pieces) of coral from 120 exporting nations between 1985-1997. The USA has dominated the international trade in coral, receiving 56% of all the coral traded globally since species were listed by CITES (Figure 1). Hong Kong and Japan are also important traders in corals, Germany imports most of the coral coming into the European Union with other EU nations each responsible for 1-2% of global trade (Figure 1).

Figure 1. Ten nations imported 98% of the coral recorded under CITES 1985-1997



A similar pattern is revealed for exporting nations (Figure 2) with the trade dominated by one country, Indonesia.

Coral exported from the Philippines has constituted 18% of the trade in the past 12 years, but Figure 3 shows this to be largely historical. In the mid to late 1980s Indonesia and the Philippines were exporting approximately the same quantity of coral per year. Indonesian exports increased to approximately 1000t per year after the moratorium on coral trade in the Philippines, but have since declined to about 500t per year. The release in 1992 of stockpiled coral from the Philippines is evident in Figure 3.

As these figures would seem to suggest, the trade between Indonesia and the USA constituted a large proportion (26%) of the global coral trade in coral. This is

Figure 2. Ten nations exported 94% of the coral recorded under CITES, 1985-1997

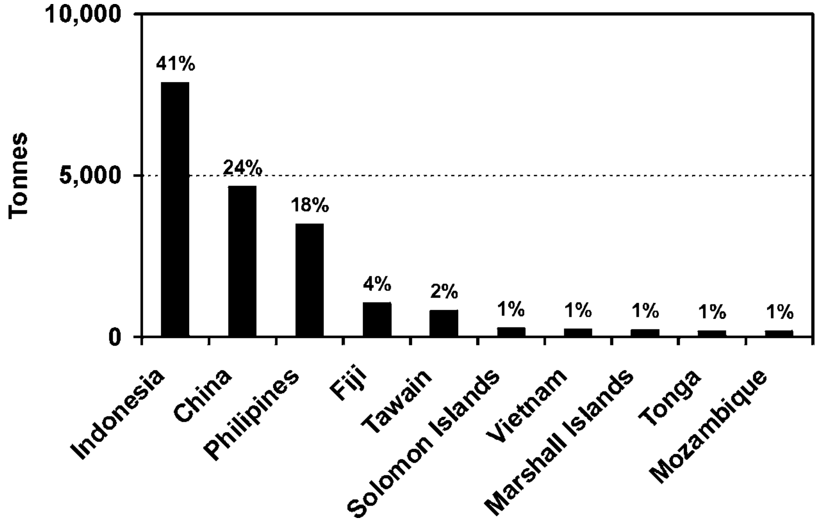
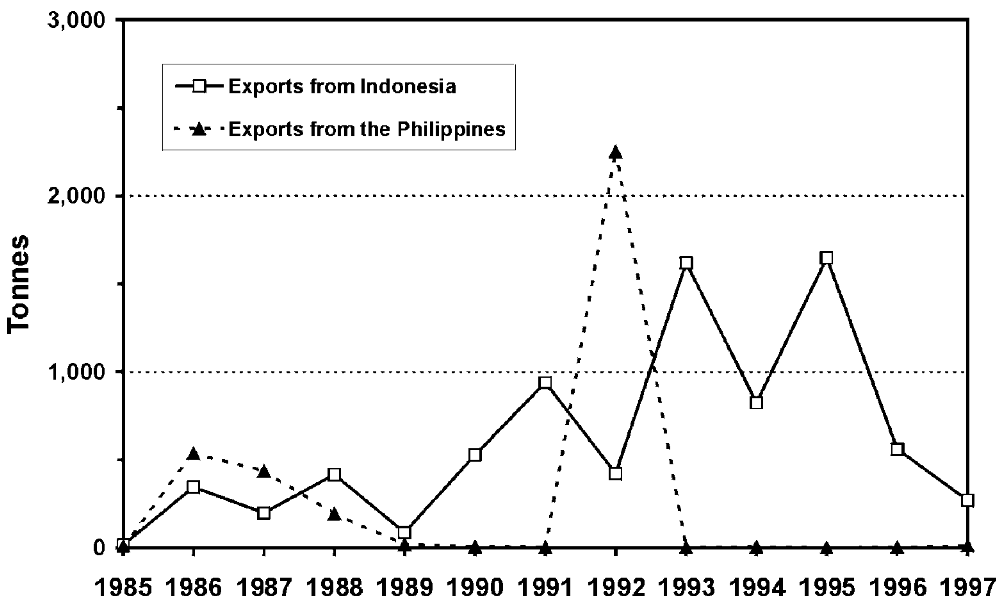


Figure 3. The quantity of coral exported from the Philippines and Indonesia



Notes:

The quantity of coral exported from the Philippines and Indonesia was approximately equal until the late 1980s, when the former declined as a result of national legislation prohibiting the collection and export of coral. Indonesian exports rose subsequently. In 1992 there was a temporary suspension of the ban of coral trade in the Philippines to allow stocks of old coral to be cleared.

Table 4. Trade links between the top ten coral importing and the top ten exporting nations

	The Principal Exporting Nations										
	Indonesia	**China**	**Philippines**	**Fiji**	**Taiwan**	**Solomon Is**	**Vietnam**	**Marshall Is**	**Mozambique**	**Tonga**	**Total**
USA	4,967	748	2,786	979	583	255	9	209	19	155	11,000
Hong Kong	40	2,690	0.038	-	-	-	-	-	-	-	2,730
Japan	795	1,122	58	2	142	3	200	-	-	-	2,322
Germany	1,321	-	64	40	16	2	16	-	0.001	0.057	1,458
Italy	109	-	140	0.123	35	-	-	-	32	-	317
France	184	-	45	0.682	35	-	-	-	30	-	295
Spain	110	7	33	15	3	0.171	-	-	41	0.045	208
UK	69	0.001	113	1	8	-	-	-	-	-	190
Netherlands	102	0.002	46	0.027	20	0.001	-	-	-	-	168
Portugal	0.35	-	0.03	-	0.002	-	-	-	0.085	-	118
Total	7,698	4,567	3,314	1,037	842	261	225	209	207	155	18,516

Notes:

Data are expressed as the weight of coral, in metric tonnes, traded in the years 1985-1997. All USA trade with Vietnam trade took place in 1997.

evident from Table 4 which illustrates the trade links between the top ten coral importing nations (who accounted for 98% of the total weight of traded coral) and the top ten exporting nations (who accounted for 94% of all coral exports). The trade between China and Hong Kong (14% of world trade) and Indonesia and Germany (7% of world trade) was also substantial. Although the USA imported coral from 72 different nations, trade with Vietnam only began in 1997, presumably because of previous political barriers. Historical links between nations can be seen elsewhere. For example, Portugal imported the majority of its coral from Mozambique, an ex-colony, in contrast to most other EU countries who imported mainly from Indonesian and the Philippines. Regionally the USA imports three to five times as much coral as the entire European Union (Table 5), and twice as much as the rest of the world.

Table 5. Coral imports to different regions

Importer	Tonnes	%	Pieces	%
USA	9,968	56	22,258,047	71
ROW*	5,349	30	4,615,879	15
EU†	2,723	15	4,420,523	14
Total	**18,030**		**31,294,449**	

Notes:

* Hong Kong accounts for 57% of coral imports to the rest of the world (ROW), Canada 2% and 52 countries account for the remainder (each less than 1% of total global coral imports).

† Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom

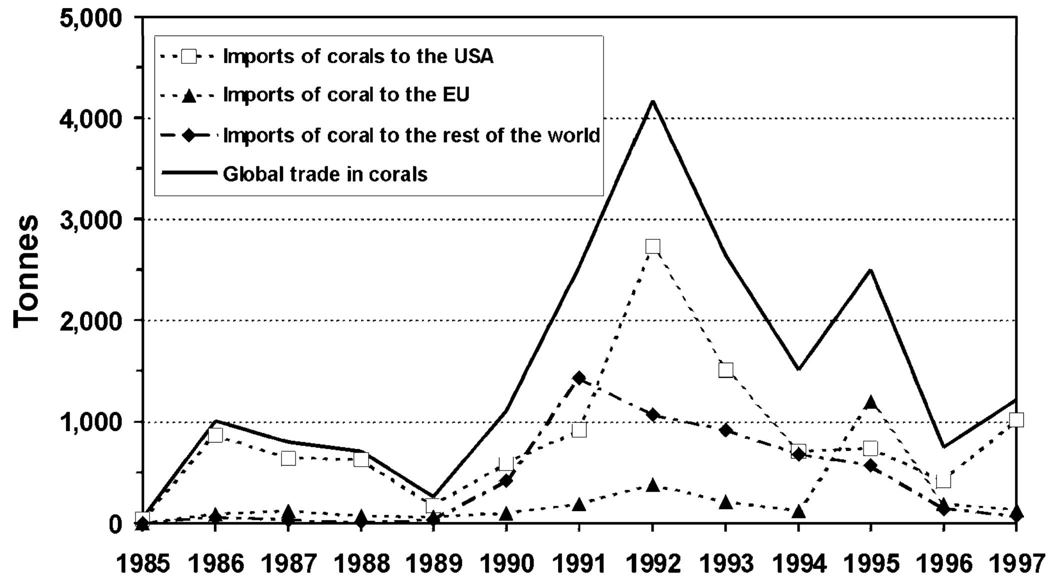
TRENDS IN THE AMOUNT OF CORAL EXPORTED BY DIFFERENT COUNTRIES

In the 1980s the average amount of coral traded internationally was 565t per year (Figure 4), with the trade split fairly evenly between the Philippines (mean exports 239t per year) and Indonesia (mean exports 212t per year). The international trade increased in the 1990s peaking twice, first in 1992 at 4172t and again in 1995 at 2499t. The volume of trade in 1997 was 1221t. The number of signatories to CITES also increased over the same period and so it is reasonable to assume that present trade volumes are broadly comparable to those of the 1980s.

One further point emerges from Figure 4. The pattern in global trade in coral tracked the changes in imports to the USA until 1994. The second peak in the amount of coral traded in the 1990s was caused by rising demand in Europe, not the USA where coral imports have decreased substantially since 1992. However this may prove to be temporary because the increase in trade from 1996 to 1997 would appear to have been driven by the USA market (Figure 4).

There have also been some interesting trends in the amount of coral exported from countries other than Indonesia and the Philippines (Figure 5). Wells and Wood

Figure 4. Trends in the global trade in coral as recorded under CITES, 1985-1997



Notes:
Trends in the amount of coral exported to the USA, European Union and rest of the world are also shown.

(1989) analysed early CITES data from 1986-1987 to demonstrate that Malaysia, Taiwan, Fiji, Haiti, New Caledonia and Thailand were also exporting coral to temperate nations. The most dramatic increase in trade since the mid 1980s occurred in Fiji which exported an average of 27t per year between 1990-1994. In the mid 1990s this increased by an order of magnitude to an average of 293t between 1995-1997. Trade from the Solomon Islands also increased over the same period. By contrast China and Taiwan, both important historical exporters of coral, decreased their traffic in hard corals by many orders of magnitude to levels that are negligible compared to the late 1980s and early 1990s (Figure 5). Vietnam and Mozambique are the seventh and tenth largest exporters having produced 2% of the total amount of coral traded internationally over the last 12 years (Figure 2), but nearly all of it in the years 1994-1997.

Regionally the picture is less clear, but imports to the USA from South East Asia have declined and are now less than a third of what they were in the mid 1980s (when there were fewer signatories to CITES and fewer species were listed under the convention). The USA market seems to be increasingly supplied by nations in the South Pacific region: imports from this region have risen, from an average of 38t in preceding years to 821t in 1997. Likewise the Indian Ocean appears to have become more important to the European trade because tiny amounts were imported from this region in the 1980s, but trade has increased from 0.5t in 1995 to 32t in 1997. While causal effects cannot be deduced directly from the data, it may be that trade from these regions is increasing in response to declining activity in South East Asia.

Figure 5. Trends in the amount of coral exported from the major exporting nations in Figure 2, excluding Indonesia and the Philippines (Figure 3) as recorded under CITES, 1985-1997

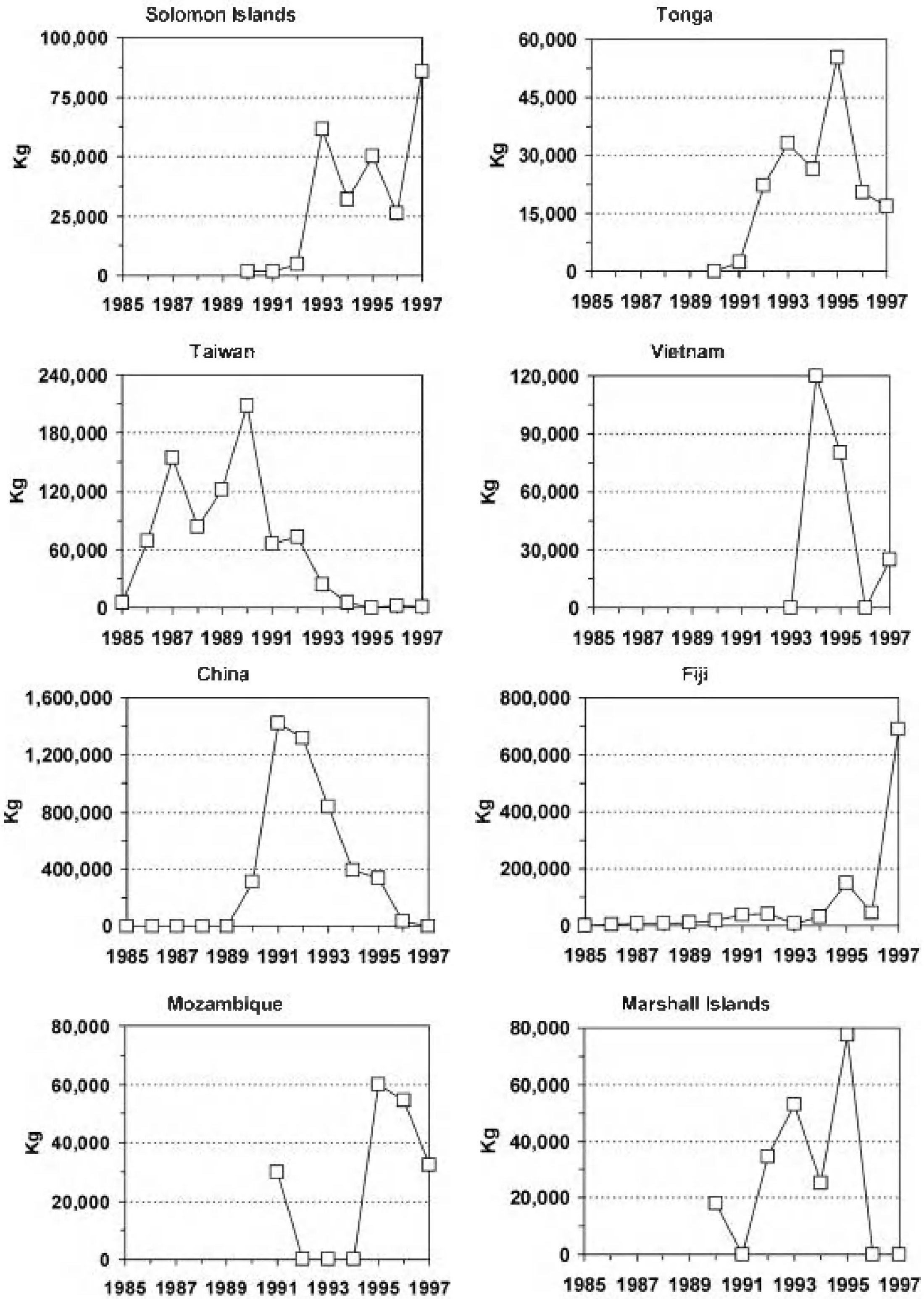


Table 6. Trade links (expressed as the weight of coral, in kg, traded in the years 1985-1997) between coral importing and exporting regions

	Arabian Gulf	Caribbean	Indian Ocean	North Atlantic	North Pacific	Red Sea	South Atlantic	South East Asia	South Pacific
EU†	99	39,878	58,664	105	18,031	1	157	2,521,313	209,547
ROW*	47	20,602	6,995	1,167	86,595	64	195	5,063,952	234,703
USA	343	17,493	24,905	3,988	76,492	101	0	9,574,155	1,283,688
Total	489	77,973	90,564	5,260	181,118	166	352	17,159,420	1,727,938
Coral Reef Area (1000 km^2)	3	20	36	2	17	17	1	68	91
kg/1000 km^2	163	3,899	2,516	2,630	10,654	10	352	252,344	18,988

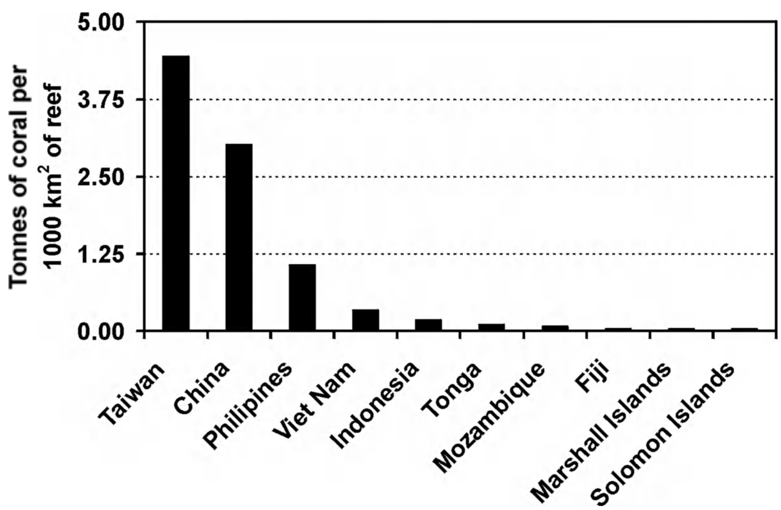
Notes:

Links are also expressed in weight of coral traded per unit area of coral reef (coral reef areas defined and calculated in Spalding and Grenfell, 1998).

* Rest of the world (i.e. not USA or EU members)

† Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom

Figure 6. Exports of coral recorded under CITES expressed as tonnes per 1000 km^2 of coral reef



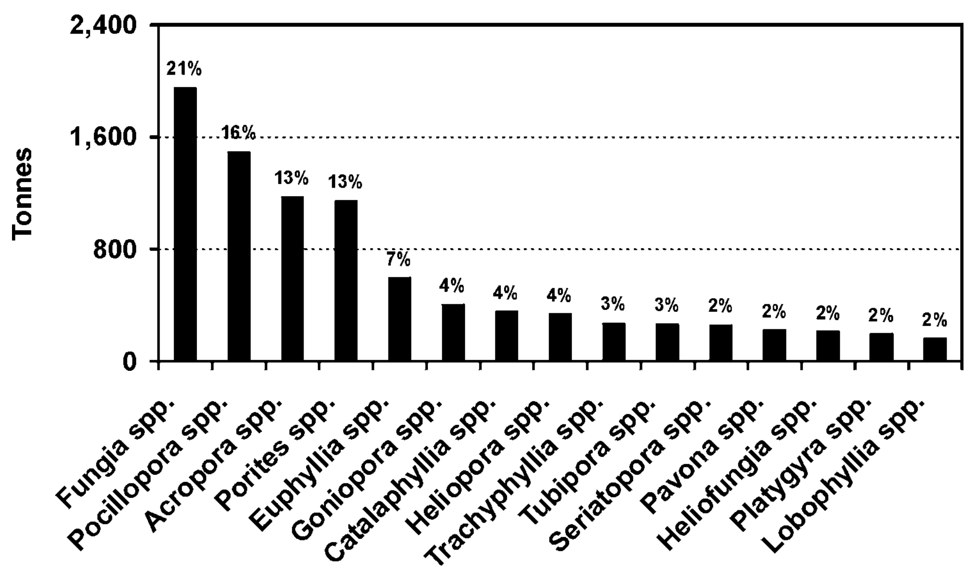
CORAL TRADE AS A FUNCTION OF CORAL REEF AREA

Exports can be expressed in terms of coral reef area using estimates provided by Spalding and Grenfell (1998). In this analysis, if the country of origin was not stated, then the coral was assumed to have originated in the export nation (Figure 6). Comparison with Figure 2 reveals that in proportion to the amount of coral reef supplying material for export, Taiwan, China and Vietnam were the major exporters. The reefs of South-East Asia have supplied an order of magnitude more coral per 1000km^2 than either the North or South Pacific, and two orders of magnitude more than either the Caribbean or the Indian Ocean, despite the large areas of reef in these regions (Table 6). Trade from other coral reef regions is negligible by comparison.

THE TAXONOMIC COMPOSITION OF THE CORAL TRADE

A total of 143 groups of corals have been recorded in the CITES database and were traded internationally between 1985-1997 (Table 7), 119 of which are recognised scleractinian genera. All but two of these genera are zooxanthellate scleractinian ('reef-building') corals, and the majority (*Heliofungia* spp. are the exception) are colonial, attached, species which have to be removed from the reef substrate by force. The non-scleractinians are *Heliopora* spp. which belongs to the Order Coenothecalia (*Heliopora coerulea* is the only species in the genus) and *Tubipora* spp. which belong to the Order Stolonifera (*Tubipora musica* is the only species in the genus). Transactions in *Fungia* spp., *Pocillopora* spp., *Acropora* spp., *Porites* spp., *Euphyllia* spp., *Goniopora* spp., *Catalaphyllia* spp., *Heliopora* spp., *Trachyphyllia* spp., *Tubipora* spp., *Seriatopora* spp., *Pavona* spp., *Heliofungia* spp., *Platygyra* spp., *Lobophyllia* spp., constitute 47% of all coral traded between 1985–1997 (Figure 7). A minority of records, 15% in 1997, classified the taxon as 'Scleractinia spp.' but over the period 1985-1997 Scleractinia spp. accounted for 8841t or 46% of the total weight of coral traded. The 1997 database records indicate that transactions of Scleractinia spp. appear to be larger (mean quantity = 188 ± 28kg) than those identified to genus level (mean quantity = 21 ± 3kg). Traffic in all other groups of coral accounted for just 7% of the traded weight in the last twelve years.

Figure 7. The most frequently traded genera of coral recorded under CITES 1985-1997



Notes:
The labels are the percentage by weight of the trade, excluding transactions recorded as Scleractinia spp., which occurred in each genus.

There are some interesting oddities in the CITES records including a shipment of 1.1t of *Crispatotrochus* spp. for commercial trade in 1996. *Crispatotrochus*, however, is an extinct genus, and is only known from the fossil record. Likewise some species of azooxanthellate coral, such as the microscopic *Holcotrochus* spp. or *Deltocyathus* spp. which grow in extremely deep water (80-2300m), can only have been collected using highly specialised techniques.

Table 7. Taxonomy and general ecology of corals in trade

A = attached, C = colonial, F = free living, SC = some colonial species, some solitary (single polyp) species, SF = some free living, some attached species, S = solitary (single polyp) species. Ten most traded (dead) genera are in bold type, ten most traded (live) genera are in boxes.

Zooxanthellate scleractinian corals (= approximately, 'reef corals'), n = 84.

Acanthastrea spp.	C, A	*Dichocoenia* spp.	C, A	*Leptoseris* spp.	C, A	*Plerogyra* spp.	C, A
Acanthophyllia spp.	C, A	*Diploastrea* spp.	C, A	*Lithophyllon* spp.	C, A	*Plesiastrea* spp.	C, A
Acrhelia spp.	C, A	*Diploria* spp.	C, A	*Lobophyllia* spp.	C, A	***Pocillopora* spp.**	C, A
***Acropora* spp.**	C, SF	*Echinophyllia* spp.	C, A	*Manicina* spp.	C, SF	*Podabacia* spp.	C, A
Agaricia spp.	C, A	*Echinopora* spp.	C, A	*Merulina* spp.	C, A	*Polyphyllia* spp.	C, F
Alveopora spp.	C, A	***Euphyllia* spp.**	C, A	*Montastrea* spp.	C, A	***Porites* spp.**	C, A
Anacropora spp.	C, A	*Favia* spp.	C, A	*Montipora* spp.	C, A	*Psammocora* spp.	C, A
Astreopora spp.	C, A	*Favites* spp.	C, A	*Moseleya* spp.	C, A	*Sandalolitha* spp.	C, F
Australogyra spp.	C, A	*Fungia* spp.	S, A	*Mussa* spp.	C, A	*Scapophyllia* spp.	C, A
Barabattoia spp.	C, A	*Galaxea* spp.	C, A	*Mycedium* spp.	C, A	*Scolymia* spp.	S, A
Blastomussa spp.	C, A	*Gardineroseris* spp.	C, A	*Mycetophyllia* spp.	C, A	***Seriatopora* spp.**	C, A
***Catalaphyllia* spp.**	C, F	*Goniastrea* spp. (3)	C, A	*Nemenzophyllia* spp. (4)	C, A	*Siderastrea* spp.	C, A
Caulastarea spp.	C, A	***Goniopora* spp.**	C, SF	*Oulastrea* spp.	C, A	*Simplastrea* spp.	C, A
Coeloseris spp.	C, A	*Halomitra* spp.	C, F	*Oulophyllia* spp.	C, A	*Solenastrea* spp.	C, A
Colpophyllia spp.	C, A	***Heliofungia* spp.**	C, F	*Oxypora* spp.	C, A	*Stephanocoenia* spp.	C, A
Coscinastrea spp. (1)	C, A	*Herpolitha* spp.	C, F	*Pachyseris* spp.	C, A	*Stylocoeniella* spp.	C, A
Ctenactis spp.	C, A	*Heteropsammia* spp.	C, F	*Pavona* spp.	C, A	*Stylophora* spp.	C, A
Cycloseris spp. (2)	S, F	*Hydnophora* spp.	C, A	*Pectinia* spp.	C, A	*Symphyllia* spp.	C, A
Cynarina spp.	S, SF	*Isophyllia* spp.	C, A	*Physogyra* spp.	C, A	*Trachyphyllia* spp. (5)	C, SF
Cyphastrea spp.	C, A	*Leptastrea* spp.	C, A	*Physophyllia* spp.	C, A	*Turbinaria* spp.	C, A
Dendrogyra spp.	C, A	*Leptoria* spp.	C, A	*Platygyra* spp.	C, A	*Zoopilus* spp.	C, F

Scleractinian corals which are partly zooxanthellate and partly azooxanthellate, n = 5.

Astrangia spp.	C, A	*Balanophyllia* spp.	C, A	*Heterocyathus* spp.	S, F
Madracis spp.	C, A	*Oculina* spp.	C, A		

Zooxanthellate scleractinian corals (= approximately 'reef corals') but suprageneric category, n = 2.

Pectiniidae spp. [a family]	Scleractinia spp. [an order]

Table 7 continued….

Azooxanthellate scleractinian corals[6], n = 34.

Caryophyllia spp.	A, F, S	*Kionotrochus* spp.	F, S	*Premocyathus* spp.	F, S
Culicia spp.	SC, A	*Lophelia* spp.	C,A	*Sphenotrochus* spp.	F, S
Cyathelia spp.	C, A	*Madrepora* spp.[7]	A, C	*Stephanocyathus* spp.	F, S
Deltocyathus spp.	S, F	*Monomyces* spp.	A, S	*Tethocyathus* spp.	S, A
Dendrophyllia spp.	C, A	*Notophyllia* spp.	F, S	*Thecopsammia* spp.	S, A
Desmophyllum spp.	S, A	*Odontocyathus* spp.	F, S	*Trematotrochus* spp.	SF
Flabellum spp.	S, SF	*Oulangia* spp.	A, S	*Trochocyathus* spp.[8]	SF, S
Fungiacyathus spp.	F, S	*Paracyathus* spp.	A, S	*Trochopsammia* spp.	S, A
Gardineria spp	A, S	*Phyllangia* spp.	C, A	*Truncatoflabellum* spp.	SF, A
Goniocorella spp.	C, A	*Placotrochus* spp.	SF, A	*Tubastraea* spp.[9]	C, A
Guynia spp.	S, A	*Platytrochus* spp.	F, S		
Holcotrochus spp.	F, S	*Polycyathus* spp.	C, A		

Azooxanthellate scleractinian coral but junior synonyms of a name not in the above list, n = 1.

Crispatotrochus spp. (= *Turbinolia*)

Extinct scleractinian coral known only from fossil record, n = 1.

Actinastrea spp.

Suprageneric octocoral groups, n = 2.

Alcyonaria spp. ('soft corals')	Coenothecalia spp.

Octocoral genera, n = 2.

***Heliopora* spp.**	***Tubipora* spp.**

Antipatharians (includes the black corals), n = 8.

Antipathes spp.	*Aphanipathes* spp.	*Cladopathes* spp.	*Leiopathes* spp.
Sibopathes spp.	*Bathypathes* spp.	*Hexapathes* spp.	*Schizopathes* spp.

Hydrocorals (Stylasterina), mostly found in deeper water, n = 7.

Conopora spp.	*Crypthelia* spp.	*Distichopora* spp.	*Stylaster* spp.
Cheiloporidion spp.	*Gyropora* spp.	*Phalangopora* spp.	

Hydrocorals (Milleporina), n = 1.

Millepora spp.

Notes:

(1) *Coscinaraea* occurs in some records but is probably a mis-spelling for *Coscinastrea*
(2) *Diaseris* occurs in some records but is regarded as a junior synonym of *Cycloseris*
(3) *Coelastrea* occurs in some records but is regarded as a junior synonym of *Goniastrea*
(4) *Nemenzophyllia* has been considered a synonym of *Plerogyra* but now considered to be a valid genus.
(5) *Wellsophyllia* occurs in some records but is regarded as a junior synonym of *Trachyphyllia*
(6) *Thalassiotrochus* occurs in some records but it is not a valid genus.
(7) *Amphelia* is an azooxanthellate scleractinian coral but is a junior synonym of *Madrepora*.
(8) *Platycyathus* occurs in some records but it is a sub-genus of *Trochocyathus*.
(9) *Coenopsammia* occurs in some records but is regarded as a junior synonym of *Tubastraea*.

THE PURPOSE OF THE INTERNATIONAL TRADE

The majority of the trade (76% by weight) was for commercial purposes, presumably with dead corals supplying the ornamental trade and the live aquarium industry. *Goniopora* and *Porites* spp. were the only two genera to be traded for biomedical purposes, peaking at 26t in 1992, but declining to extremely low levels since. These transactions probably supplied a specialised market for the use of coral in bone grafts. Hydroxyapatite (HA) is made from the rigid exoskeletons of marine corals and is used to fill voids caused by fractures or other trauma in the upper, flared-out portions of long bones because its structure is similar to human bone. The US Food and Drug Administration approved the HA product Pro Osteon Implant 500, made by Interpore International, in 1992. When HA is implanted into a bone void, its web-like structure allows surrounding bone and fibrous tissue to infiltrate the implant and make it biologically part of the body. The US Food and Drug Administration has also approved coral-derived implants for applications such as bone loss around the root of a tooth and in certain areas of the skull.

THE SOURCE OF CORALS FOR THE INTERNATIONAL TRADE

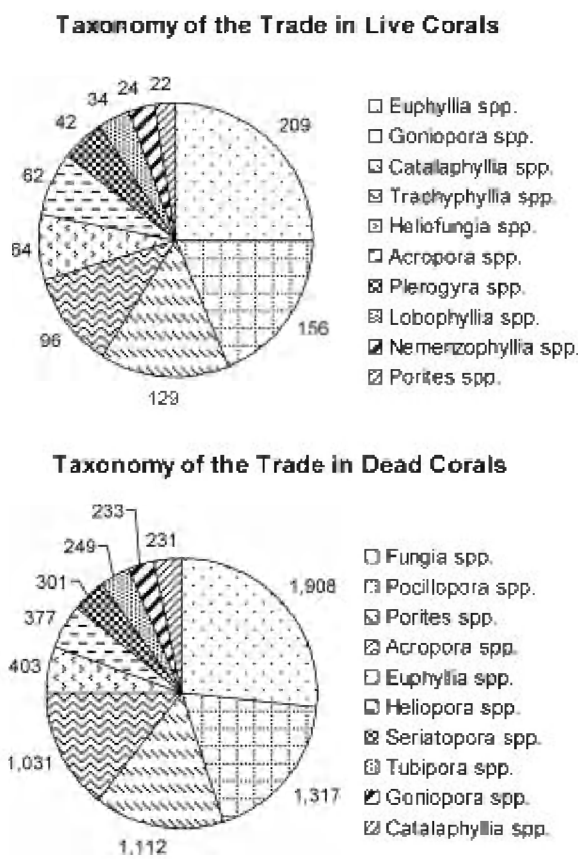
The vast majority (96%) of coral in trade is supplied from the wild with a minuscule quantity (0.03%) coming from aquaculture (bred in captivity). The remainder is accounted for by those records which fail to specify source.

5. THE LIVE CORAL TRADE

During the period 1985-1997 most coral (86% by weight) was traded dead, 84% as pieces and 2% (mainly *Cataphyllia* spp., *Euphyllia* spp. and *Goniopora* spp.) as carvings. The remainder (14% by weight) was traded alive (trade in other forms, e.g. scientific specimens, is negligible).

The reported imports of live coral amounted to 2691t or 5,940,000 pieces from 93 genera between 1985-1997. The taxonomy of the live and dead trade differs: species of *Fungia* spp., *Pocillopora* spp., *Porites* spp. and *Acropora* spp. constitute the majority of the dead trade (Figure 8), while the live trade concentrates on genera whose species tend to be more colourful or have larger polyps which can be seen during the day (e.g. *Euphyllia* spp., *Goniopora* spp., *Catalaphyllia* spp., *Trachyphyllia* spp., *Heliofungia* spp. and *Plerogyra* spp., Figure 8). These characteristics are particularly desirable for the aquarium industry.

Figure 8. The relative amounts of the ten most frequently traded genera in the live and dead coral trade as recorded under CITES 1985-1997



Notes:
Labels are tonnes of coral.

Weights and linear dimensions of pieces of live coral were obtained from seven shipments from Indonesia (Bali and Jakarta) and Fiji arriving at two aquarium wholesale companies, one in the UK and one in the USA. A total of 622 pieces from 20 genera, including nine of the genera in Figure 8, were measured (Table 8). UK corals were measured by WCMC staff, USA corals by staff of Quality Marine Ltd. The UK corals were significantly heavier than the USA corals (t-test, $p<0.05$, d.f.= 620). These specimens were not larger in the sense that they were 'taller', there was no significant difference in the height of the pieces (t-test, $p>0.05$, d.f.= 612), but because the surface area was larger (t-test, $p<0.05$, d.f.= 453). However the UK data were disproportionately influenced by a few very large pieces of *Porites* spp., all more than 590g in weight. The median weights of UK and USA corals were similar and there was no significant difference between them (median test, Mood, 1950).

Table 8. The weight and linear dimensions of pieces of live coral in the UK and USA aquarium trade

		Weight (g)	Height (mm)	Area (cm^2)
UK Corals	**median**	172.4	53	156.8
	mean	215.7	57	185.8
	±95%	16.4	3	11.7
	n	464	456	361
	maximum	1703.0	144	793.2
	minimum	27.8	10	9.8
USA Corals	**median**	150.6	65	143.7
	mean	177.9	64	158.0
	±95%	17.4	9	18.0
	n	158	158	94
	maximum	632.4	75	444.9
	minimum	31.4	5	4.7

Notes:
UK data were measured from coral arriving at The Tropical Marine Centre, Solesbridge Lane, Chorleywood, Hertfordshire, WD3 5SX, United Kingdom. USA data were obtained from Quality Marine, 5420W, 104th Street, Building 2 East, Los Angeles, CA 90045, USA.

There were significant differences between the weights of corals from different genera (i.e. the variation in weight of live corals within genera was significantly different to the variation of weight between genera, ANOVA, $p<0.01$, $F<F_{crit}$, d.f.=11, 535), although an insufficient number (<15) of corals were weighed in some genera and had to be excluded from statistical analysis (Table 9). For example *Goniopora* spp., *Trachyphyllia* spp. and *Caulastrea* spp. appear to be traded in smaller pieces than *Euphyllia* spp., *Lobophyllia* spp. and *Tubipora* spp. According to the data in Table 9 the mean weight of a piece of live coral is considerably less than 0.5kg per piece of massive coral and somewhat less than the 0.25kg per piece of branching corals, defined in the Amendments to Appendices I and II of CITES (Anon., 1989). A single figure of 0.2kg would be more appropriate.

Table 9. The mean weights and dimensions of pieces of live coral in the aquarium trade

	Weight (g)	Height (mm)	Area (cm^2)	n
Euphyllia spp.	170.8 ± 19.3	71.9 ± 3.9	169.6 ± 24.8	114
Goniopora spp.	112.8 ± 28.3	51.5 ± 3.9	138.8 ± 15.3	120
Catalaphyllia spp.	203.4 ± 54.0	56.0	-	9
Trachyphyllia spp.	101.5 ± 15.1	44.9 ± 2.4	121.4 ± 17.0	84
Heliofungia spp.	138.4 ± 45.1	19.1 ± 2.6	192.2 ± 24.4	28
Acropora spp.	180.4 ± 35.0	96.5 ± 10.5	259.2 ± 42.1	27
Plerogyra spp.	206.0 ± 39.0	66.5 ± 1.6	170.7 ± 30.7	24
Lobophyllia spp.	287.4 ± 77.9	75.2 ± 45.0	260.7 ± 66.7	31
Porites spp.	729.5 ± 145.0	72.0 ± 6.6	241.3 ± 81.8	13
Caulastrea spp.	95.7 ± 40.4	74.1 ± 5.9	181.1 ± 54.3	20
Favia spp.	361.1 ± 70.1	54.3	236.0	6
Fungia spp.	159.0 ± 27.8	14.0 ± 2.3	153.4 ± 55.8	36
Montipora spp.	185.2 ± 60.6	68.0	166.0 ± 31.8	8
Pavona spp.	161.1 ± 33.4	67.6 ± 5.5	126.0 ± 37.2	8
Physogyra spp.	232.7 ± 73.8	99.7 ± 10.8	226.9 ± 90.5	16
Seriatopora spp.	214.9 ± 95.9	92.7 ± 17.0	116.8 ± 19.6	6
Tubipora spp.	221.3 ± 79.0	67.5 ± 4.7	338.8 ± 54.7	40
Turbinaria spp.	319.8 ± 138.1	71.2 ± 18.2	230.8 ± 31.9	6
Wellsophyllia spp.	214.8 ± 39.2	42.5 ± 2.8	241.3 ± 28.8	26
All Genera – Maximum	1703.0	144.0	793.2	
All Genera – Minimum	27.8	5.0	4.7	
All Genera – Median	166.4	56.0	154.8	
All Genera – Mean	206.1 ± 13.1	58.6 ± 3.1	180.1 ± 10.1	

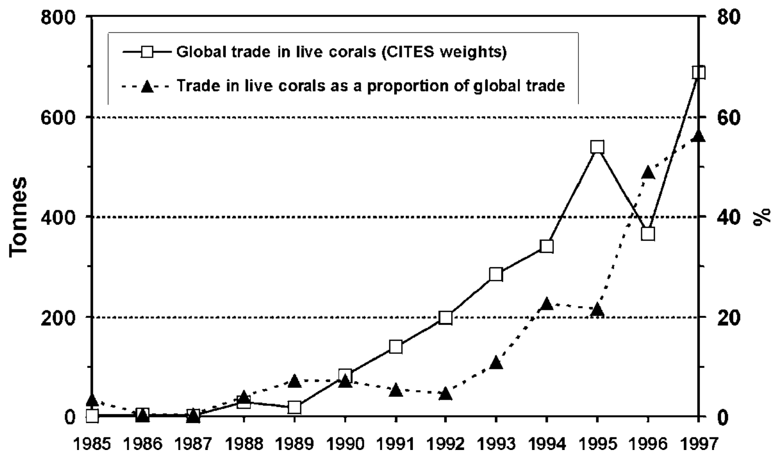
Notes:
Area was calculated as an ellipse from the longest horizontal surface axis and the axis perpendicular to the longest surface horizontal axis. Measurements were obtained from specimens in nine of the top ten genera in the live trade (shaded in order, see Figure 8). Means are given with ± 95% confidence interval.

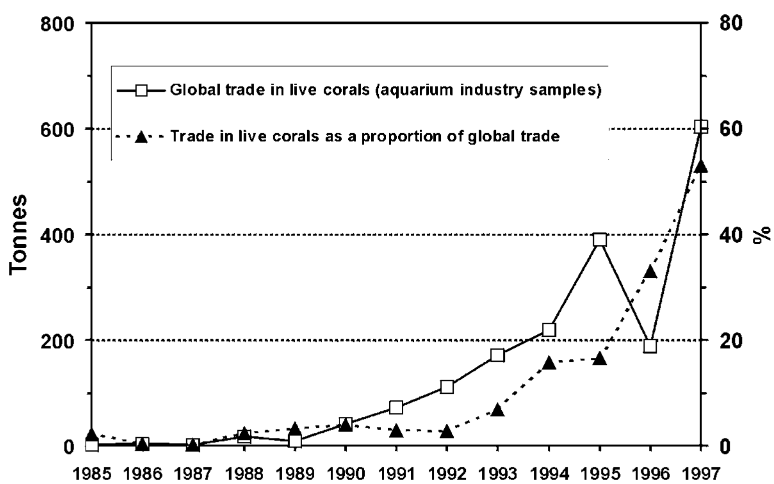
The volume of live coral traded has been calculated as a proportion of global trade in Figure 9. The global trade in live corals was calculated from CITES data in two different ways:

(i) Values of 0.5kg per piece of massive coral and 0.25kg per piece of branching corals, as defined in the Amendments to Appendices I and II of CITES (Anon., 1989) were used to convert transactions which had been recorded in numerical units into units of weight. The global trade in coral was calculated by adding live and dead coral transactions together, and the proportion of the global trade which had occurred in live coral was calculated as a simple fraction (Figure 9a).

(ii) A value of 0.2kg per piece of live coral, from Table 9, was used to convert transactions of live coral which had been recorded in numerical units into units of weight. Global trade was calculated in the same way (i.e. by using the Amendments to Appendices I and II (Anon., 1989) to convert numbers of dead coral to weight of dead coral), and the live trade again calculated as a simple fraction (Figure 9b).

Figure 9. The trend in live coral trade 1985-1997





Notes:

The global trade in live corals was calculated from CITES data in two different ways (a) by using values of 0.5kg per piece of massive coral and 0.25kg per piece of branching corals, as defined in the Amendments to Appendices I and II of CITES (Anon., 1989), and (b) by using a value of 0.2kg per piece of live coral, from Table 9.

The live trade was a small proportion (<5%) of global trade in the 1980s. However, both methods indicate that there has been an order of magnitude increase in live coral trade over the past decade: the 1997 trade in live corals as a proportion of the global trade in all coral is either (i) 56% or (ii) 53% respectively. Calculating trade using a conversion value based on Table 9 did not alter the result to any great extent because a lower estimate of the weight of live coral being traded was compensated by a lower estimate of the global trade in all corals. In both cases the conclusion is clear. The live coral trade has increased greatly during the 1990s to the point where it constitutes about half of all coral trade (Figure 9).

THE MARINE HOME AQUARIUM - THE MARKET FOR CORALS

This dramatic increase in the live coral trade has undoubtedly been driven by the large increase in home aquaria across North America and Europe. At the same time the increase has been made possible with the advent of very fast and frequent airline services between the major markets and exporting countries such as Indonesia and Fiji. A coral may now spend only 30 hours in transit, and transportation times of more than 50 hours are rare (these times refer to export-import delivery time, not time from collection in the wild). Consequently there is now a greater selection of specimens of superior quality for the home aquarist to choose from than in previous years. As aquarium technology has improved throughout the 1990s, and costs fallen, there has been an increase in the number of people setting up coral reef aquaria, typically changing from a freshwater system after a few years. According to industry figures produced by the Pet Industry Joint Advisory Council in 1999, 0.6% of American households maintain almost 622,000 marine aquaria. It would be reasonable to assume that the vast majority, perhaps 90% or 560,000, of these aquaria are tropical. There are also more than 1.1 million tropical freshwater aquaria in the USA.

Selected results of a survey of 683 home aquarists are presented in Table 10. Data on size of aquaria, number of colonies per litre and hard corals as a proportion of all colonies can be combined to estimate the amount of coral being kept in the aquaria of the USA: approximately 6 million pieces (at an average weight of 200g per piece this is 1200t). The corollary of this calculation is that there are also some 18 million colonies of soft corals. The amount of live rock in aquaria of the USA can be estimated in a similar way. It is approximately 50,000t.

CORAL GROWTH RATES AND AGES

The dimensions of pieces of coral in the live trade (Table 9) suggest a preference for corals which are roughly elliptical in surface view, measuring approximately 10 x 6cm in cross section, and about 6mm in height. Corals of this size are more easily handled and are more resistant to the rigours of transportation (Wells *et al.*, 1994), although larger colonies are certainly collected for the live trade (5% of the pieces measured were larger than 10mm in height and 10 x 10cm in cross section). This is in distinct contrast to the Amendments to Appendices I and II of the CITES (Anon., 1989) which assumed the average size of a piece of coral to be 50cm in diameter, though in 1989 there was much less live coral being traded. The trade in

Table 10. Selected results of a survey of 683 aquarists

	USA	GER	ROW
Size of aquarium:			
<100 litres	7	1	6
101-200 litres	22	3	10
201-500 litres	46	37	40
501-1000 litres	18	39	34
>1000 litres	4	19	10
Description of aquarium contents:			
a mixed show aquarium with a variety of invertebrates and fishes	62	76	70
an aquarium where the fishes dominate	8	2	8
an aquarium for clown fishes and host sea anemones	2	3	1
a stony coral aquarium	15	18	13
a soft corals aquarium	8	10	8
other	5	0	2
Material used for structure:			
live rocks	89	79	89
calcareous rocks or other type of rocks	14	50	22
artificial material	2	1	3
dead coral skeletons	6	7	8
Amount of live rock in the aquarium (kg per litre):			
< 0.1	16	50	31
0.1-0.2	38	28	40
0.2-0.3	11	10	13
0.3-0.4	7	3	3
0.4-0.5	5	1	1
>0.5	9	1	2
Number of coral colonies in aquarium (number per litre):			
<0.05	47	70	54
0.06-0.10	17	18	15
0.11-0.15	6	2	3
0.16-0.20	1	0	3
>0.20	3	1	1
Proportion of colonies which were fragments from other colonies:			
none	21	5	13
1-10%	20	18	21
11-20%	10	16	12
21-30%	10	14	10
31-40%	2	8	4
41-50%	5	7	3
Hard corals as a proportion of the corals in the aquarium:			
none	10	8	5
1-10%	10	22	15
11-20%	7	14	11
21-30%	8	10	8
31-40%	4	4	5
41-50%	12	5	6
>50%	23	21	23
Do you have regular access to cultured corals?			
yes	27	7	8
no	49	76	68
If available, would you prefer cultured corals to wild?			
yes	67	74	70
no	8	10	7
If available, would you prefer cultured corals to wild only if they were cheaper?			
yes	14	49	32
no	60	32	46
If available, would you prefer cultured corals to wild only if they were more colourful?			
yes	29	17	20
no	46	64	56

Notes:

USA (n=297), Germany (n=155) and the rest of the world, ROW, (n=231).
Data (%) taken from Fossa and Nilsen (1998a).

dead material does seems to involve larger pieces than the live trade - for example Wells et al. (1994) state that pieces 12-50cm are preferred in the curio trade, and the average size of pieces in an illegal shipment of corals from the Philippines (see Box 1) was 20 x 20cm (±2cm, n = 94). Ross (1984) reported that the average colony size collected for the ornamental coral trade in the Philippines in the late 1970s and early 1980s was 13-18cm in diameter.

In theory it is possible to estimate the age of coral pieces if the growth rate for a particular species is known. However in practice it is difficult because (i) corals with porous skeletons increase in size more rapidly than those with dense structures, and (ii) different environmental conditions can produce tremendous variation in growth rates. Coral growth is affected by temperature, light and depth. There is also considerable difference in growth rate between different species, and corals grow at different rates during their life history, irrespective of these environmental parameters. It is not clear how well measurements of rates taken from colonies on artificial reefs or in aquaria relate to growth rates in the wild under conditions of competition, predation, disease and, in many cases, pollution and sedimentation. Only a few groups of species are sufficiently well understood to make predictions about their age from measurements of size and growth rate: as in many other branches of science research has focused on just a few species, or groups of similar species. Growth rate data is available for only ten of the most frequently traded genera, and of these there are only single measurements for three genera (Table 11). Therefore it is difficult to make general yet meaningful comments about coral growth rates, and predictions of age for pieces of coral of a certain size should be conservative.

Table 11. The growth rates of species in ten genera of commonly traded coral

Most Important Genera in the Live Trade	Linear Growth Rates (cm year^{-1})		Area Growth Rates (cm^2 year^{-1})	
	min	max	min	max
Acropora spp.	2.3	20	19	1404
Catalaphyllia spp.	0.8	15.2	-	-
Euphyllia spp.	4.6	7.9	96.5	-
Fungia spp.	0.8	2.8	2.2	-
Goniopora spp.	1.8	-	-	-
Lobophyllia spp.	1.6	-	-	-
Pavona spp.	2.1	3.4	33.1	561.6
Porites spp.	0.9	2.8	22.9	44
Seriatopora spp.	1.6	6	17.9	53
Tubipora spp.	16	-	-	-

Notes:
Growth rates were taken from Veron 1986, and references cited in Buddemeier and Kinzie, 1976, and Gomez et al. 1985.

Acknowledging these constraints, however, it is possible to estimate roughly the age of corals. It is known that wild corals rarely grow more than 10mm in their first year of life (Harrison and Wallace, 1990). After that the average growth rate for massive corals under optimum conditions, is 10-12mm per year (Buddemeier and Kinzie, 1976). The branches of some species of *Acropora* grow extremely fast (100-200mm per year) but 30-40 mm per year is a more representative rate for finely branching species (Buddemeier and Kinzie, 1976). There is then some considerable variety in the *linear* extension rates, but when *colony* growth is normalised to a standard mean solid radius, this apparent variability is much reduced (Maragos, 1978). On this basis most corals growing under good conditions have an equivalent extension rate of 0.5-1.0cm per year (Kinzie, 1996). Relatively fast growing species have growth rates of 3cm per year diameter increase, or more (UPMSC 1979, 1980, 1982, cited in Ross 1984). These published data would therefore seem to suggest that the 'typical' piece of coral in the live trade, i.e. a piece that has been collected from the wild with mean dimensions similar to the specimens in Table 9, is at least three years old - perhaps one year's growth after settlement to 1 cm in size, then 3-4 years growth to attain a colony of 10 x 6cm in cross section. Some pieces of *Acropora*, for example, may be younger, but many other pieces would possibly be much older. Three years is therefore a reasonable but conservative estimate of the age of the corals which are traded live, while six years would be better for dead corals in the ornamental trade (Ross, 1984).

BOX 1 THE ILLEGAL TRADE IN CORALS

Several large consignments of coral entered the UK illegally during the temporary lifting of the export ban by the Philippines government in 1992. Acting on an anonymous tip concerning a company called Trilcott HM Customs and Excise searched a freighter at Tilbury and discovered 17t of corals from the Philippines described as “driftwood and rock” (Wood, personal communication). Further seizures were made from Trilcott, including another 27t at Tilbury and 53t at Felixstowe. The corals had been harvested quite recently since fresh organic matter was still attached to some of the corals and so the shipments were in clear violation of the regulations permitting trade which were issued solely for the clearance of pre-1986 stockpiles. The trader was fined out of court and the corals confiscated. It is thought that the corals originated from the area around Cebu City (Wood, personal communication) because it was one of the main ports for the export of corals in the late 1980s and early 1990s.

Much of the coral seized in 1992 was distributed to national aquariums, museums and zoos for use in education and displays. Some was ground down for use in aquarium filtration systems. Approximately 20t was donated to London Zoo in July 1992 part of which has been used to construct a public exhibit at the entrance to the aquarium: the remainder is stored.

Over 300 pieces of coral were selected at random from the London Zoo collection. With the exception of *Fungia* spp. each piece had been meticulously wrapped in newspaper by the trader and labelled with trade names (e.g. 'lace coral', 'mushroom coral'). The specimens were from 18 different genera:

Genus	**Number**
Acropora spp.	45
Echinophyllia spp.	2
Euphyllia spp.	1
Fungia spp.	145
Heliopora spp.	6
Lobophyllia spp.	1
Merulina spp.	2
Millepora spp.	9
Montipora spp.	1
Plerogyra spp.	1
Pocillopora spp.	43
Sandalolitha spp.	17
Seriatopora spp.	2
Stylophora spp.	11
Trachyphyllia spp.	1
Tubipora spp.	16
Turbinaria spp.	3
Wellsophyllia spp.	1
Total	**307**

The average weight of these pieces was 580 ± 121g, average dimensions were 20 x 20 ± 2cm, 12 ± 1.5 cm in height (n=94).

These data were obtained in collaboration with Helen Hendry, Department of Zoology, University of Cambridge.

6. THE TRADE IN BLACK CORAL

Species from eight genera were traded (Table 7), the majority being *Antipathes* spp. or *Cirripathes* spp. Problems with coral identification and taxonomy are again suggested by the 47% by weight of transactions which are recorded simply as Antipatharia spp. In fact the species was classified in only 18% by weight of transactions - the rest of the records transactions were recorded as *Antipathes* spp. (25%) or *Cirrhipathes* spp. (10%).

Table 12. Trade links between the largest importers and exporters of black coral

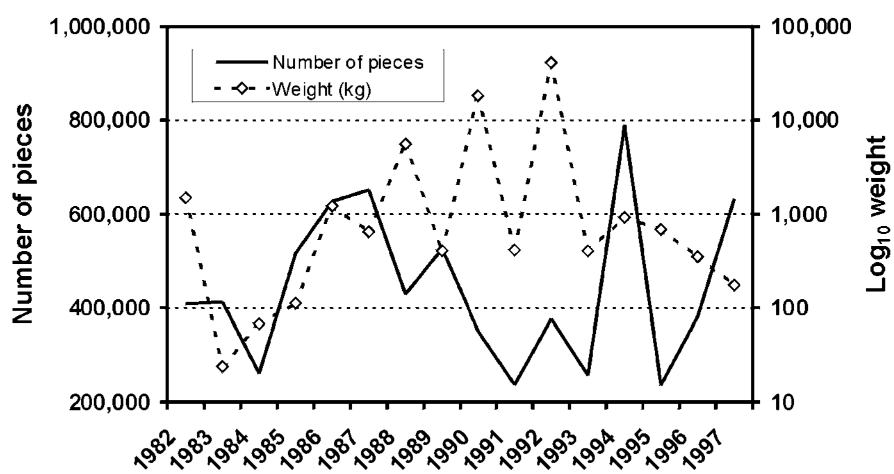
	Trade from exporters recorded as number of pieces (1000s)										Trade from exporters recorded in units of weight (tonnes)						
Importers	Taiwan	Philippines	China	Dominican Republic	Hong Kong	USA	Cayman Islands	Thailand	Mexico	Total (1000s)	Taiwan	Philippines	Dominican Republic	Hong Kong	USA	Cayman Islands	**Total (t)**
USA	5,793	283		13	11		5	7	5	6,117	4	6	0.3	0.1		0.3	10.7
Japan	354	1			0.4	0.5				356	17				0.01		17.01
France	76	0.7								77							
Cuba	235									235							
Korea			40							40							
Germany	0.5	25				0.06				25.6							
Netherlands		15								15							
Greece		9								9							
Cayman Islands	0.1					7				7.1					0.8		0.8
Total	6,458	334	40	13	11.4	7.6	5	7	5	6,881	21	6	0.3	0.1	0.81	0.3	28.5

Notes:
It was not possible to convert between weight and number of pieces for black coral so trade is expressed separately in tonnes and number of pieces traded, as recorded under CITES for the years 1985-1997. A large amount of black coral was traded with permits which did not specify the exporting (14,600 pieces and 421t) or importing nation (9,986 pieces): this is not included in Table 12.

It was not possible to convert between weight and numerical units for black coral: trade data therefore have to be stated separately in tonnes and numbers of pieces. Together they indicate the total traded volume of black coral. A total of 72t and 7,100,000 pieces of black coral were recorded as being traded between 1982-1997. The USA totally dominated this trade importing 14% of those transactions recorded by weight and 82% of those recorded by number of pieces (Table 12). Japan was the next largest importer of black corals (24% of transactions recorded by weight and 5% of those recorded by number of pieces). Although it is interesting to note that countries absent from Table 4 and therefore not active in the hard coral trade, such as Cuba, the Republic of Korea and the Cayman Islands, feature in Table 12, in the global context the amount of coral that they have imported has been negligible. Most of the USA black coral imports came from Taiwan (99% of transactions recorded by number) and the Philippines (55% of transactions recorded by weight).

An average of 430,000 pieces of black coral have been traded internationally per annum since 1982 and trade in pieces of black coral is comparable in the late 1990s to levels in the early 1980s (Figure 10). To calculate a similar average from transactions recorded by weight would not be meaningful because annual totals have varied considerably, occasionally by two orders of magnitude in successive years (1989-1993, Figure 10), from a minimum of 24kg in 1983 to a maximum of 41,213 kg in 1992. The 1997 total was 174 kg.

Figure 10. The annual variation in the global trade in black coral



Notes:

It was not possible to convert between weight and numerical units for black coral: trade data therefore have to be stated separately in kg and numbers of pieces. Together these figures indicate the total trade in black coral. Note that the secondary y-axis is logarithmic.

7. IS CITES AN EFFECTIVE TOOL FOR MONITORING TRADE IN CORAL?

Parties to CITES are obliged under Article VIII, paragraph 6(b), to identify specimens to the species level. With species being identified in a very small proportion (2% in 1997) of records there is a widespread failure to fulfil this obligation for corals. Reasons can only be inferred but a predominance of coral derived products such as gravel, sand and rock in the trade is unlikely to cause this situation. Transactions in materials which are clearly derived from corals, but where more precise identification is impossible, are frequently recorded as Scleractinia spp. However, while this type of transaction may be significant in terms of the weight of material being exported (46%), they constituted a minority of records (in 1997). Therefore it does not seem that Scleractinia spp. is being used as a general option when closer identification is problematical. Instead the failure to record species is most likely symptomatic of the very real difficulties in identifying coral species, *per se* (Box 2). This is apparent in genera such as *Porites* spp. with many closely related species only distinguishable by close examination of the structure of the coral skeleton (Table 13).

Table 13. The number of coral species per genus recorded in the CITES Trade Database compared with the number of coral species per genus listed in CITES Appendix II

Fifteen most traded genera of coral (after Figure 7)	Percentage of records which are identified to species	Number of coral species recorded in CITES Trade Database	Number* of coral species listed in CITES Appendix II
Fungia spp.	12	5	25
Pocillopora spp.	35	12	19
Porites spp.	5	6	70
Acropora spp.	40	69	165
Euphyllia spp.	30	7	10
Goniopora spp.	9	5	34
Heliopora spp.	26	1	1
Catalaphyllia spp.	28	4	4
Tubipora spp.	27	1	1
Seriatopora spp.	19	3	7
Trachyphyllia spp.	7	1	1
Pavona spp.	23	9	24
Heliofungia spp.	11	1	1
Platygyra spp.	15	8	8
Lobophyllia spp.	9	4	6

Notes:
*Source of data WCMC (1999).

Surprisingly, more species are identified in the genus *Acropora* than any other even though the taxonomy of *Acropora* is particularly difficult. Identification keys do exist but have been typically produced for a scientific audience orientated towards research (e.g. Wallace and Wolstenholme, 1998). Less technically demanding, more general, keys also exist but are rarely complete. The CITES Identification Manual (CITES, 1984) implicitly recognises this issue in that only five corals are identified to species, including the two unusual species *Tubipora musica* and *Heliopora coerulea*. However, despite being relatively easily identifiable, and the only species in their genera, just a quarter of CITES records for *Tubipora musica* (bright red skeleton consisting of a mass of vertical tubes connected by horizontal plates) and *Heliopora coerulea* (distinctive blue coloured skeleton with a smooth surface perforated by pits of two sizes) were completed to the species level (Table 13). In total the CITES Identification Manual describes 5 species and 17 genera. With over 2000 species listed under Appendix II (WCMC, 1999) and approximately 120 genera being traded CITES does not therefore appear to be effective in monitoring trade in individual species of coral. As a consequence it is not possible to be sure whether species of coral listed under Appendix II but not recorded in the CITES Trade Database (Table 13) are not being traded or whether they are being misidentified.

However the response of the international coral trade to events affecting it can be detected using CITES trade data at the generic level. For example, the FDA gave approval for skeletal material from *Goniopora* spp. and *Porites* spp. to be used in clinical trials for bone grafts in 1992. This is clearly seen in the CITES records - the volume of dead *Goniopora* and *Porites* imported to the USA for biomedical purposes increased 500% from 1991 to 1992. Similarly CITES permits began to be used more commonly for coral sand, gravel and rock following several prosecutions in the early 1990s for importing undeclared coral derived material. This material is normally labelled as Scleractinia spp. and is imported in bulk. The effect of this change in habit is clearly detectable in the CITES trade data which reveal that the total quantity of Scleractinia spp. shipments increased from an average of 13kg per year between 1986-1989 to 1829kg in 1991. The ability to detect changes which are attributable to factors such as these indicates that CITES trade data are effective in monitoring international trade in coral, albeit at taxonomic levels higher than the species level (but see Box 3).

BOX 2 PRACTICAL ASPECTS OF IDENTIFYING CORAL SPECIES

CITES requires Parties to the Convention to identify corals to species on permits yet in the overwhelming number of cases the practice is to record taxon as genus only. This is certainly a result of many factors, but the sheer number of species (2000+), the availability and accessibility of identification guides, the familiarity with taxonomic terminology which is required to use existing guides effectively and the time necessary to identify a coral specimen to species are probably the most significant.

The practicalities of identifying species in a coral genus which is important in both the dead and live trade was illustrated using specimens of *Acropora* spp. This is a highly speciose genus with 368 nominal species and an unknown number of true species. Branched growth forms are common but show enormous variety even within species. Massive or encrusting forms are rarely found. *Acropora* is characterised by its mode of growth, in which a central or axial corallite extends and buds off subsidiary or radial corallites. The axial corallites are often larger and positioned at the end of branched forms (in many cases this makes the identification of the genus relatively easy) or scattered over the rarer lobed or semi-massive forms. The identification of *Acropora* species requires the determination of the growth form of the specimen (ten growth forms are recognised) and detailed microscopic observations of:

(i) The arrangement and form of the axial and radial corallites, their size and orientation and the shape of the septa. Thirteen categories of corallite shape are recognised.

(ii) The texture of the coenosteum on the radial and axial corallites and inter-corallite areas. The coenosteum is the skeletal material between the corallites and in *Acropora* is also the wall of the axial corallite, due to the nature of budding of new corallites.

A recent and comprehensive guide to the genus exists in the scientific literature (Wallace and Wolstenholme, 1998) and was used to identify nine specimens, and the time recorded:

Acropora digitifera (Dana, 1846)	25 minutes
Acropora pulchra (Brook, 1891)	20 minutes
Acropora millepora (Ehrenberg, 1834)	20 minutes
Acropora florida (Dana, 1846)	8 minutes
Acropora subulata (Dana, 1846)	35 minutes
Acropora nasuta (Dana, 1846)	30 minutes
Acropora cerealis (Dana, 1846)	30 minutes
Acropora solitaryensis (Veron & Wallace, 1984)	35 minutes
Acropora palifera (Lamark, 1816)	15 minutes

The nine specimens took a total time of 3 hours 38 minutes to identify to species. By way of illustration approximately 63,000 pieces of *Acropora* spp. were imported into the EU in 1997. Clearly there will never be enough human resources available to identify coral to species with a worthwhile degree of accuracy.

These data were obtained in collaboration with Helen Hendry, Department of Zoology, University of Cambridge.

BOX 3 PRACTICAL ASPECTS OF IDENTIFYING CORAL GENERA

The CITES Trade Database provides very limited information on coral species, but genus is well recorded (83% of records in 1997 and 47% by weight between 1985-1997). However the identification of coral genera is still far from straightforward, and it would be fair to say that it is probably quite challenging for people without particular experience in coral taxonomy, e.g. customs personnel responsible for checking the contents of shipments against CITES export and import permits.

The ability of non-specialists to identify coral genera accurately was tested experimentally. Two replicate experiments were carried out in which a total of 32 volunteers, half of whom had a graduate level zoological background, were asked to identify dead specimens from 10 genera of corals. Four identification guides were used:

(i) Corals of Australia and the Indo-Pacific (Veron, 1986). This is a substantial volume with photographs and descriptions of over 700 live and dead corals mostly to species level, without a key.

(ii) Corals of the Indian Ocean CD-ROM (Sheppard, 1998). This is a CD ROM containing a scrollable list of over 100 coral species with short description and one to several pictures of whole specimens and polyp detail. Most pictures are of live corals.

(iii) Corals of the World (Wood, 1983). This book has photographs of over 80 live and dead corals from the Caribbean and Indo-Pacific with description to genus level only, with a key.

(iv) The CITES Identification Manual (CITES, 1984). This guide does not include photographs but has clear line drawings and descriptions of 17 genera of corals. Descriptions of species are very limited, except for five genera that are mono-specific.

The experiment was designed so that equal numbers of zoological and non-zoological volunteers used one of these guides to identify all specimens. The accuracy of the volunteers, expressed as a score achieved from a maximum of eight, is tabulated below:

	CITES, (1984)	**Wood, (1983)**	**Sheppard, (1998)**	**Veron, (1986)**	**Total (out of 32)**
Fungia spp.	8	5	6	7	26
Acropora spp.	5	6	8	6	25
Tubipora spp.	8	4	5	5	22
Millepora spp.	5	8	3	2	18
Pocillopora spp.	8	4	1	4	17
Sandalolitha spp.	0	7	5	3	15
Halomitra spp.	5	6	2	0	13
Merulina spp.	5	3	4	1	13
Lobophyllia spp.	5	0	1	1	7
Hydnophora spp.	0	1	1	2	4
Total (out of 80)	49	44	36	31	

Zoologists were not more successful at identifying genera than those people without a zoological background (Wilcoxon paired sample test: $T\_ > T_{0.05\ (2)\ 16}$, see p. 167, Zar 1996). However the accuracy of a volunteer (irrespective of background) using any guide was not the same across all genera (Freidman analysis of variance by ranks: $X^2_r > X^2_{r\ 0.05,10,4}$, see p. 267, Zar, 1996). The identification accuracy of volunteers in identifying genera irrespective of the guide used, and the accuracy achieved with each guide irrespective of specimen, was tested (non-parametric Tukey type multiple comparisons, see p. 226, Zar 1996). Values of q for the genera comparison are tabulated below (significant differences, where $q > q_{0.05}$, are shaded):

	Acropora spp.	*Tubipora* spp.	*Millepora* spp.	*Pocillopora* spp.	*Sandolithia* spp.	*Halomitra* spp.	*Merulina* spp.	*Lobophyllia* spp.	*Hydnophora* spp.
Fungia spp.	0.128	0.962	1.668	1.989	2.224	2.481	2.695	4.670	4.856
Acropora spp.	-	0.834	1.540	1.860	2.096	2.352	2.566	4.571	4.597
Tubipora spp.	-	-	0.706	1.026	1.262	1.518	1.732	2.737	4.393
Millepora spp.	-	-	-	0.321	0.556	0.813	1.026	2.032	2.588
Pocillopora spp.	-	-	-	-	0.235	0.492	0.706	1.711	2.267
Sandolithia spp.	-	-	-	-	-	0.257	0.470	1.476	2.032
Halomitra spp.	-	-	-	-	-	-	0.214	1.005	0.556
Merulina spp.	-	-	-	-	-	-	-	1.005	1.561
Lobophyllia spp.	-	-	-	-	-	-	-	-	0.556

A significantly higher accuracy was therefore achieved for *Fungia, Acropora* and *Tubipora* spp. than for *Hydnophora* spp. *Fungia* and *Acropora* spp. were also identified more accurately than *Lobophyllia* spp. Values of q for the guide comparison are tabulated below (significant differences, where $q > q_{0.05}$, are shaded):

	Wood, (1983)	Sheppard, (1998)	Veron, (1986)
CITES, (1984)	1.799	2.746	3.937
Wood, (1983)	-	0.947	2.137
Sheppard, (1998)	-	-	1.190

The only significant difference in accuracy was between the CITES guide and Veron (1986). This difference can be readily explained. Eight of the ten genera used in this experiment were included in the CITES guide which includes so few genera in total that the probability of misidentification was lower. The identification accuracy for the two genera not included in the CITES guide (*Sandalolitha* and *Hydnophora* spp.) was, not surprisingly, zero for those volunteers using it. Furthermore it was not possible to include live specimens in the experiment. The line drawings in the CITES guide are ideal for identifying dead specimens but the majority of the photographs in Veron (1986) are of live corals, *in situ*.

The experiment indicates that the identification of genera is indeed challenging for non-specialists, with only three genera, *Fungia*, *Acropora* and *Tubipora* spp. being identified to more than 67% accuracy (and the latter is monospecific and highly distinctive). Despite differing in format and content the use of any one guide did not affect accuracy significantly. The content of the CITES guide needs to be broadened to include at least those genera most prevalent in trade, and any guide designed to assist identification of traded corals should contain both line drawings of skeletal detail, growth forms and photographs of living colonies and polyps.

These data were obtained in collaboration with Helen Hendry, Department of Zoology, University of Cambridge.

8. THE IMPACT OF TRADE ON CORAL REEFS

The USA imported an average of 200t of coral per year in the 1960s, 440t per year in the 1970s and 350t per year from 1980-1985 (source US Customs statistics presented in Wells and Wood, 1989). Though estimates of 48,000t of coral per year (Rubec 1988, cited in Cesar, 1996) being collected for the ornamental trade must be erroneous, Mulliken and Nash (1993) estimated that the Philippines had exported 13,000t of coral since 1960. Estimates of the amount of coral being harvested on the Great Barrier Reef, about 50t year per year, go back to the late 1970s (Garrett, 1977 cited in Oliver and McGinnity, 1985). Clearly the coral trade is not a new phenomenon and sufficient time has passed to observe the long term effects of collecting corals for trade.

Grigg (1976) estimated the effect of commercial collection by comparing undisturbed and harvested populations using a mathematical model of population dynamics. For slow growing species of precious corals population changes and reduced abundance were described by him as being inevitable (Grigg 1977). The most thorough attempt to quantify the effect of collection in the field was carried out by Ross (1984) who compared coral community parameters at two sites, one heavily harvested, off Cebu in the Philippines. Driven by a market demand for large, mature colonies for the ornamental trade collection had resulted in a reduction in coral density (31%) and percent coral cover (64%) on the lower reef crest (Ross, 1984). *Seriatopora* spp., common in the area, were completely absent from the harvested site, and the population structure of one species, *Pocillopora verrucosa*, had been altered by the extraction of large, sexually mature colonies to consist predominantly of small, juvenile colonies (Ross, 1984).

So, not surprisingly, the intense extraction of corals at a particular location can profoundly alter the community structure. However, as Figure 3 clearly shows, the Philippines is no longer an important exporting nation having been superseded by Indonesia in the early 1990s. An analogous study to Ross, 1984 has not been carried out for Indonesia but the same effects are likely to occur in places where collection is concentrated in a small area. This is especially likely to be the case in the collection of live corals which are usually gathered from reefs no more than a day's easy travel from an international airport (dead corals are usually shipped by sea). In this sense Table 6 is slightly misleading as it assumes collection to have occurred uniformly over the entire reef area. A more realistic calculation might have considered the quantity of live coral as having come from the area of reefs within, say, 50-100km of international airports. Bentley (1998) compared the live and dead (ornamental) coral trade in Indonesia with other extractive and destructive practices, namely the mining of reefs for construction material and the production of lime from burning coral. Historically the amount of coral mined for construction in the Jakarta area has been estimated at between 10,000-25,000m^3 per year (Polunin, 1983) which equates to 15,000-37,500t at an intermediate skeletal density of 1.25g per cm^3 (for measurements of density see Bosscher, 1993). Bentley (1998) estimated the quantity of coral being mined nowadays to be no more than 5000t annually. Data on the production of lime from coral are patchy, but the best documented case study is from West Lombok where 60 families produce six hundred 25kg bags of lime per year (Cesar, 1996), an annual total of 900t which necessitates the collection of approximately 1600t of coral. Considering that Indonesia has never exported more than 2000t of coral (Figure 4) it is clear that there are processes extracting considerably more coral there than either the live or ornamental trade. Elsewhere, the amount of coral mined in a single year for construction in the Maldives, where other building materials are particularly scarce, is 20,000m^3 (Brown and Dunne, 1988) or 25,000t at an intermediate skeletal density of 1.25g per cm^3 - more than all the coral traded since 1985.

In a similar vein dynamite fishing is having a major impact on coral reefs in Indonesia and has increased dramatically over recent years. Cesar (1996) conservatively assumed a bombing rate of one bomb per day per km^2 which, over a reef area of 41,960km^2 (Spalding and Grenfell, 1998), equates to a total of 15 million bombs per year. If each bomb destroyed only 1kg of coral then the amount of coral killed annually in this manner would be approximately ten times that exported from Indonesia each year during the 1990s. Unfortunately over exploitative and destructive fishing practices are not the only pressure on coral reefs. Fifty-eight percent of the world's reefs are threatened by human activity ranging from coastal development, marine pollution, sedimentation and eutrophication from inland deforestation and farming (Bryant *et al.*1998). In comparison with these factors, and climate change, the adverse but localised effects of the international coral trade are tiny.

9. THE ECONOMICS OF THE LIVE CORAL TRADE

Generally foreign companies wishing to import coral place orders with national collecting agents whose stock is priced and sold free-on-board (FOB). The free-on-board price is the cost of a single specimen, and excludes any transportation, packaging and taxation costs which are incurred additionally by the importer. The free-on-board price (Table 14) is therefore particularly useful in an economic analysis of the international trade because it represents the revenue to exporters in the country of origin generated by the sale of a piece of coral.

Table 14. The 1999 free-on-board prices of single pieces of live coral from Indonesia

	Minimum	**Maximum**
Euphyllia spp.	2.50	7.00
Goniopora spp.	2.25	2.50
Catalaphyllia spp.	4.00	25.00
Trachyphyllia spp.	2.00	6.00
Heliofungia spp.	2.25	3.50
Acropora spp.	8.00	11.50
Plerogyra spp.	3.00	6.00
Lobophyllia spp.	2.25	3.50
Nemenzophyllia spp.	3.50	5.00
Porites spp.	2.00	7.50
Blastomussa spp.		6.50
Cynarina spp.	2.25	5.00
Favia spp.	2.00	2.50
Fungia spp.		2.25
Galaxea spp.	2.00	5.00
Herpolitha spp.		2.00
Hydnophora spp.		6.50
Merulina spp.		11.50
Physogyra spp.	3.00	6.00
Pocillopora spp.		11.50
Polyphyllia spp.		2.25
Scolymia spp.		9.50
Seriatophora spp.		11.50
Symphyllia spp.		2.00
Tubastrea spp.	2.25	5.00
Tubipora spp.		5.00
Turbinaria spp.		2.50
Mean	2.30	5.68

Notes:
The ten genera most frequently traded live (Figure 8) are shaded. Prices are in US$.

Typically, the country of origin is a developing tropical nation and the free-on-board price is payable in hard currency, usually US dollars. Table 14 lists the 1999

Indonesian free-on-board prices for all the major genera in the live coral trade, and can be considered to be reasonably representative given the dominance of that country in the global trade. The revenue flowing from developed to developing nations as a result of the international trade in corals can be estimated by combining the prices in Table 14 with the volume of trade in each genus.

Catalaphyllia spp., *Acropora* spp., *Merulina* spp., *Seriatophora* spp. and *Pocillopora* spp. are the most expensive corals. The former is relatively rare, and therefore may be more expensive to collect, and the others are delicate, highly branched, corals which require careful collection and handling techniques. Species in other genera cost just a few dollars each and Table 14 suggests that the mean FOB price for a piece of coral is between US$2-5. In practice though the price of a piece of coral varies not only according to the species, but also its size and colour, and so it is difficult to be precise about the cost of a typical piece of *Acropora* spp., for example. The average price of a piece of coral imported to the USA was US$ 2.04 between 1997-1999 (World Trade Atlas, 1999) which may suggest that the majority of corals are traded at low FOB prices. However, the range of revenue generated by exporting coral reef nations can be estimated by using the maximum and minimum free-on-board prices.

The value of the international trade in coral to exporting nations has increased dramatically over the 1990s (Figure 11a), mirroring changes which are evident in Figure 9. In 1997 the international trade in live coral generated between $2.8 - 7.4 million in revenue, depending on whether minimum or maximum free-on-board prices were used in the calculations, respectively. It therefore seems reasonable to state that the global trade in live coral sees a sum of approximately $5 million pass from developed importing nations of the northern hemisphere (primarily the countries in Figure 1) to developing exporting nations of the tropics (primarily the countries in Figure 2).

However these calculations may contain a bias which has its cause in the CITES data and the transactions (29% in 1997) involving live coral which recorded the taxon as Scleractinia spp. The database records in 1997 indicate that the mean weight of these transactions (332 ± 34kg, n= 1,691) is two orders of magnitude greater than those transactions in which taxon is recorded to at least the generic level (9 ± 1kg, n= 29,967). One explanation for this discrepancy in mean weight is that the Scleractinia spp. transactions were large shipments of coral rubble and coraline algae, destined to be used in aquaria as live rock. Live rock is so called because it is collected from the wild and is colonised by bacteria and algae. Aquarists consider live rock to be the healthiest and most beneficial (to aquarium organisms) means of biological filtration. It is also the material most commonly used to provide a structural framework to the aquarium and living space for some reef fish and invertebrates (Table 10). Although it is not possible to be absolutely certain that Scleractinia spp. is not being used as a general term where more accurate identification is difficult, or to describe a shipment of mixed coral species, this is unlikely because it is difficult to know how else such amorphous material, which is obviously derived from coral, could be described. The term live is probably reliable as it implies that the specimens were shipped wet or moist.

Indonesia and Fiji were the largest exporters of live Scleractinia spp. between 1985-1997, accounting for 37% and 35% of the global trade (1561t) respectively. The next largest supplier was the Marshall Islands with 10%, 154t, over the same period. However in 1997 Fiji recorded exports of live Scleractinia spp. totalling 386t (86% of the international trade in live Scleractinia spp. in that year) whereas Indonesia recorded only 9t. Fijian live rock sold for $3.2 per kg free-on-board in 1999, and is usually supplied in boxes of 20kg. In the USA live rock is sold to aquarists by weight, for between $5.5-11 per kg, depending on the amount of curing (a process which preserves the bacteria, coralline algae and other beneficial organisms associated with live rock, such as clams, sponges, starfish and snails, while eliminating potentially harmful organisms such mantis shrimp and bristle worms). The aquarium supply companies surveyed in Table 16 only offered live rock from Fiji.

The previous financial calculations, which produced Figure 11, assume that all live Scleractinia spp. transactions were live corals of species not in the ten most traded genera. If instead we assume that all live Scleractinia spp. transactions were indeed live rock, then the calculations can be refined to take into account the different free-on-board price of live rock. This requires the relative amounts of (i) species in the ten most traded genera, (ii) species in other genera, and (iii) live rock (live Scleractinia spp.) to be known. All these can be derived from the CITES database.

Doing so produces a slightly tighter estimation of the revenue accruing to reef nations from the international trade in corals, i.e. the difference between the maximum and minimum revenue is reduced (Figure 11). If we assume that all the trade in live Scleractinia spp. to have been trade in live rock then the revenue which flows from importing nations to exporting nations was between $2.8-6.8 million in 1997. It must be stressed, however, that there is no direct evidence that live rock is indeed recorded as Scleractinia spp., and that in any case making this assumption does not appreciably change the estimated value of the global trade in coral of $5 million in 1997.

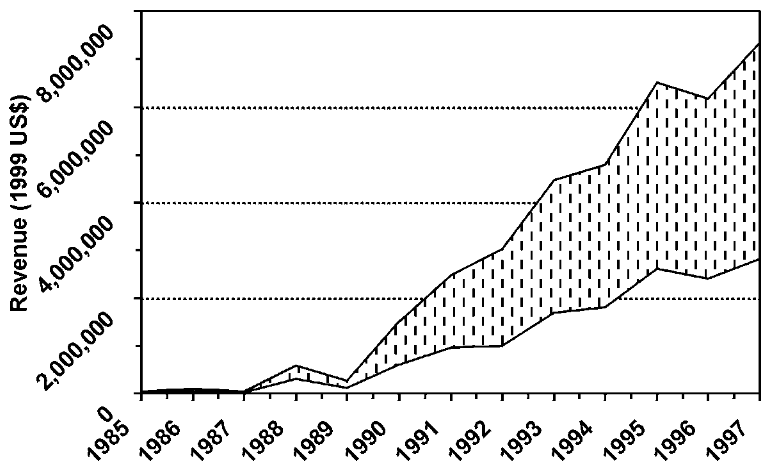
Table 15. The value to exporting nations of different genera in the live coral trade, as percentages

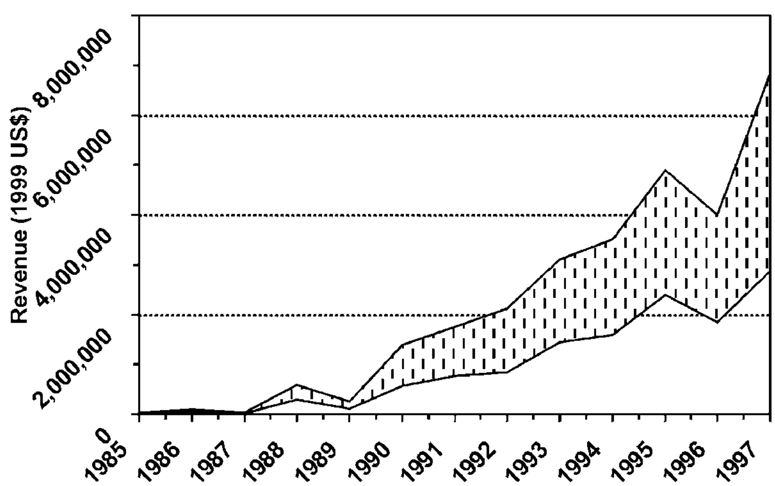
	Minimum FOB	Maximum FOB
Acropora spp.	14	8
Catalaphyllia spp.	7	18
Euphyllia spp.	5	6
Goniopora spp.	4	2
Heliofungia spp.	2	1
Lobophyllia spp.	2	1
Nemenzophyllia spp.	1	1
Plerogyra spp.	3	3
Porites spp.	1	2
Trachyphyllia spp.	3	4
Species in other genera	49	51
Live rock	9	4

Notes:
Minimum and maximum FOB refer to whether minimum or maximum free-on-board prices were used to estimate revenue.

Although more *Euphyllia* spp. and *Goniopora* spp. are traded than any other genus (Figure 8) their value to exporting nations as a proportion of the live coral trade is relatively low at 5-6% and 2-4 % respectively (Table 15). *Catalaphyllia* spp. and *Acropora* spp. are traded in lesser quantities but are more valuable to coral reef nations by virtue of their higher free-on-board price. Approximately half of the revenue to exporting nations is derived from species in genera other than those represented in Figure 8 and live rock accounts for 4-9% of income earned through the live coral trade (Table 15).

Figure 11. The value of the international trade in live coral in terms of the revenue in 1997 US dollars accruing to exporting nations





Notes:

Revenue is calculated in two ways: (top) assuming that all records of live Scleractinia spp. involved corals of species not in the ten most traded genera, and (bottom) assuming that all records of live Scleractinia spp. describe shipments of live rock. See text for further discussion.

Table 16. The average retail prices in US dollars for 805 pieces of live coral from seven retail outlets in the USA in 1999

Genus	S	M	L	U	Genus	S	M	L	U	Genus	S	M	L	U	Genus	S	M	L	U
Acropora spp. (66)	40	53	73	105	***Caulastrea*** spp. (18)	26	32	37	55	***Merulina*** spp. (3)	80	100	125		***Psammocora*** spp. (3)	50	70	110	
Catalaphyllia spp. (33)	37	53	78		***Cynarina*** spp. (13)	27	34	41	38	***Millepora*** spp. (3)	60	80	100		***Oxypora*** spp. (9)	24	28	37	
Euphyllia spp. (87)	22	28	33		***Diploastrea*** spp. (3)	20	25	35		***Montipora*** spp. (17)	41	54	75	45	***Scolymia*** spp. (18)	28	32	42	48
Goniopora spp. (33)	26	30	36		***Diploria*** spp. (3)	19	24	31		***Mycedium*** spp. (4)		50	78		***Seriatopora*** spp. (16)	30	40	52	
Heliofungia spp. (18)	25	33	38		***Favia*** spp. (30)	25	31	41	58	***Pachyseris*** spp. (12)	29	44	52		***Stylaster*** spp. (3)	25	30	35	
Lobophyllia spp. (43)	23	32	37		***Favites*** spp. (20)	22	26	32	47	***Pavona*** spp. (9)	35	45	56		***Stylophora*** spp. (15)	36	50	65	
Nemenzophyllia spp. (12)	27	32	38		***Fungia*** spp. (21)	30	38	35		***Pectinia*** spp. (12)	31	43	54		***Symphyllia*** spp. (12)	31	39	47	
Plerogyra spp. (30)	23	31	39		***Galaxea*** spp. (12)	30	37	48		***Pocillopora*** spp. (12)	33	43	53		***Tubastraea*** spp. (30)	24	31	38	
Porites spp. (28)	31	45	63	48	***Heliopora*** spp. (9)	26	33	39		***Physogyra*** spp. (6)	34	47	68		***Tubipora*** spp. (15)	24	29	34	
Trachyphyllia spp. (30)	26	38	41		***Herpolitha*** spp. (3)	40	60	80		***Platygyra*** spp. (12)	33	45	52		***Turbinaria*** spp. (24)	29	37	45	
Blastomussa spp. (12)	36	49	59		***Hydnophora*** spp. (22)	41	55	71		***Polyphyllia*** spp. (24)	26	32	39						

The price of a 'typical' piece of live coral from the ten most traded genera

	S	M	L
Minimum	22	28	33
Maximum	39	53	78

The price of a 'typical' piece of live coral from other genera (*Blastomussa - Turbinaria* spp.)

	S	M	L
Minimum	19	24	32
Maximum	71	80	100

Notes:

The ten genera most frequently traded live (Figure 8) are shaded.

S = small, M = medium, L = large and U = unspecified size. The number of coral in each genus is given in parentheses.

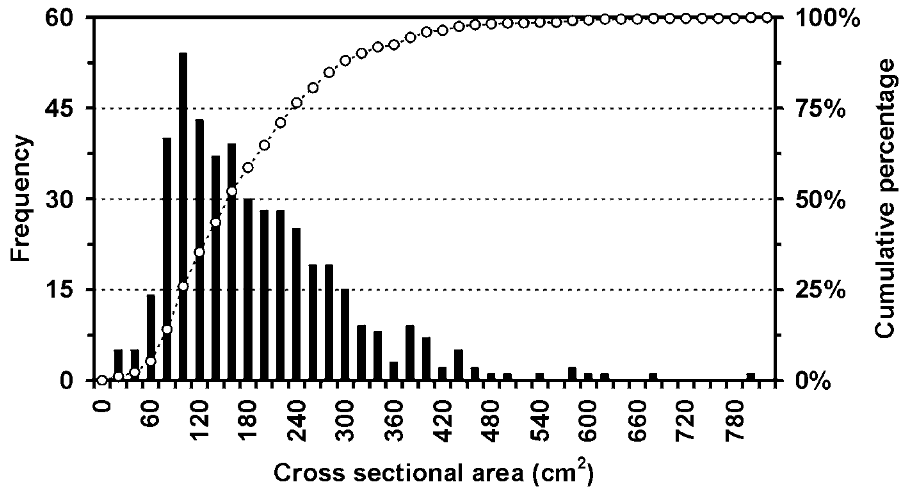
Table 17. The retail prices in pounds sterling of 73 pieces of live coral in the UK in 1999

Price in £	S	M	ML	L	XL	U
Acropora spp.						8-11.5
Blastomussa spp.						6.5
Catalaphyllia spp.	4-10	12		14	25	
Caulastrea spp.	3.5		6.5			5-6.5
Cynarina spp.						2.25-5
Euphyllia spp.	2.5-5		5-7			
Favia spp.						2
Favites spp.						2.5
Fungia spp.						2.25
Goniopora spp.						2.25-2.5
Galaxea spp.						2-5
Heliofungia spp.						2.25-3.5
Herpolitha spp.						2
Hydnophora spp.						6.5
Lobophyllia spp.						2.25-3.5
Merulina spp.						11.5
Nemenzophyllia spp.	3.5		5			
Physogyra spp.	3		5			6
Plerogyra spp.	3		6			6
Pocillopora spp.						11.5
Polyphyllia spp.						2.25
Porites spp.	4.5	6		7.5		2
Scolmyia spp.						9.5
Seriatopora spp.						11.5
Symphyllia spp.						2
Trachyphyllia spp.	3		4.5-6			2
Tubastrea spp.	2.25	3.5		5		5
Tubipora spp.						3
Turbinaria spp.						2.5

Notes:
S = small, M = medium, ML = medium large, L = large, XL = extra large and U = unspecified size. Data source was the Ornamental Aquatic Trade Association, UK.

A survey of seven companies in North America selling live coral was conducted in February 1999. Corals appear in the catalogues of companies which supply organisms for the home aquarium, and are usually listed by species or genus, and by size and colour. Prices among the ten most traded genera do not show much variation - *Acropora* and *Catalaphyllia* spp. are again slightly more expensive for a given size, presumably for the reasons previously given - and prices do not seem to vary widely between different suppliers (Table 16). A superficial survey of retail prices in the UK suggested that corals may be sold more cheaply than in the USA at about £4.50 ($8) a piece (Table 17). Given the relative sizes of the USA and UK markets (Figure 1) the prices in the former were taken as being the most representative of the global trade.

Figure 12. Size-frequency distribution of corals in the live trade



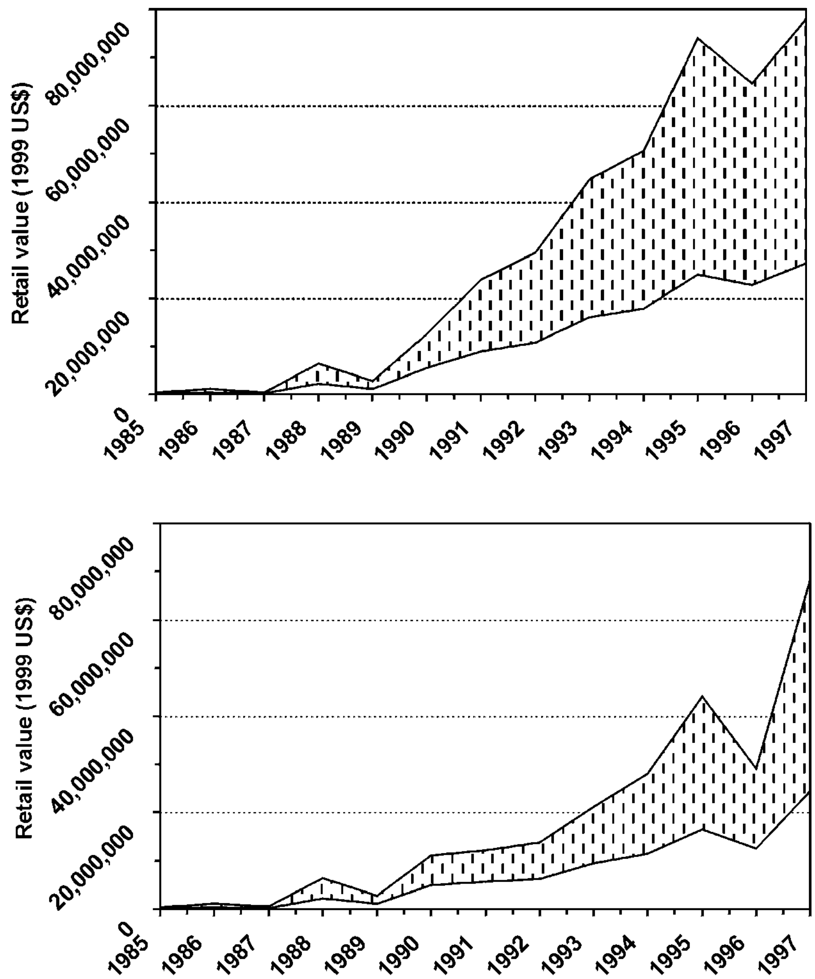
Notes:

Data taken from the specimens measured at two wholesale marine aquarium companies, and summarised in Table 9. Ignoring small groups of specimens which are either very small or very large then small corals (between 60-120 cm^2) constitute 25% of trade, medium corals (between 120-340 cm^2) constitute 65% and large corals (between 340-540 cm^2) constitute 10%.

The variation in retail price with size poses a problem when trying to calculate the retail value of the international trade in live corals because it is necessary to have some understanding of the relative amounts of different sized pieces being sold. This can be obtained if the sample of live corals in Table 8 are assumed to be globally representative: the size data can be used to determine the proportion of 'small', 'medium' and 'large' pieces in the international trade. Ignoring small groups of specimens which are either very small or very large it would appear that 'small' corals (between 60-120 cm^2) constitute 25% of trade, 'medium' corals (between 120-340 cm^2) constitute 65% and 'large' corals (between 340-540 cm^2) constitute 10% (Figure 12). These quantitative definitions of size are somewhat arbitrary because the classification of coral pieces for sale is undoubtedly qualitative, but they are reasonable estimates based on the size frequency distribution of a large number of live corals from different sources (Figure 12).

The total retail value of the live coral trade can then be estimated by combining the size frequency of traded corals, the maximum and minimum retail value of 'typical' pieces (Table 16) and the quantities traded (from the CITES database). Doing so reveals that the retail value of the international trade in live corals has quadrupled during the 1990s (Figure 13) and generated between $27-78 million in sales in 1997. The range occurs depending on whether the minimum or maximum retail prices are used, and the actual retail value of the trade lies between the two. Similarly the figures can be adjusted to take into account the trade in live rock: if all records of live Scleractinia spp. are assumed to be live rock then the retail value of the trade in 1997 was between $24-68 million (Figure 13).

Figure 13. The retail value in 1997 US dollars of the international live coral trade between 1985 and 1997



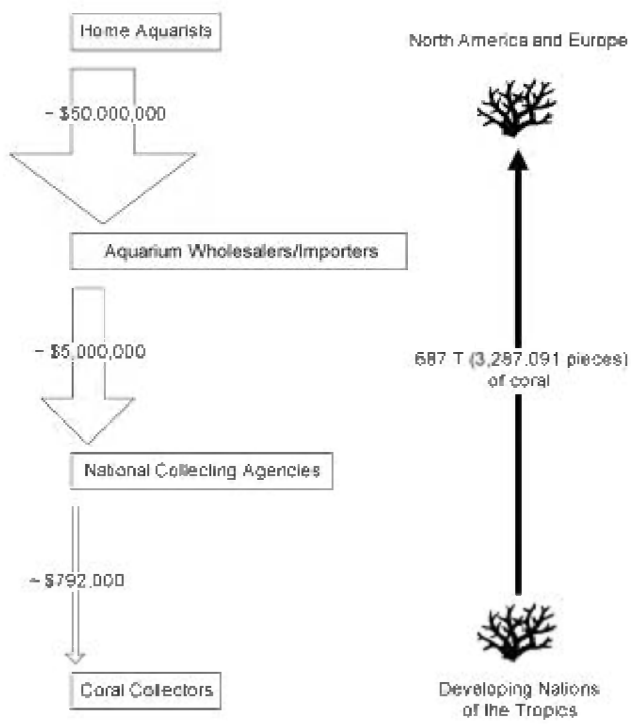
Notes:

Retail value is calculated in two ways: (top) assuming that all records of live Scleractinia spp. involved corals of species not in the ten most traded genera, and (bottom) assuming that all records of live Scleractinia spp. describe shipments of live rock. See text for further discussion.

Either way, at a first approximation, during the 1990s the international trade in live corals generated increasing amounts of revenue to those tropical nations exporting coral, who received $5 million (in 1999 US$) in 1997. This was converted into approximately $50 million (in 1999 US$) of sales, primarily in the markets of North America and Europe.

The sums in Figure 11 are estimates of the annual income of national coral collecting agents who are the point of contact for foreign importers. In socio-economic terms it is equally important to calculate the proportion of this revenue which passes down the supply chain to people in coastal communities, whose welfare is highly dependent on the reefs which supply the corals. This can be done if an important assumption is made. Fishermen collecting corals for the ornamental trade from the waters around Cebu city, which was once the centre of the Philippines trade in corals, were paid US$0.20 per piece of coral in 1983 (Ross, 1984). These fishermen were collecting 28 species of 17 genera, many of which are still important in the global live trade today. After adjustment for inflation the value of an item costing US$0.20 in 1983 is US$0.24 in 1999. If we assume that this rate of pay is representative of what fishermen everywhere were being paid to collect corals in 1997, then their revenue can be estimated. In 1997 a total of 3.3 million pieces of coral were traded globally. Under this assumption the coral collectors received US$792,000 (in 1999 US$) from this trade. This is approximately 15% of the revenue accruing to the collecting agencies, and 1.5% of the retail value of the corals in the world market.

Figure 14. Schematic representation of the economics of the live coral trade



These figures may have to be adjusted if coral collectors are paid more for live corals than dead but in the absence of this type of information the revenue flowing along the chain of supply for live corals can be summarised as in Figure 14. Conversely it should be noted that coral collectors could have received much less than US$0.24 per piece because in 1980 coral divers in Mindanao were earning just US$1 per day for gathering between 30-50 pieces (Alcera 1981, cited in Mulliken and Nash, 1993). Using Alcera's figures in this calculation suggests that collectors may have received only US$105,000 (in 1999 US$) or 2% of the revenue generated in exporting nations by the sale of coral and a fraction of 1% of its retail value in the market place. Typically collectors sell their harvest to village-based dealers who in turn sell to the national collecting agencies/exporting companies. Clearly statements concerning collector's income cannot be anything but broad generalisations as the price which a village-based dealer receives for a piece of coral may vary substantially: Bentley (1998) states that these dealers receive between 300-3000 Indonesian rupiahs (US$0.10-1.00) per piece. However from this it should also be noted that the collectors, and village-based dealers, are paid in local currency (and the Indonesian rupiah was very vulnerable in 1998) while the national collecting agencies/exporting companies are paid in US dollars.

Ross (1984) also states that coral collectors can gather an average of 100 pieces per day. Assuming that it takes the same amount of time to gather live and dead corals then the 1997 harvest represents approximately 33,000 hours of labour for the collectors who earned in the region of US$25 (in 1999 US$) per day.

10. THE SUSTAINABILITY OF THE LIVE CORAL TRADE

It is interesting and sensible to compare the possible effects of the coral trade with other extractive and destructive practices on reefs. However the conclusion that other factors are having worse impacts on coral reefs than collection for the international trade is, in itself, hardly cause for satisfaction. On one hand the coral trade may simply be another addition to the litany of pressures which have brought about a decline in much of the world's coral reefs (Wilkinson, 1993). Alternatively it may be a sustainable low impact, high value trade which, if managed properly, could bring a much needed economic impetus to coral reef conservation. At the global scale, comparison with other extractive and destructive practices illustrates that the impact of the international coral trade is low: approximately 1000t annually. Unlike many anthropogenic impacts on coral reefs it is relatively straightforward to assess the value of allowing this trade to occur: approximately $5 million per year. However it is far more difficult to judge whether the international trade in live corals is sustainable in the sense that it is not removing more coral than can be replaced by reproduction, recruitment and growth in the wild.

Data on the age of corals in trade and their longevity in aquaria are central to a discussion of the sustainability of the international trade. At the simplest level if a three year old piece of coral is harvested from the wild and survives in an aquarium for more than three years then sufficient time has passed for it to have been replaced by natural processes. However this is not the case if that piece of coral dies in less than three years, and the trade which brought the coral to the aquarium cannot be sustainable by reproduction. The problems associated with ageing corals in trade have already been discussed, but how long can they be expected to survive in aquaria?

Again, answering this question is not straightforward as survival varies with many factors, some within the control of the aquarist (e.g. quality of equipment, light and heat regimes, pH, nutrient depletion, water movement, mechanical and chemical filtration etc.) and some outside (e.g. care taken during collection and transportation, condition of the coral on import). Furthermore keeping corals successfully in an aquarium is time consuming, expensive and requires a thorough understanding of biology and the technology associated with husbandry. The willingness of aquarists to invest the necessary time and money, and the expertise to do so efficiently, will vary. There is little doubt that some corals can survive for long periods, in some cases almost indefinitely. The best documented case is that of an *Acropora* species originally imported to Germany in the early 1980s. Although it is impossible to ascertain the species of this coral (possibly because of morphological changes induced by the aquarium environment), it is well known by aquarium hobbyists and traders by the name of the owner of the mother colony, Dietrich Stuber. Herr Stuber is credited with being the first person to successfully grow hard corals in a closed aquarium system. He also freely

Table 18. Characteristics of some common aquarium corals, summarised from Fossa and Nilsen (1998b)

Species	General Aquarium Suitability	Toxicity	Sensitivity
Acropora gemmifera	~	+	~
Acropora microphthalma	+	+	+
Acropora selago	+	+	+
Acropora cytherea	+	+	+
Acropora latistella	+	+	+
Acropora elseyi	+	+	+
Acropora cervicornis	~	+	~
Blastomussa spp.	+	-	+
Catalaphyllia jardinei	+	+	+
Caulastrea furcata	+	+	+
Cynarina lacrymalis	+	+	+
Euphyllia ancora	+	-	+
Euphyllia divisa	+	~	+
Euphyllia glabrescens	+	~	~
Favites abdita	+	~	+
Favites flexuosa	+	+	+
Fungia spp.	+	+	+
Galaxea fascicularis	+	-	+
Goniastrea retiformis	+	-	+
Heliofungia actiniformis	+	+	~
Herpolitha limax	+	+	+
Hydnophora spp.	+	+	+
Lobophyllia hemprichii	+	+	+
Montastrea valenciennesi	+	+	+
Montastrea curta	+	+	+
Montipora spp.	+	+	+
Oulophyllia crispa	+	~	+
Pavona cactus	+	+	+
Pectinia paeonia	+	+	+
Platygyra spp.	~	+	~
Plerogyra sinuosa	+	-	+
Pocillopora damicornis	+	+	+
Pocillopora verrucosa	+	+	~
Porites rus	+	+	+
Psammocora contigua	+	+	+
Seriatopora hystrix	+	+	~
Stylophora pistillata	+	+	~
Tubipora musica	~	0	~
Turbinaria mesenterina	+	+	+
Turbinaria peltata	+	+	+
Turbinaria reniformis	+	+	+

Notes:
The relative toxicity of the species is a measure of how dangerous it is to other aquarium inhabitants. Sensitivity refers to how sensitive the species is to unfavourable environmental factors in general, but also to how strongly it is likely to react to toxins from other species. The + sign indicates a characteristic favourable for a mixed species aquarium, i.e. General Aquarium Suitability = good spp. (+), intermediate spp. (~) or poor spp. (-), toxicity = weak spp. (+), intermediate spp. (~) or strong spp. (-) and sensitivity = not sensitive spp. (+), intermediate spp. (~) or very sensitive spp. (-). Unavailable data are indicated by a zero.

distributed fragments so that there are several hundred aquarists who keep clones of 'Stuber's Acropora' not only in Germany but also Norway, Sweden, Denmark, the Netherlands, France, Italy, the United Kingdom, Bahrain, the USA and Canada. For the last 5-6 years clones have been commercially available from an American company (Fossa, personal communication). There are similar examples from *Blastomussa* spp., *Cycloseris* sp., *Fungia* spp., *Pavona cactus*, *Pocillopora damicornis* and *P. verrucosa*, *Seriatopora hystrix*, and *Stylophora pistillata* (Fossa, personal communication) and the Waikiki Aquarium in Hawaii has many colonies between five and ten years of age (Atkinson *et al*., 1995). Aspects of the biology of these corals appear to make them generally suitable and successful in aquaria (Table 18), although it would be misleading to assume that their care is simple.

However examples of long lived colonies perpetually propagated by fragmentation must be exceptions. Otherwise it is hard to see how the industry could thrive if aquarists only bought corals from a desire to vary the species they have on display. Corals other than those listed in Table 18 do not fare so well. For example, *Heliopora* and *Goniopora* spp. usually do not survive much more than a year (Delbeek, personal communication). Obviously, there is a world of difference between what is possible and what is actually achieved in the home aquarium. For example, a survey of UK aquarists revealed that corals do not survive much longer than two years (Jarvis, personal communication). Similar claims have been made for home aquaria in the USA; Derr (1992) cites work which concluded that complete mortality occurs after 18 months. A study by Baquero (1991) registered 76% mortality in Scleractinian corals kept in aquaria of various sizes over 18 months. Even species believed to survive robustly in aquaria, such as *Plerogyra sinuosa* (54%) and *Catalaphyllia jardinei* (60%), suffered high mortality (Table 19).

Table 19. The mortality of Scleractinia corals in aquaria

	33	50	80	100	125	180	Mortality
Catalaphyllia spp.	1 (2)	1 (4)	1 (3)	2 (3)	3 (7)	0 (1)	60%
Euphyllia ancora	0 (7)	0 (5)	1 (2)	0 (2)	4 (16)	0 (1)	84%
Euphyllia glabrescens	3 (7)	3 (9)	2 (10)	1 (6)	4 (24)	0 (2)	77%
Goniopora spp.	1 (6)	1 (9)	0 (8)	0 (3)	0 (15)	0 (1)	95%
Heliofungia spp.	0 (3)	0 (2)	0 (3)	0 (1)	0 (9)	0 (1)	100%
Plerogyra spp.	3 (5)	3 (5)	1 (2)	1 (1)	4 (13)	-	54%
Scolymia spp.	4 (5)	2 (4)	2 (2)	1 (1)	4 (4)	1 (1)	17%
Tubastrea spp.	0 (2)	0 (2)	0 (2)	0 (2)	0 (3)	0 (1)	100%
Total	12 (37)	10 (40)	7 (32)	5 (19)	19 (91)	1 (8)	76%

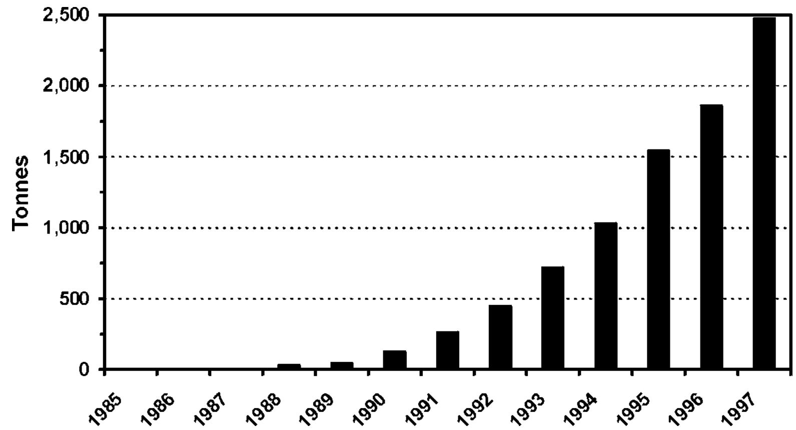
Notes:
A total of 228 pieces were maintained in aquaria ranging from 33-180US gallons (125-680litres) over 18 months. Figures are total number of pieces alive after 18 months (total number of pieces). Data taken from Baquero (1992).

Although reef aquarists in the UK are regarded as being years behind those in North America and Europe (Fossa and Delbeek, personal communications) some mortality must occur everywhere. An estimated 1200t of live coral is presently maintained in USA aquaria yet twice this amount (2427t) was imported during the

1990s (Figure 15). Presumably the rest died (as re-exports of coral from the USA to third party nations are not included in this calculation).

Corals may die in the first few weeks after import because of insufficient packing, handling and delays in transport. They may also die during the first few months in an aquarium (i) as a result of the long term effects of stress, (ii) because they end up with aquarists who lack the necessary knowledge on coral husbandry, (iii) because they belong to less hardy species or (iv) because sufficient knowledge on husbandry does not exist. The mortality at these different stages has been estimated at: less than one month, 3-6%; 1-18 months, 20-25%; 1.5-5 years, 17-20%; more than 5 years 52-58% (Fossa, personal communication).

Figure 15. Cumulative imports of live corals to the USA, as recorded by CITES 1985-1997



The uncertainty associated both with the age of corals in trade, and more so with coral longevity in aquaria, means that it is not possible to state categorically that the global trade in live coral is sustainable. Conversely it is not possible to condemn the trade for being unsustainable. What is more likely is that the trade in those species known to flourish in aquaria (i.e. those with the ability to establish viable colonies from fragments, fast growth rates, good reattachment ability) is probably sustainable and that the trade in other species is probably not. Improvements in husbandry techniques and in the spread of this expertise amongst aquarists will serve to improve the situation. Conversely if the hobby expands so rapidly that large numbers of poorly prepared, semi-committed people are attracted to the hobby then the opposite may occur.

PROPAGATION OF CORALS BY FRAGMENTATION

Two activities, fragmentation and mariculture, may potentially serve to reduce the quantity of coral being collected in the wild.

Fragmentation is an important means of asexual reproduction for many coral species (Richmond and Hunter, 1990) and these species typically survive well in aquaria (Table 20). Fragments of these species are frequently traded between

Table 20. The viability in aquaria of some coral species which may be propagated by fragmentation spp.

Species	Fragment Viability	Husbandry
Acropora cervicornis	Good	Difficult
Acropora palmata	Good	Difficult
Pocillopora damicornis	Good	Marginal
Acropora cytheria	Fair	Marginal
Porites compressa	Good	Marginal
Turbinaria spp.	Good	Marginal
Pocillopora meandrina	Unknown	Unsuccessful
Acropora monticulosa	Poor	Unsuccessful
Acropora florida	Good	Probable
Seriatopora hystrix	Good	Successful
Stylophora pistillata	Good	Successful
Acropora aspera	Good	Successful
Acropora digitera	Poor	Successful
Acropora echinata	Good	Successful
Acropora elseyi	Good	Successful
Acropora formosa	Excellent	Successful
Acropora glauca	Good	Successful
Acropora microphthalma	Excellent	Successful
Acropora pulchra	Good	Successful
Acropora subglabra	Good	Successful
Acropora verweyi	Good	Successful
Acropora valida	Good	Successful
Montipora digitata	Excellent	Successful
Montipora verrucosa	Good	Successful
Anacropora spp.	Excellent	Successful
Goniopora spp.	Good	Successful
Goniopora stokesi	Good	Successful
Pavona cactus	Good	Successful
Diaseris fragilis	Excellent	Successful
Zoopilus echinatus	Good	Successful
Herpolitha limax	Unknown	Successful
Polyphyllia talpina	Good	Successful
Cynarina lacrymalis	Poor	Successful
Lobophyllia hemprichii	Good	Successful
Hydnophora rigida	Good	Successful
Caulastrea furcata	Good	Successful
Euphyllia spp.	Good	Successful
Catalaphyllia jardinei	Good	Successful
Plerogyra sinuosa	Good	Successful
Montipora ramosa	Good	Unknown

Notes:
Taken from Yates and Carlson, 1992

aquarists who need to regularly 'prune' their colonies to prevent overcrowding or antagonistic behaviour between adjacent species. This provides an alternative supply source to corals harvested from the wild, one which would only be monitored by CITES records if the fragments were shipped internationally.

The Waikiki Aquarium distributed 780 in fragments 1997 and 505 in 1998, although it had more orders than could be processed (Carlson, personal communication) and about 40% of aquarists have obtained up to a third of their hard corals from fragments (Table 10). Fragments therefore seem to be a useful source of some species on occasions, but the majority of colonies in the majority of aquaria have been harvested from the wild and traded internationally, and this is unlikely to change.

CORAL FARMING (MARICULTURE)

It is possible to grow corals in the wild and over the past few years coral farms have been established, especially in the Solomon Islands which appears to supply most of the cultured coral for the USA. The species being grown are again those with fast growth rates which can be easily propagated by fragmentation, mainly *Acropora* spp. and some *Pocillopora* spp. (Table 20). Many of these farms are small scale local businesses, frequently managed by women who collect growing tips from large colonies in the wild. These fragments are cultivated in the sea suspended from fishing line until the colonies are large enough to be sold into the aquarium trade. Although there is an initial impact on wild colonies, the collection sites can be rotated so that the mother colonies can recover.

The retail prices of cultured corals (Table 21) are comparable to those harvested from the wild (Table 16), presumably because the amount of labour involved in collecting seed fragments is comparable to that involved in collecting larger, saleable pieces. Importantly aquarists seem to be willing to buy them (Table 10). However it is difficult to find outlets which sell cultured corals (Kirda, personal communication). A survey of marine wholesale companies in the USA in 1999 found only two selling cultured corals, in both cases from the Solomon Islands. Outlets may either fail to appreciate that aquarists are willing to buy cultured corals, or perhaps aquarists, who in the past have shown a reluctance to buy cultured fish if they were less colourful or differently patterned to wild animals, over estimate their readiness to buy.

However it is more likely that the opportunity of purchasing cultured corals is constrained by supply. CITES data reveal that the amount of cultured ('bred in captivity') coral being traded internationally is tiny, much less than 1% of the annual total in terms of either weight or numbers of pieces. Whilst trade in some cultured coral may not be recorded by CITES permits (e.g. because the Solomon Islands are not a signatory to the Convention) it would appear that culturing schemes have a long way to go before they can supply coral in quantities which are significant compared to those harvested directly from the wild. Having said that there has been a steady increase in the amount of cultured coral being traded with no records up to 1989, just 11kg in 1990, 110kg in 1996 and 2442kg in 1997. However the term 'bred in captivity' is strictly defined under Resolution 10.16 of CITES. This definition, which requires amongst other criteria specimens to have been *'maintained without the introduction of specimens from the wild, except for the occasional addition of animals, eggs or gametes*' and to have *'produced offspring of second generation (F2) or subsequent generation (F3, F4, etc.) in a controlled environment*', would not include the products of these coral farms. In this sense the coral recorded as being 'bred in captivity' is an error in reporting.

Table 21. The retail price of cultured corals from two USA suppliers surveyed in 1999

Species	Small	Large
Acropora austera	$25	$30
Acropora cerealis	$30	
Acropora digitifera	$40	$50
Acropora echinata	$40	$50
Acropora horrida	$40	$50
Acropora millepora	$30	
Acropora millepora	$35	
Acropora millepora	$30	$35
Acropora millepora	$30	
Acropora secale	$30	$35
Acropora secale	$35	
Acropora selago	$29	
Acropora spp.	$50	$60
Acropora tenuis	$30	$40
Acropora tenuis	$30	
Acropora valida	$25	
Acropora valida	$30	$35
Caulastrea furcata	$25	$35
Fungia spp.	$15	
Hydnophora spp.	$20	$25
Monitpora spp.	$30	
Montipora digitata	$25	$60
Montipora stellata	$35	
Montipora verrucosa	$30	
Pachyseris spp.		$30
Pectinia spp.		$30
Pocillopora damicornis	$30	$40
Pocillopora damicornis	$40	$50
Pocillopora spp.	$30	$35
Pocillopora verrucosa	$40	$50
Pocillopora verrucosa	$40	$50
Stylophora pistillata	$35	
Heliopora spp.	Fragments $20 up to full colonies @ $35	
Montipora capricornis	Fragments $10 up to full colonies @ $35	
Montipora digitata	Fragments $20 up to full colonies @ $35	

INDONESIAN EXPORT QUOTAS

The imposition of quotas in certain species is one method that attempts to restrict trade to sustainable levels. There are many reasons for setting quotas - one is to ensure an annual export that can be theoretically sustained by wild populations without detriment. Trade in these species is supposed to cease once the quota has been filled. In practice for most species listed under CITES, including corals, the quotas are based on very limited data and it is frequently difficult to ascertain whether there is any real basis for accepting that trade at the quota level is in fact sustainable.

Indonesia has established quotas for some corals in consultation with the CITES Secretariat. In 1997 these applied to 39 genera (Table 22). Table 22 demonstrates that for eight of the most important genera in the live trade, and two of the most important genera in the dead trade (*Tubipora* spp. and *Fungia* spp.), the number of pieces being exported were much less than the quota. In other words the quotas were meaningless in terms of the amount of coral being traded in 1997 and could be reduced substantially. More pieces of *Euphyllia* spp., *Goniopora* spp., *Catalaphyllia* spp., *Trachyphyllia* spp. and *Heliofungia* spp. are traded than any other genera. These genera have the highest quotas despite there being no scientific reason to suppose that they are capable of supporting higher harvests than other genera. It is therefore easier to believe that these quotas have been set at levels which will not interfere with trade than at levels which will ensure sustainability. *Acropora* and *Pocillopora* spp. are probably more resilient to collection by virtue of their success at asexual reproduction through fragmentation. However the number of pieces of *Acropora* and *Pocillopora* spp. traded, as recorded on export permits issued by the Indonesian CITES authorities (and not including unused or cancelled permits as occurred in years prior to 1997), greatly exceeded the quota (Table 22). Clearly there was a failure to regulate, and stop, trade in these species once the quota had been filled.

Up to 1998 export quotas were based on genera, but those for 1999 are based on individual species. *Wellsophyllia* spp. is now considered to be a synonym of *Trachyphyllia* spp. (Table 7) and so was not assigned a separate quota for 1999 (Table 22). When the quotas for 1997 and 1999 are compared, by summing the quotas for congeneric species, it is clear that while some have been reduced substantially (e.g. *Tubipora* spp., *Favia* spp., *Hydnophora* spp., *Favites* spp. and *Cataphyllia* spp.) the majority of quotas have been increased. In fact 24 of the 39 quotas have been increased from 1997. Furthermore problems of species' identification (Box 2) will probably make the application of these quotas more difficult. There is no obligation for Indonesia or any other country to set quotas, and it may be argued that a willingness to do so is commendable. However if quotas are set at levels which are unrealistically high in comparison to the levels of trade, and if trade in some genera exceeds the quota without being restricted, then their value as a management tool for the sustainability of trade must be questioned.

Table 22. Indonesian coral export quotas (numbers of pieces) for 1997 compared to the number of pieces traded, as calculated from the CITES database, and the quotas set for 1999

	Genera	1997 Quota	Pieces traded in 1997	Difference between quota and amount traded	1999 Quota	% change from 1997
Species traded under quota in 1997	*Euphyllia* spp.	124,200	65,169	-59,031	126,000	+1
	Goniopora spp.	111,600	66,115	-45,485	135,000	+21
	Catalaphyllia spp.	89,775	51,698	-38,077	67,500	-25
	Trachyphyllia spp.	72,000	42,177	-29,823	83,700	+16
	Heliofungia spp.	45,000	23,227	-21,773	57,600	+28
	Tubastraea spp.	32,850	14,162	-18,688	NQ	
	Turbinaria spp.	27,000	11,793	-15,207	34,700	+29
	Plerogyra spp.	45,000	29,871	-15,129	36,000	-20
	Lobophyllia spp.	24,750	12,805	-11,945	27,900	+13
	Caulastrea spp.	18,000	8,053	-9,947	21,600	+20
	Nemenzophyllia spp.	18,000	8,537	-9,463	NQ	
	Galaxea spp.	15,750	6,303	-9,447	22,950	+46
	Hydnophora spp.	15,750	6,895	-8,855	19,440	+23
	Physogyra spp.	15,750	7,090	-8,660	10,800	-31
	Tubipora spp.	19,350	11,439	-7,911	10,350	-47
	Blastomussa spp.	8,550	2,471	-6,079	8,100	-5
	Fungia spp.	9,000	4,304	-4,696	13,000	+44
	Favia spp.	9,000	4,332	-4,668	4,500	-50
	Favites spp.	9,000	5,074	-3,926	5,850	-35
	Polyphyllia spp.	6,300	2,384	-3,916	900	-85
	Wellsophyllia spp.	9,000	5,282	-3,718	NQ*	
	Montastrea spp.	4,500	1,904	-2,596	5,760	+28
	Cynarina spp.	7,200	4,840	-2,360	9,900	+38
	Scolymia spp.	3,600	1,298	-2,302	3,600	0
	Symphyllia spp.	2,250	568	-1,682	1,440	-36
	Merulina spp.	1,800	1,043	-757	2,700	+50
	Herpolitha spp.	900	288	-612	1,260	+40
	Pavona spp.	675	201	-474	1,080	+60
	Goniastrea spp.	450	116	-334	810	+80
	Distichopora spp.	225	12	-213	NQ	
	Diploastrea spp.	225	22	-203	270	+20
	Montipora spp.	900	700	-200	2,070	+130
	Seriatopora spp.	225	59	-166	900	+300
	Pectinia spp.	675	517	-158	900	+33
Species traded above quota in 1997	*Stylophora* spp.	450	502	52	900	+100
	Porites spp.	25,200	25,727	527	33,750	+34
	Millepora spp.	675	1,253	578	NQ	
	Acropora spp.	31,600	34,484	2,884	33,300	+5
	Pocillopora spp.	2,700	13,005	10,305	6,300	+133

Notes:

The top ten genera in the live coral trade spp. (Figure 8) are shaded. Note that 1997 was the first year in which Indonesia reported on the basis of actual items traded, not permits issued, so reducing the over-estimation of trade which had occurred in previous years. NQ = no quota for 1999 spp. (*Wellsophyllia* is now considered to be a synonym of *Trachyphyllia* and so was not assigned a separate quota for 1999).

11. CONCLUSIONS

Thirteen years of data of the international trade in hard corals are available in the CITES Trade Database and no comparable source of information exists. The volume of information available (more than 300,000 database records) and the scope of coverage (permits for transactions between 143 parties to the Convention) allow the trade to be set in a truly global context. However, it soon becomes apparent when using CITES coral data in this way that there are two aspects of the reporting process which have to be emphasised clearly before drawing summary conclusions from them.

Firstly, only a tiny minority of records identified specimens to species despite an obligation under CITES to do so (Chapter 3). With the majority of records (98% in 1997) not recording species any analysis at that taxonomic level would be pointless, and therefore the effectiveness of CITES in monitoring trade in individual coral species is low. There can be little doubt that this feature of the CITES data is a direct result of the practical difficulties of coral taxonomy and the detailed examination of large numbers of specimens which would be necessary to record the species in trade accurately. Data presented in Box 2 would suggest that about 20 minutes is required to identify a single piece of *Acropora* spp., a genus which is important in both the live and dead trade. Millions of pieces of coral are exported on an annual basis and so the recording of coral species under CITES is never likely to be a practical, or even desirable, use of available monitoring resources. While it may be constitutionally difficult within the framework of the Convention to make an exception in the case of corals, nonetheless we would propose that consideration be given to reporting corals at the genus level only, given that this appears to be common practice now and that it is unlikely to change. Chapters 4 and 5 demonstrate that the global trade can be monitored using generic data, and Chapters 8-10 illustrate that generic data can then be used to assess the effects and value of trade. However, it would be misleading to assume that the identification of coral genera is highly accurate simply because the problems of species identification are avoided by recording specimens to a higher taxonomic level (Box 3). Investment in measures which would increase the capacity of personnel involved in the reporting process to identify coral genera appears to be needed. These measures might include the development of a comprehensive identification guide specifically designed for a non-scientific audience having to record the taxa of both live and dead corals in trade. Ideally any such guide should include (i) colour photographs of live corals, (ii) diagrams of common growth forms, and (iii) line diagrams of skeletal detail, especially polyp structure. This is not to imply that past CITES data, at genus level, do not provide detailed information on the taxonomy of the coral trade (see Table 7 and Figure 8) – indeed they can be used to monitor changes in the international trade to factors affecting it (Chapter 7).

Secondly, the use of different units on CITES permits means that a global analysis of the coral trade is absolutely dependent on the use of a conversion factor based on the weight of a typical piece of coral in trade. This was used to convert numerical records to weight and *vice versa*, and any error in this conversion factor will therefore have skewed the results proportionately. The need for a reliable conversion factor is evident from only a superficial glance at CITES trade data for corals – without it one is faced with the difficult task of trying to interpret data of different units. Furthermore in the absence of a reliable conversion factor shipments would have to be recorded only by a number of pieces, a qualitative measure of limited use, or weighed directly. Weighing live corals will always be problematical because of the care necessary to avoid bias in the measurement by including water, yet the specimens must be kept wet in order to avoid damage and undue disturbance to the living coral. We propose therefore, on the basis of data presented in Chapter 5, that a value of 200g per piece be used for live corals. We would also recommend that renewed attention be give to the USA resolution that reports of trade in specimens of coral transported in water should record the number of pieces traded (Chapter 2) and that these records should then be converted to kilograms. In contrast shipments of dead coral can be weighed directly more easily than live. For those shipments of dead coral recorded by number of pieces we propose that a conversion value of 500g per piece is reliable. This value is based on the data presented in Box 1, for corals which were presumably intended to supply the same market as legally imported items, and which were also in close agreement to the conversion factor suggested in the Amendments to Appendices I and II of CITES (Anon., 1989). In the case of dead corals there are no advantages to using a conversion factor and it would therefore be preferable to avoid one altogether, if possible. For these reasons the second component of the USA resolution, that reports on trade on coral specimens other than specimens of coral transported in water should record the weight in kilograms (Chapter 2), seems as sensible as the first. Indeed given the importance of records which identify taxa as Scleractinia spp., 46% by weight of all coral traded between 1985-1997, then renewed attention to the third component of the USA resolution (Chapter 2) is probably also necessary so that the reporting of coral rock and derived material might be standardised.

Acknowledging these two features of CITES coral data it was possible to estimate the quantity of coral that has been traded between 1985-1997, and to use the weight of coral to illustrate the trade links between exporting and importing nations, and trading regions (Chapter 4). Seventy nations imported a total of 19,262t of coral from 120 exporting nations over this period. The USA has accounted for more than half of the global trade, being supplied mainly by both the Philippines and Indonesia in the 1980s, and Indonesia in the 1990s. In total the USA imported more than three times the amount of coral going into the EU and about twice as much as the rest of the world combined. Over these thirteen years Taiwan and China, important exporters of coral in the 1980s and early 1990s respectively, reduced their coral exports by several orders of magnitude, while Fiji and the Solomon Islands have increased theirs substantially (Figure 5). Regionally exports from South East Asia were an order of magnitude greater than those from the Pacific and two orders of magnitude more than the Caribbean and Indian Ocean. Present levels of traded coral, about 1000t per year, are comparable with the 1980s. The value of a reliable conversion factor was illustrated in the analysis of data for black corals – the lack of data on the weight of a typical piece of black coral precluded meaningful interpretation of the data for those genera (Chapter 6).

The recording of the term 'live' on CITES permits is probably very reliable as specimens shipped in water or damp containers are clearly intended to be live rather than dead. This means that the trade in live corals for aquaria can be examined separately from the trade in dead corals for curios and ornaments (Chapter 5), revealing that very different genera are targeted by the live and dead coral trades. Genera with delicate branching or mushroom growth forms dominate the trade in dead corals, while the live trade mainly consists of genera with large colourful polyps which can be seen during the day; features of obvious interest to aquarists. In the 1980s the coral trade consisted almost entirely of these dead corals, but there was a substantial increase in the amount of live coral traded each year throughout the 1990s so that in 1997 more than half of the global trade was in live specimens. Although quantitative data are not available, anecdotal information would suggest that there has been a similar substantial increase in the number of home aquaria in the USA, the principal importing nation. Certainly the 1990s saw great advances in techniques for coral husbandry, falling prices of equipment and a large expansion in international air freight services all of made such a large increase in the live coral trade possible.

CITES trade data allow the environmental impact of the global trade in coral to be estimated. The effects on coral populations of harvesting specimens for the aquarium trade can be profound but are likely to localised and, on a global scale, minimal because the amount of coral harvested is small (Chapter 8). Although small, is the global harvest in live corals for the aquarium trade sustainable through natural rates of reproduction and regeneration? An answer to this question is not readily available because of the difficulty of (i) assessing the age of corals in trade, and (ii) the variability in rates of mortality in aquaria. It is best then to conclude that trade in those species known to flourish in aquaria may be sustainable and that trade in other species is probably not (Chapter 10).

An economic assessment of the global trade in coral is possible when CITES data are combined with export and retail prices (Chapter 9). The trade in live corals generated a revenue to exporting nations of approximately $5 million (in 1999 US$) in 1997, the most recent year for which CITES data are available. While this revenue is certainly tiny in the context of international trade, the aquarium industry is unusual in the context of human impacts on coral reefs in that the monetary value of the disturbance can be estimated. In 1997 $5 million dollars were generated by the sale of 687t of live coral, so the trade can be valued at approximately $7000 per tonne (in 1999 US$).By comparison the value of lime produced from coral reported by Cesar (1996) was approximately $60 per tonne (in 1999 US$).The value of the trade in live coral may be relatively high compared with some other extractive activities but globally it is neither a high value nor a high impact industry. On the basis of the data presented here it would be more realistic to conclude that, globally, it is a low value business with little long term impact.

REFERENCES

Alcera, V.B. 1981. The coral industry of Zamboanga-Basilan-Sulu area. In: *Coral Reef, Proceedings of Symposium Workshop*, December 1980. Quezon City, Philippines.

Anon. 1989. Amendments to Appendices I and II of the Convention, Other Proposals. 3rd Meeting of Conference of the Parties to CITES, Lausanne, Switzerland, 9-20th October 1989. p85-104.

Armstrong, J. and Crawford, J. 1998. Convention on international trade in endangered species of wild fauna and flora. Coral reefs, challenges and opportunities for sustainable management. Eds: Hatziolos, M.E., Hooten, A.J. and Fodor, M. *Proceedings of an associated event of the 5th Annual World Bank Conference on Environmentally and Socially Sustainable Development*. The World Bank, Washington D.C., 65-67.

Atkinson, M.J., Carlson, B. and Crow, G.L. 1995. Coral growth in high nutrient, low pH seawater: a case study of corals cultured at the Waikiki Aquarium, Honolulu, Hawaii. *Coral Reefs*, 14:215-223.

Baquero, J. 1991. Scleractinians or stony corals and the aquarium trade. Part I. *Sea Wind*, 5(2): 6-12.

Bentley, N. 1998. An overview of the exploitation, trade and management of corals in Indonesia. *TRAFFIC Bulletin*, 17(2), 67-78.

Best, M.B. 1997. Trade in living corals and stones. *Proceedings of the 6th International Conference on Coelenterate Biology*, 1995. p47-52.

Bosscher, H. 1993. Computerised tomography and skeletal density of coral skeletons. *Coral Reefs*, 12:97-103.

Brown, B.E, and Dunne, R.P. 1988. The impact of coral mining on coral reefs in the Maldives. *Environmental Conservation*, 15:159-165.

Bryant, D., Burke, L., McManus, J and Spalding, M. 1998. *Reefs at Risk, A Map-Based Indicator of Threats to the World's Coral Reefs*. World Resources Institute, Washington D.C. 56pp.

Buddemeier, R.W. and Kinzie, R.A. 1976. Coral growth. *Oceanography and Marine Biology Annual Reviews*, 14:179-200.

Cesar, H. 1996. Economic analysis of Indonesian coral reefs. The World Bank, Washington D.C., USA. p97.

CITES. 1984. CITES Identification Manual, Volume 4.

Derr, M. 1992. Raiders of the reef. *Audubon Magazine*, 48(2): 48-54, 56.

Edwards, S.R. and Nash, S.V. 1992. Wild bird trade: perceptions and management in Indonesia. In: Thomsen, J.B., Edwards, S.R. and Mulliken, T.A. (Eds.). *Perceptions, conservation and management of wild birds in trade*. TRAFFIC International, Cambridge, UK. 165pp.

Fossa, S.A. and Nilsen, A.J. 1998a. Korallenriff-Aquarium, Band 6. Birgit Schmettkamp Verlag, Bornheim, Germany, 592pp.

Fossa, S.A. and Nilsen, A.J. 1998b. The modern coral reef aquarium. Volume 2. Birgit Schmettkamp Verlag, Bornheim, Germany, 479pp.

Garrett, R.N. 1977. Impact of commercial coral collecting. Unpublished report. Research Session, Northern Fisheries Committee, CSIRO, Cleveland. 157-159.

Gomez, E.D., Alcala, A.C., Yap, H.T., Alcala, L.C. and Alino, P.M. 1985. Growth studies of commercially important Scleractinians. Proceedings of the 5th International Coral Reef Congress, Tahiti. Volume 6: p199-204.

Grigg, R.W. 1977. Fishery management of precious corals in Hawaii. *Proceedings of the 3rd International Coral Reef Symposium*, 609-616.

Grigg, R.W. 1976. Fishery management of precious and stony corals in Hawaii. Sea Grant Technical Report, NUIHI. Sea Grant TR-77-03, University of Hawaii, 48pp.

Harrison, P.L. and Wallace, C.C. 1990. Reproduction, dispersal and recruitment of scleractinian corals. In Ed. Z. Dubinsky, *Ecosystems of the World: Coral Reefs*. Elsevier, Amsterdam, 550pp.

Kinzie, R.A. 1996. Reefs happen. *Global Change Biology*, 2: 479-494.

Kirkby, D.L. 1992. A historical overview of CITES with emphasis on the import and export of corals. American Association Zoological Parks and Aquariums /Canadian Association of Zoological Parks and Aquariums 1992 Annual Conference Proceedings. p 534-542.

Maragos, J. 1978.Coral growth: geometrical relationships. In: Eds. Stoddart, D.R. and Johannes, R.E., *Handbook of coral reef research methods*, Unesco, Paris, Vol. 5: 543-550.

McManus, J.W. 1980. Philippine coral exports: the coral drain. *ICLARM Newsletter*, January, 18-20.

Mood, A.M. 1950. *An introduction to the theory of statistics*. McGraw-Hill, New York, USA. 433pp.

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

O'Brien Shoup, C. and Gaski, A.L. 1995. Trade in CITES listed hard corals. TRAFFIC USA, Washington D.C., USA. 133pp.

Oliver, J. and McGinnity, P. 1985. Commercial coral collecting on the Great Barrier Reef. *Proceedings of the 5th International Coral Reef Congress*, Tahiti. Volume 5, p563-568.

Polunin, N.V. 1983. The marine resources of Indonesia. *Oceanography and Marine Biology Review*, 21, 455-531.

Richmond, R.H. and Hunter, C.L. 1990. Reproduction and recruitment of corals: comparisons among the Caribbean, the tropical Pacific and the Red Sea. *Marine Ecology Progress Series*, 60:185-203.

Ross, M.A. 1984. A quantitative study of the stony coral fishery in Cebu, Philippines. P.S.Z.N.I. *Marine Ecology*, 5 (1):75-91.

Rubec, P.J. 1988. The need for conservation and management of Philippine coral reefs. *Environmental Biology of Fishes*, 23 (1-2):141-154.

Sheppard, C. 1998. *Corals of the Indian Ocean*. CD-ROM.

Spalding, M and Grenfell, A. 1998. New estimates of global and regional coral reef areas. *Coral Reefs*, 16:225-230.

University of the Philippines Marine Sciences Center. 1982. Investigation of the coral resources of the Philippines. Phase III Final Report. Marine Sciences Center, University of the Philippines, Diliman, Quezon City.

University of the Philippines Marine Sciences Center. 1980. Investigation of the coral resources of the Philippines. Phase III-A Final Report. Marine Sciences Center, University of the Philippines, Diliman, Quezon City.

University of the Philippines Marine Sciences Center. 1979. Investigation of the coral resources of the Philippines. Phase II Final Report. Marine Sciences Center, University of the Philippines, Diliman, Quezon City.

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

Wallace, C.C. and Wolstenholme, J. 1998. Revision of the coral genus *Acropora* (Scleractinia: Astrocoeniina: Acroporidae) in Indonesia. *Zoological Journal of the Linnean Society*, 123:199-384.

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

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

Wells, S.M. 1985. Stony corals, a case for CITES. *TRAFFIC Bulletin*, 7(1):9-11.

Wells, S.M. 1981. The coral trade in the Philippines. *TRAFFIC Bulletin*, 3(5):50-51.

Wilkinson, C. 1993. Coral reefs are facing widespread devastation: can we prevent this through sustainable management practices? *Proceedings of the 7th International Coral Reef Symposium*, Guam, 1992, Volume 1.p11-21.

Wood, E.M. 1983. *Corals of the World.* T.F.H Publications, Redhill, Surrey.

World Conservation Monitoring Centre, 1999. Checklist of fish and invertebrates listed in the CITES Appendices and in the Annexes of the Council of the European Union Regulation (EC) No. 338/97. 4th edition. *Joint Nature Conservation Committee Report* No. 292. 239pp.

World Conservation Monitoring Centre, 1996. A guide to interpreting outputs from the WCMC CITES Trade Database Version 3.1 September. Wildlife Trade Monitoring Unit, World Conservation Monitoring Centre, Cambridge, UK.

World Trade Atlas. 1999. *World Trade Atlas*, US Edition. Source data, US Department of Commerce.

Yates, K.R. and Carlson, B.A. 1992. Corals in aquariums: how to use selective collecting and innovative husbandry to promote reef conservation. *Proceedings of the 7th International Coral Reef Symposium*, Guam, 1992, Volume 2. p1091- 1095.

Zar, J.H. 1996. *Biostatistical Analysis*, 3rd edition. Prentice Hall, New Jersey, USA. 662pp.

This study assesses the global trade in corals in an ecological and economical context. Throughout the report emphasis is placed on the trade in live corals for aquaria because the last decade has seen an enormous increase in this business. The taxonomic composition of the trade is identified and the quantities of coral passing between nations illustrate the links between major exporters and importers. Subsequent sections present data on the practicalities of monitoring international trade in corals at the global scale. In the last two sections size and growth rate data are used to assess the sustainability of the trade in live coral: export and retail prices are used to estimate the revenue to exporting nations.

The **WCMC Biodiversity Series** presents the results of projects carried out by the World Conservation Monitoring Centre, often in partnership with other organisations. This series is focused on providing support to the Parties to the **Convention on Biological Diversity**, helping them to identify and monitor their biodiversity, to manage and apply information on biodiversity effectively and to exchange information. The WCMC Biodiversity Series **General Editor** is Mark Collins, Chief Executive of the World Conservation Monitoring Centre.

Other titles in the series:

1. Biodiversity Data Sourcebook
2. The Biodiversity Clearing House - Concept and Challenges
3. Priorities for Conserving Global Species Richness and Endemism
4. The Diversity of the Seas: a regional approach
5. Assessing Biodiversity Status and Sustainability
6. Biodiversity Conservation in the Tropics
7. Industrial Reliance on Biodiversity
8. Freshwater Biodiversity: a preliminary global assessment
9. Global Review of Protected Area Budgets and Staff

The **World Conservation Monitoring Centre**, based in Cambridge, UK, was established in 1988 as a company limited by guarantee with charitable status. WCMC is managed as a joint venture between the three partners in the World Conservation Strategy and its successor Caring For The Earth: IUCN - The World Conservation Union, UNEP - United Nations Environment Programme, and WWF - World Wide Fund for Nature. WCMC provides information services on the conservation and sustainable use of the world's living resources and helps others to develop information systems of their own.

IUCN UNEP WWF

Further information is available from
World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge CB3 0DL, United Kingdom
Tel: +44 (0)1223 277314
Fax: +44 (0)1223 277136
Email: info@wcmc.org.uk