

International trade in hard corals: review of management, sustainability and trends

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Abstract. Since international trade in hard corals began in the 1950s, there have been major changes in the supply chain, end use and the way coral fisheries are regulated. Traditionally, pieces of dead coral were used either as curios or to decorate aquarium tanks, but international trade in these commodities has declined noticeably in recent years, with many countries prohibiting collection and export. In contrast, since the mid-1980s there has been a steady rise in trade in live corals and live rock (bioactive reef bedrock) for private and public aquaria. Based on import data, trade in coral rock reached a peak of 2,527mt in 2005 but since then has been on a declining trend, falling to 1,233mt in 2010. Trade in live corals is increasing and the main supplier continues to be Indonesia. According to import data, this country has provided an average of 70% of trade in live corals in the past decade. There is now a growing trend towards fragmentation and propagation of corals which are seen as ways of taking pressure off wild populations and as possible solutions for making the trade self-sustaining in the long-term. However, these initiatives have concentrated on the fast-growing, small-polyp corals such as *Acropora* and there has been little or no commercial success with popular large-polyp varieties such as *Catalaphyllia*, *Plerogyra* and *Trachyphyllia*. This paper provides an analysis of international trade from 2000–2010 and examines the management challenges for sustainable harvesting into the future.

Key words: Coral, CITES, aquarium trade, curio trade, coral mariculture

Introduction

International trade in coral skeletons for decorative purposes was established by the 1950s and was dominated by the Philippines until 1977, when a national ban on collection and export was introduced (Wood and Wells 1988). By the late 1980s about half of the trade still originated from the Philippines but by 1993 the ban was fully effective (Mulliken and Nash 1993).

Countries such as Fiji, New Caledonia, Malaysia and Singapore were also exporting reef coral in the 1970s and 80s (Wood and Wells 1988), but it was Indonesia that rapidly took over from the Philippines as the major exporter, with raw (dead) coral pieces initially making up most of the exports (Bentley 1998). In the Pacific region, the focus of coral collection until the 1990s was mainly on dead corals for curios and aquarium decoration, with the main taxa traded being *Fungia* spp., *Pocillopora* spp., *Porites* spp. and *Acropora* spp. (Kinch *et al.* 2011).

Trade in live coral for commercial and private aquaria increased in past decades in response to consumer demand for reef tanks and significant advances in coral husbandry. Indonesia became the lead exporter and by early 2000 was supplying 70–80% of the global trade in live corals (Bruckner 2003).

Hard corals are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Exports are permitted only if the specimens have been legally acquired and export will not be detrimental to the survival of the species or its role in the ecosystem (CITES 2012a). CITES monitoring requirements have led to a number of initiatives to try to improve management of coral harvesting and trade (Harriott 2001; Bruckner 2003; Bruckner and Borneman 2006; Atkinson *et al.* 2008; Kinch *et al.* 2011).

This paper documents current trends in trade as derived from CITES data and discusses progress towards the goal of sustainable harvest.

Material and Methods

Parties to CITES are required to submit annual reports detailing trade in CITES-listed species in accordance with CITES guidelines (CITES 2011). The data from these reports are entered into the CITES Trade Database managed by the UNEP World Conservation Monitoring Centre (UNEP-WCMC). For this analysis, all trade in hard corals for the period 2000–2010 inclusive was extracted from the CITES Trade Database on 20th January 2012 and updated on 20th April. Each record represents trade reported by either

the importing or exporting country and includes the details provided in Table 1.

Record	Explanatory notes
Year	Year in which the trade took place
Taxon	Species name unless trade recorded at a higher taxonomic level. Some genera are permitted to be traded at the genus level in accordance with Resolution Conf. 11.10 (Rev. CoP15), and 'coral rock' is recorded to the level of order Scleractinia.
Importing country	Country of import.
Exporting country	Country of export.
Origin	Country of origin of re-exports.
Quantity	Quantity
Units	Unit of measure (e.g., kg). Coral trade was almost entirely weight or number of specimens.
Term	Description of specimen(s) traded (e.g. live, raw).
Purpose	Purpose of transaction. Recorded purposes include commercial trade (T), bio-medical research (M), scientific (S) and other minor categories.
Source	Source of the specimen. Recorded sources include taken from the wild (W), bred in captivity (C), born in captivity (F), ranches (R) and seizures (I).

Table 1. Details provided for each CITES trade record

For the global review, direct trade reported by both importers and exporters was analyzed, thus ensuring there was no double-counting due to re-exports. All purposes were included in the analysis, although the vast majority of trade was reported as commercial (T).

Results

Coral rock recorded as Scleractinia by weight

Coral rock (also live rock and substrate) is hard consolidated material >3 cm in diameter, formed of dead coral fragments that may also contain cemented sand, coralline algae and other sedimentary rocks (CITES 2008). 'Live rock' is coral rock colonized by live coralline algae and other non-CITES-listed taxa.

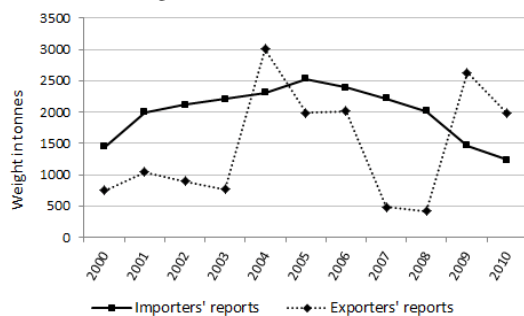


Figure 1. Direct trade in coral rock (*Scleractinia* spp.) by weight. Entries in the database are either as 'live' or 'raw coral' according to how they were reported by Parties in their annual reports. For this analysis, the records were combined because it was evident there were inconsistencies in reporting the separate categories.

Direct trade based on importers' reports reached a peak of 2,527mt in 2005 (Fig. 1) but since then has been on a declining trend, falling to 1,233mt in 2010.

The fluctuating export values are due to high figures reported by Fiji for 2004–2006 and 2009–2010 but zero records in the database in intervening years.

Fiji is the main supplier of coral rock, providing an average of 60% over the period 2000–2010. Indonesia supplied an average of 11%. Recently, these two countries have increased their market share. In 2010 Fiji supplied 69% of imports (850mt) and Indonesia 22% (268mt). Amongst the smaller suppliers, Haiti provided between 6–88mt annually over the decade and 7% of total imports in 2010.

Several countries have recently stopped trading. For example, imports were recorded from Tonga until 2008 (maximum 600mt in 2004) and the Marshall Islands until 2007 (maximum 94mt in 2001). Imports from Vietnam declined from a peak of 428mt in 2001 to 5mt in 2010. Vanuatu imports peaked at 30mt in 2006 but there have been none reported since 2008.

Despite inconsistent reporting, it is likely that most of the trade is 'live' because the reports state the source as 'wild' and this is the commodity in demand for which quotas have been set. Export quotas for Fiji and Indonesia for wild-sourced live rock in 2010 were 805,601 and 450,000 kg respectively (CITES 2012b).

Based on importers' reports, the United States (US) is the leading importer, accounting for 70–86% of the market over the period 2000–2008, but dropping to 62% in 2010. Conversely, the share imported by European countries has ranged from 9–15% over the period 2000–2007 but had risen to 33% by 2010.

Coral rock recorded as Scleractinia by pieces

Pieces of reef rock used as substrate for soft corals and other non-CITES listed organisms are recorded by number to the order level *Scleractinia* (CITES 2008). According to importers' reports, the number of pieces of substrate reached a peak of 1.22 million in 2007 and fell to 0.69 million in 2010. This decrease might reflect the fact that since 2007 the European Union (EU) does not require permits or record imports for coral rock substrate because it is viewed as 'fossilized' (CITES 2008). In addition, artificial substrata are increasingly being used for soft corals.

Live coral

Overall trends

Live corals are pieces of coral transported in water and identifiable to species or genus (CITES 2008). Importers' reports (Fig. 2) show direct trade rose from 599,431 pieces in 2000 to 1,114,069 in 2009, dipping to 988,535 pieces in 2010. The 2007 peak of 1,590,268 was due to large numbers imported from Indonesia. Exporters' reports do not reveal the 2007 peak but show a similar overall increasing trend with exports rising from 837,270 in 2000 to 1,590,268 in 2009 and a dip to 1,424,233 in 2010.

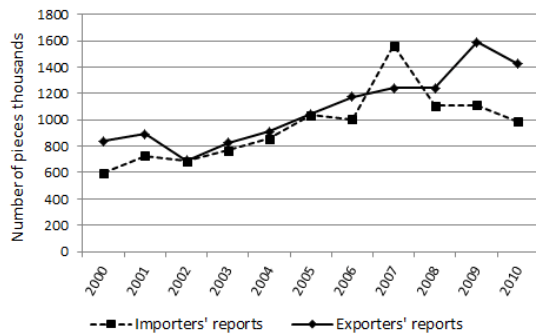


Figure 2. Trade in pieces of live coral (thousands) identified to species or genus. Coral pieces recorded as 'live' in the database but identified only to order level (*Scleractinia* spp.) were excluded from the analysis because these are pieces of substrate with other, non-CITES-listed, living animals attached (CITES 2008).

Producers and consumers

Trade is dominated by Indonesia. Over the period 2000–2010 this country has supplied an average of 70% of imports according to importers' reports. Other important suppliers include Fiji (10.3%), Tonga (5.3%), Australia (4.5%) and Solomon Islands (4.2%) with a number of other countries supplying smaller amounts (e.g. Haiti 0.6%).

Importers' reports show that over the period 2000–2010, the US accounted for an average of 61% of global trade. European countries took 31%.

Maricultured coral in trade

For the purposes of this analysis, source codes C, F and R were considered to refer to maricultured corals. These codes have agreed definitions (Table 2) and exporters self-determine the appropriate code when applying for a permit. This has to be endorsed by the exporting country Management Authority before the permit is issued and there may be some inconsistencies in the way these codes are applied.

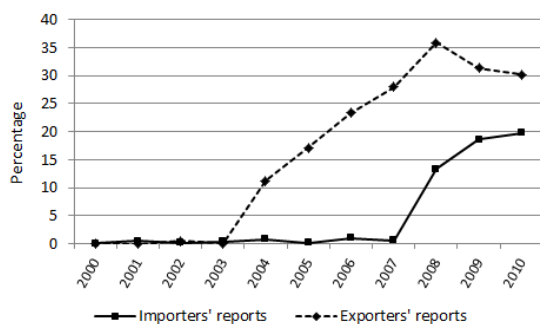


Figure 3. Percentage of live corals in direct trade reported with source codes C (bred in captivity), F (produced in captivity) and R (ranching). The rest are taken from the wild. Note: Exporters' reports for the sources codes C, F and R for 2010 show that all except one specimen were recorded as source code F. Importers' reports showed 99.7% as source code F and the rest under C and R.

C	Bred in captivity in accordance with Resolution Conf. 10.16 (Rev.) i.e. in a controlled environment (CITES 1997). Note: Genuine captive bred corals reared in land-based facilities (i.e. a controlled environment) are produced by some public aquaria and hobbyists, but availability for commercial trade is currently extremely limited.
F	Produced in captivity but not meeting all the requirements of Resolution Conf. 10.16 (Rev.) (CITES 1997). Note: These corals are produced by cultivation of fragments taken from larger or 'mother' colonies. First generation corals are obtained by fragmentation of the original wild coral. Second or subsequent generations are produced by fragmenting 'daughter' colonies derived from the original 'mother'. They are grown in open seabed facilities, not a controlled environment.
R	Ranching specimens: specimens taken as eggs or juveniles from the wild and reared in a controlled environment. Note: There are currently no production systems for commercial trade that rear wild-taken eggs or planulae in a land-based facility likely to meet the definition of a 'controlled environment' (Fleming pers. comm. 2012).

Table 2. Definitions of source codes for C, F and R (CITES 2011) and explanatory notes.

Exporters first record trade in maricultured corals in 2004, but importers do not record it at any significant level until 2008 (Fig. 3). In 2010, these corals accounted for 20% of total live trade according to importers' reports and 30% according to exporters' reports. Both importer and exporter reports show that maricultured corals come almost entirely from Indonesia. Since 2002 the Indonesian government has promoted coral mariculture with the intention that it may gradually replace wild-harvest (Timotius *et al.* 2009). The significant disparity in the mid-2000s could possibly reflect the importance Indonesia places on reporting progress in mariculture.

	Importers' reports		Exporters' reports	
	Total pieces	% CFR	Total pieces	% CFR
Acroporidae	222424	58.4	363121	75.5
Pocilloporidae	41105	52.5	82179	59.4
Pectiniidae	18768	9.6	19151	48.9
Merulinidae	17157	26.1	44730	23.2
Caryophylliidae	175676	11.3	215169	20.7
Faviidae	89914	7.2	105126	14.9
Oculinidae	16071	11.9	33839	14.4
Dendrophylliidae	58911	6.1	79855	10.4
Poritidae	94033	6.2	199436	4.1
Milleporidae	1611	0.2	6730	0.5
Stylasteridae	1794	0.6	5338	0.2
Fungiidae	54972	0.1	93003	0.0
Agariciidae	18486	0.0	13958	0.0
Helioporidae	1113	0.0	2425	0.0
Mussidae	110468	0.0	56796	0.0
Trachyphylliidae	55463	0.1	66860	0.0
Tubiporidae	10560	0.0	18948	0.0

Table 3. Quantity of live corals in trade in 2010 and the percentages declared under source codes C, F and R. The rest were taken from the wild.

An analysis of 2010 records (Table 3) shows that the highest proportion of maricultured corals in trade is amongst the fast-growing, small-polyp species from the families Acroporidae and Pocilloporidae. An increasing proportion from the families Merulinidae and Pectinidae are also reported as maricultured. Maricultured corals in the Family Caryophylliidae are reported to be *Euphyllia ancora* and *E. glabrescens* and in the family Faviidae, *Echinopora lamellosa* and *Caulastrea* spp.. The overall proportion of slower-growing, large-polyp species in trade is currently very low or zero.

Dead corals

Dead corals are pieces of coral that are dead when exported but that may have been alive when collected. The structure of the corallites is still intact and they should be identifiable to species or genus and recorded on CITES permits as such (CITES 2008).

Obtaining accurate results for this category was difficult because of incomplete export records, in particular, lack of data from major supplying countries such as Solomon Islands. Import data also contained apparent discrepancies with some corals (e.g. *Catalaphyllia*, *Euphyllia*, *Plerogyra*) recorded as 'raw coral' in the database on the basis of annual report data, but most likely to be live specimens.

Corals used for the decorative market come mainly from the genera *Acropora* and *Pocillopora* as well as the family *Fungiida*. Blue Coral *Heliopora caerulea* and Organpipe Coral *Tubipora musica* are also used (Bentley 1998; Lovell 2001; Kinch *et al.* 2011). Therefore imports of these taxa alone were analyzed.

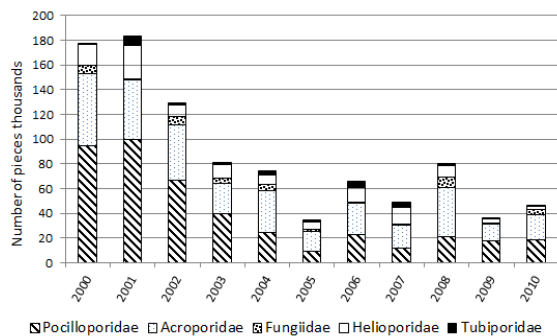


Figure 4. Direct imports of raw coral (identified to species and/or genus) from the key families used for the decorative market.

The number of pieces of raw coral from the selected families (Fig. 4) fell from around 180 thousand in 2001 and 2002 to 46,704 in 2010. Fiji, Vietnam and Mozambique contributed significantly to trade in the early 2000s, but by 2010 Vietnam and Mozambique were no longer in the market and the majority of pieces were imported from Solomon Islands.

Discussion

The CITES Trade Database contains valuable data about the coral trade although some anomalies emerged from this study, including differences between exporter's and importers' reports. These irregularities may reflect the basis of reporting (actual trade versus permits issued), misreporting (e.g. listing of live corals as raw corals) or missing annual reports. Despite the discrepancies, some trends are apparent.

Based on import data, trade in coral rock is on a declining trend, falling from 2,527mt in 2005 to 1,233mt in 2010. Exports from some countries have ceased (see below) and Fiji annual export quotas have been cut from 1,432mt in 2007 to 805mt in 2009 (CITES 2012b). Artificial (non-reef) live rock is now widely available and provides a viable alternative which may have contributed to the downward trend in trade in wild live coral rock. Trade in dead coral for decorative purposes is also declining, falling from around 180 thousand in 2001 and 2002 to 6.7 thousand in 2010. In contrast, trade in live corals for aquaria shows an overall increasing trend. Importers' reports show imports rose from nearly 600 thousand pieces in 2000 to 1.1 million in 2009.

Trade in coral products can bring economic benefits to coastal communities (Lovell and McLardy 2008). However, considering the well documented stresses faced by coral reefs and the decline in coral cover in the Indo-Pacific (Bruno and Selig 2007; Burke *et al.* 2011) it is vital that coral harvesting is managed to ensure long-term sustainability. Collection of corals can result in selective population changes and reduced abundance of exploited species (Ross 1984; Knittweis and Wolff 2010; Jones 2011). Extraction of live rock is potentially damaging because it removes or damages habitat, undermines the structure of the reef and can lead to increased erosion (Lovell 2001).

Recently, a number of countries have introduced legislation prohibiting harvesting and commercial trade in corals and coral rock. These include Mozambique (Order of the Ministry of Fisheries, 2002) and Vietnam (Circular N° 02/2006/TT-BTS of March 20, 2006). Vanuatu prohibited the export of wild-harvested corals in 2009 (Anon 2009). Export of live rock from the Marshall Islands ceased in 2007 (Edwards 2011). In 2008, Tonga banned live rock harvesting and reduced the live coral quota to 150 pieces per week per exporter (Anon 2008).

Inclusion of corals in CITES Appendix II has been one of the drivers of management action for coral harvesting because of the requirements placed on Parties to CITES if they wish to conduct international trade. The 'non-detriment finding' (NDF) is an important tool in this respect (CITES 2012a) and this methodology has been assessed in cases studies on coral fisheries in Australia (Atkinson *et al.* 2008) and

Indonesia (Suharsono and Bruckner 2008). Guidance on conducting NDFs has been updated (CITES 2012a), but management challenges and uncertainties still remain. For example, Indonesia has established species quotas for harvesting and export of live coral from different regions but these are not established at site level and there is a danger of local or regional over-exploitation (Timotius *et al.* 2009; Knittweis and Wolff 2010). Bruckner and Borneman (2006) concluded that quotas for certain species were contrary to observed abundances and known information on life history strategies.

The EU, under stricter domestic measures, requires an NDF for imports of CITES Appendix II species and has raised concerns that have led to trade suspensions for species from Indonesia and elsewhere, even though they may have been allocated quotas by the source country Management Authority. Examples of current suspensions for wild-collected specimens include *Catalaphyllia jardinei* from Indonesia and Solomon Islands, *Trachyphyllia geoffroyi* from Fiji and Indonesia, *Scolymia vitiensis* from Tonga and Indonesia, *Plerogyra* spp. from Indonesia and *Agaricia agaricites* from Haiti (EU 2009).

Maricultured corals appeared in trade in the mid-2000s and by 2010 accounted for 20% of trade according to importers' reports. Techniques for asexual propagation of corals are relatively straightforward. Virtually all 'small polyp', fast-growing varieties such as *Acropora*, *Montipora* and *Pocillopora* can be 'fragmented' and the pieces grown-out to produce colonies of marketable size. However, there has been significantly less success with many of the large polyp corals such as *Catalaphyllia*, *Plerogyra*, *Trachyphyllia*, *Heliopfungia*, *Scolymia* and *Cynarina* that are slow growing and more difficult to propagate. It is these taxa where mariculture would be particularly beneficial because of high demand yet for some species, lower, patchier distributions in the wild.

Another challenge is in the monitoring of coral mariculture operations. For example, in Indonesia discrepancies have been found between company reports and facts in the field with regard to species and numbers transplanted (Timotius *et al.* 2009).

Acknowledgement

Grateful thanks to Vin Fleming, Joint Nature Conservation Committee, UK for invaluable advice on interpretation of CITES data and to colleagues who have provided useful insights into the coral trade. We are also very grateful to Barbara Best, Cara Cooper and Daniel Thornhill for their helpful and constructive comments.

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