Trade in Coral Reef Animals, Algae and Products: An Overview

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Statement of Issue

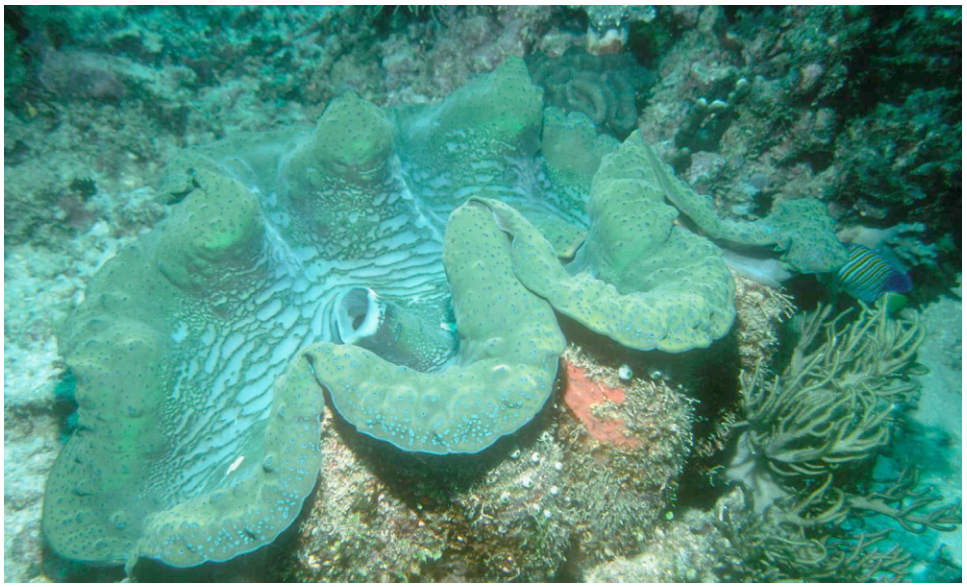

Photo: Roger Steene

Giant clam on coral reef in Raja Ampat, Indonesia

IN many countries, domestic and international trade in coral reef species and products is driving the overexploitation of reef resources and the use of destructive fishing practices that destroy reef habitats. These unsustainable and destructive practices are altering the ecosystem functions of reefs and greatly diminishing long-term benefits to local communities. Although often referred to as "productive" ecosystems, coral reefs can be easily overexploited and must be carefully managed and monitored. Coral reefs are characterized by many species with relatively low population numbers, many rare species, complex food webs, and tight-nutrient recycling which makes reefs especially vulnerable to overexploitation.

Numerous presentations at the 9th International Coral Reef Symposium addressed various aspects of commercial trade and management issues. An overview of trade issues is presented in this paper, with particular emphasis on issues not covered in other chapters. Major issues associated with trade, both domestic and international, include:

- Overexploitation of reef resources.
- Targeting of spawning aggregation sites.
- Use of destructive fishing practices, such as blast fishing, poisons (cyanide), dredging, trawling and muro-ami drive nets.
- Environmental impacts of seaweed mariculture in reef environments.
- Vulnerability of reefs to extractive uses following bleaching events.
- High incidence of paralysis and death in collectors associated with the inappropriate use of diving equipment (such as hookah rigs).

Please refer to these other relevant chapters as well – *Conservation Biology of Coral Reef Fishes*, *Coral Reef Fisheries, Destructive Fishing Practices, Marine Ornamental Trade,* and *Status Reports* from the Global Coral Reef Monitoring Network and Reef Check.

State of Knowledge

Coral Reef Animals and Products in International Trade

International trade involves live reef substrate ("live rock"), live corals, fish and invertebrates for the marine aquarium trade; live reef fish, giant clams, giant tritons, lobsters, shrimp, clams and snails (*Trochus*) for the live food fish trade; dead and dried sea cucumbers (beche-de-mer), fish, sharks, sea turtles, seahorses, and other invertebrates for the dried food and medicinal trades; and dead and dried

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corals, precious corals (black, red, gold, bamboo), seashells, starfish, and other invertebrates for the curio and jewelry trades. Mariculture of seaweed and other species on and near coral reefs is also increasing, as is black pearl production in lagoon areas.

Trade is also driving the loss of critical habitats associated with coral reef ecosystems, especially mangrove forests and seagrasses. The destruction and loss of mangrove forests occurs for shrimp mariculture and wood harvest; destruction is also occurring due to upland and coastal development.

Geographic Extent of Trade, Overfishing and Destructive Fishing Practices

Many organisms of high economic value have been impacted by overfishing in all coral reef regions of the world, as indicated by the results of Reef Check surveys (see *Reef Check - Status of Reef Health Indicators*). The international trade is relatively mobile, moving from area to area. Even remote reefs are targeted for collection, particularly as nearby reefs are overfished. The targeting and decimation of grouper spawning aggregations has also been widely reported from areas where live reef food fish collection is occurring – over a very short time period, almost the entire adult population can be collected at these spawning aggregations.

The trade in live reef fish has grown in volume and expanded its geographic extent over the last decade. The use of cyanide to stun and capture target species began in the Philippines in the 1960s and spread throughout the Philippines and Indonesia. As the trade in live reef fish has grown, the use of cyanide for the capture of both ornamental and live reef food fish species has spread across the Indo-Pacific region, including the Western Indian Ocean.

Destructive and harmful fishing practices were reported in the following countries and regions: Federates States of Micronesia, India, Indonesia, Madagascar, Malaysia, Pacific Islands, Papua New Guinea, the Philippines, Republic of Mauritius, South Africa, Tanzania, Vietnam.

Marine ornamental fish are presently collected in over 40 countries to supply hobbyists primarily in the United States, European Union, Japan and Canada. Overexploitation, the use of cyanide, and the local loss of rare or endemic species were reported in some countries.

Sea Cucumber Overexploitation

Overfishing of sea cucumbers has occurred in many locals, even while under some sort of management plan. For example, sea cucumber fisheries were closed in the late 1990s, due to decreasing catch rates, in both the Great Barrier Reef of Australia and the Commonwealth of the Northern Mariana Islands (CNMI) (Trianni, 2000; Uthicke and Benzie, 2000). In the CNMI, a pre-harvest stock assessment was not conducted and the fishery was managed based on catch-effort statistics only. This approach was not effective – an analysis revealed that 78-90 percent of the initial population sizes had been over-collected. Pre-harvest stock assessments along with harvest statistics are essential for coherent management.

Seaweed Mariculture

Globally, the collection and mariculture of seaweed generates over US$6 billion per year. Approximately one half of this trade is from the harvest of wild seaweed, and one half from seaweed mariculture. In the tropics, seaweed farms are located primarily on coral reefs or reef flats, where *Euchema spp*. and *Kappaphycus spp*. are farmed for the global demand for carrageenan. Three major types of environmental impacts are identified with tropical seaweed farming in coral reef habitats (Zemke-White, 2000): 1) the effects of introducing seaweed species to a new location, 2) effects from farming operation, and 3) effects of related human activities. Given the spread of seaweed farming in the tropics, possible impacts on coral reefs, and paucity of impact studies, a more comprehensive assessment of potential and realized environmental impacts is needed.

The introduction of alien species of macroalgae may impact reefs by reducing the grazing pressures by herbivorous fishes on native macroalgae, as documented in Kaneohe Bay, Hawaii (Conklin, 2000). Fishes forage far from shelter onto reef flats to feed on preferred algal species that have been introduced into the bay, ignoring less preferred species that are more easily obtainable and potentially allowing these native species to overgrow corals.

Collection for Pharmaceuticals and Mariculture

The collection of coral reef organisms for the pharmaceutical trade is increasing, requiring that appropriate harvest and mariculture strategies be developed. Organisms expressing modular growth, such as octocorals and corals, are often presumed to have "indeterminate" growth, that is, colonies continue growing after reaching maturity. This presumption of

Photo: Coastal Resources Center, URI

Seaweed farming in East Kalimantan, Indonesia

indeterminate growth among modular taxa suggests that colonies readily recover from harvesting, and that they can be easily partitioned to generate brood stock for mariculture. However, one study on the Caribbean gorgonian *Pseudopterogorgia elisabethae*—harvested for the extraction of commercially valuable pseudopterosins—illustrates that this assumption is incorrect (Lasker, 2000). An analysis of growth patterns in *P. elisabethae* indicates that it has "determinate" growth. Therefore, the assumptions about the resilience of colonies to harvesting are probably inaccurate. Species-specific analyses may be required to develop management plans and mariculture techniques.

Vulnerability of Reefs to Extractive uses following Coral Bleaching Events

Several studies have documented shifts in species richness and diversity of fishes at reefs following significant coral bleaching events in 1998. Some of these reefs were reported to be at risk from illicit harvests that threaten recovery of the fish communities from the bleaching events (Donaldson and Myers, 2000).

Rarity of Species and Monitoring Programs

International trade often targets rare and relatively rare species, such as groupers and wrasses for the live food fish trade and rare fish and invertebrates for the live marine aquarium trade; these organisms often command the highest prices. A species may be rare in terms of its numerical abundance or its geographic range. An analysis of rarity in coral reef fish communities confirms some patterns of rarity in communities, but also highlights the generally poor availability of data for marine organisms (Dulvy and Polunin, 2000). The status of a species as rare or common has important implications for local ecological interactions and for conservation and management issues (Caley et al., 2000).

Studies of fishing impacts over small geographic scales may have little statistical power to detect rarity or extinction of large rare species, which theoretically are more vulnerable to exploitation than smaller species due to lower rates of population increases. This in turn may explain why so few studies have documented marine extinction, and highlights the need for large geographic assessments of fish communities to capture the large, rarer species. To understand patterns of biodiversity, many community ecologists now recognize that there is a need to synthesize large-scale phenomena with local processes (Hughes et al., 2000).

Reef Connectedness, and Sources and Sinks

Critical to the management of reef resources is an understanding of how ecologically "linked" or "connected" reef populations are on small, medium, and large spatial scales. Does larval or juvenile recruitment depend upon "sources" other than that particular reef or locale? Or is the population "self-seeding" and relatively independent of other sources of recruitment? Presentations documented both scenarios, highlighting the need to continue studies on the degree and scale of interaction among local populations (Figueira, 2000; Sale, 2000).

The white grunt (*Haemulon plumieri*) is an important component of the reef-based fisheries of the Wider Caribbean, and current indications are that it is on the decline. Spawning/settlement experiments suggest that populations have some degree of self-recruitment; thus local management needs to protect critical habitat and establish marine reserves (Hill, 2000). In a second example, a mitochondrial analysis of genetic structure in the rabbitfish (*Signans fuscescens)* indicated that the population was self-recruiting and that larval dispersal may not be as widespread as is usually assumed among fishes with an early planktonic phase (Ochavillo et al., 2000). This implies that management can be more local in scale. A third example examined the assumption that some reef species with extended planktonic larval stages may have a very broad larval distribution range. The planktonic larval duration for the spiny lobster (*Panulirus argus*) is estimated to be 6 months to one year; this lobster is a major fishery species throughout the Central Western Atlantic. Management of this key fishery species will require coordination on a wide geo-political scale (Yeung, 2000).

The degree to which coral reefs are dependent on other tropical habitats is another important aspect of connectedness. Mangrove forests and seagrass meadows

Photo: Coastal Resources Center, URI

Coral for sale in Lampung, Indonesia

are critical habitats for many reef fishes during some portion of their life-history. For example, one study documented that most reef fish species were absent, or present only in reduced densities, in those bays or island reefs lacking these critical nursery habitats (Nagelkerken et al., 2000).

Deeper Reefs as Spatial Refugia

For some species, deeper reefs may be a spatial refugia that has been maintaining fisheries despite the intense fishing pressures in shallower habitats (Ferreira and Maida, 2000). However, exploitation in these deeper reefs are increasing as the technology develops, and as local fishers move into deeper waters. Enhanced SCUBA technologies and the use of submersibles are allowing the collection of animals from deeper reefs for the aquarium trade. Fishers in the Philippines are draping narrow, but long, fishing nets over reefs that are several hundred feet deep; these nets are left out all night to ensnare fish, molluscs and other invertebrates. Very little is known about the ecology of these deeper reefs or potential impacts from exploitation, and it is extremely difficult to monitor or manage at these depths.

Human Health Impacts of Diving Practices

Collectors face serious health problems due to improper hookah and diving practices that lead to frequent decompression incidences, particularly for the international trade of live food fish, aquarium fish and lobsters. The Diving Fisherman Project is investigating the extent of diving-related injury to indigenous diving communities in East Asia, and providing help and assistance to avoid injuries (Cross et al., 2000). The project estimates that in the Asia Pacific area there are 50,000 to 80,000 indigenous divers, primarily in Indonesia and the Philippines. Mortality among divers is about 4 percent per year; 10 percent have obvious difficulty in walking; 18 percent have experienced some degree of paralysis; 20 percent exhibit clinical signs of spinal cord injuries; and 38 percent are diagnosed with aseptic necrosis of bone. Hookah diving is a dangerous and unsafe way of fishing. Most divers indicated that they do not want their children to take up hookah diving.

Devastating impacts on collector health from hookah and scuba diving also occur along the Miskito Coast of Central America – close to 100 percent of divers show symptoms of neurological damage, presumably due to inadequate decompression. The industrial fleet has resorted to fishing in deeper waters due to depletion of lobster reserves in shallower waters. The human health impacts of international trade are often ignored, but need to be addressed on a local and global basis through education, improved regulation, reform of the fisheries, and inclusion of collector health considerations in certification schemes.

Photo: Barbara Best

Child cleaning seashell in Cebu, Philippines

Management and Policy Implications

Creative trade regulations and market incentives that reward and encourage responsible use of coral reef resources and discourage destructive practices are possible strategies to address the negative environmental impacts of the trade. Central to the use of these market forces and regulations is the concept of *shifting the burden of proof* – commercial users must demonstrate that products are collected sustainably and without the use of destructive practices, rather than the burden falling on others to prove that harm has been done. Creative import regulations

and eco-certification schemes can shift the burden of proof onto the commercial users who profit from the use of these resources, and encourage sustainable management in source countries.

Importing countries, whose citizens are driving the demand for some coral reef animals, must share responsibility along with the exporting countries for creating market incentives for sustainable products. For example, importing countries could require individual importers to show documentation that products came from areas under sustainable management; importers would then have to work with the exporters and collectors in the source country to ensure sustainable practices are implemented. Demand can also be driven by educated and well-informed consumers in importing countries, through consumer choice for eco-certified products.

Specific Recommendations for Actions

- Adopt precautionary, ecosystem-based approaches to coral reef management.
- Prohibit commercial exploitation of a species until a management plan has been developed that includes that particular species.
- Develop management plans with strong stakeholder involvement, and balance commercial uses with local uses and needs.
- Utilize environmental performance bonds, posted by commercial operators, as stakeholder investment.
- Establish substantial ecological, no-take areas as integral components of all management plans.
- Zone specific areas for specific uses and users, and establish appropriate monitoring plans for each area and use. Where appropriate, establish well-defined, small geographic areas that can be used as concessions to individuals, cooperatives or communities to increase stakeholder "investment" in sustainable use.
- Address destructive fishing practices through strong enforcement and appropriate fines.
- Share responsibility among exporting and importing countries. Importing countries can require individual importers to show documentation that animals and products were not taken by destructive means, and that they were taken from areas under sustainable management. Stiff fines should be levied on importers for falsification of documentation.
- Address the health impacts on divers from excessive diving and hold commercial operators responsible for diving safety. Include collector health as a component of permitting and eco-certification schemes.
- Educate consumers to the role that consumer choice can play in reducing impacts on reefs.
- Promote environmentally-sound mariculture.
- Characterize the nature, volume, and ecological impact of the marine curio trade, such as seashells, and develop appropriate management strategies.

Useful References and Resources

This paper was prepared from presentations at the 9th International Coral Reef Symposium. Authors and titles of referenced presentations can be found at: www.nova.edu/ocean/9icrs/

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Web site: www.coralreef.gov

Destructive Fishing Practices

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Statement of Issue

DESTRUCTIVE fishing practices (DFPs) are those that result in direct damage to either the fished habitat or the primary habitat-structuring organisms in that habitat (for example, scleractinian corals), and include such well-known problems as blast and cyanide fishing and muro-ami drive nets. DFPs have been recognized as important threats to coral reefs on a regional basis for at least two decades, and are becoming more widespread and globally significant. In fact, in a number of developing countries, particularly those in the center of reef diversity in SE Asia, DFPs represent the most immediate and significant threat to the continued existence of coral reefs.

Photo: Lida Pet-Soude

Dynamite blast-fishing

State of Knowledge

Widespread Use of Destructive Fishing Practices

DFPs are reported from every tropical sea and encompass a wide range of techniques. The two undisputed "heavy-weights" are blast or dynamite fishing, and cyanide fishing for both the live reef fish aquarium trade and the Asian live reef food fish trade. These two techniques are used widely throughout the Indo-West Pacific with an epicenter in SE Asia. Blasting is also common in the Red Sea and Western Indian Ocean. Estimates suggest that up to 80 percent of Indonesian and Philippine reefs have been damaged by blast and cyanide fishing. Other common DFPs in the Indo-West Pacific include muro-ami drive nets, inshore trawling, and trap fishing. An interesting phenomenon prevalent in the Hawaiian Islands is damage from derelict fishing gear, which causes entanglement of marine life, direct damage to the reef, and introduction of alien species. In the Caribbean, DFPs are not as prevalent, although steel trap fishing and lobster traps can result in the crushing of substrate and the use of poisons like bleach are reported.

Impacts on Coral Reefs

Unlike many other anthropogenic impacts on coral reefs, DFPs directly destroy the reef framework, making recovery a long and difficult process even after the acute threat is removed. Studies indicate that the rubble fields created from blasting are a "rough neighborhood" for juvenile hard corals; the constantly shifting rubble buries new coral growth, while the aggressive soft coral mats that often invade these rubble fields are also capable of out-competing and even killing juvenile hard corals. Additionally, DFPs are often species-indiscriminate and have been shown to directly reduce fish diversity. As with most gears with high catchability, DFPs typically lead to smaller average sizes of target species. Just as importantly, DFPs are not limited to reefs near large population centers; rather, a paradox exists whereby the most remote reefs are often the most damaged by DFPs due to a complete lack of enforcement in these regions.

Socioeconomic Causes

The socioeconomic causes of DFPs are complex and vary from place to place. In many coastal communities, poverty and declining catches from conventional fishing techniques encourages fishers to use DFPs. In other areas, however, some recent studies have suggested that it is "greed rather than need" that drives the introduction and spread of DFPs like many criminal activities; it is simply a way to make more money faster than can be obtained from legal occupations. In the case of the live reef fish

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trade, traders and exporters, frequently in collusion with corrupt local officials, have often systematically introduced cyanide fishing. In Indonesia, for example, fishers engaged in blasting and cyanide fishing can easily earn more than government officials or university professors. In one case study, the "outlaw image" was a major incentive for young fishers to take up DFPs.

Management Solutions to Destructive Practices

Regarding solutions to the DFP problem, numerous case studies documented both successes and failures. There is very strong evidence that marine protected areas (MPA) are one of the most effective means of preventing DFPs, especially when a combination of patrols and active marine tourism discourages the use of DFPs. Unfortunately, enforcement activities both inside and outside MPAs are often hampered by persistent corruption, especially in the lucrative live reef fish trade, and by a lack of funding. At times there seems to be an unwritten policy of both conservation non-governmental organizations (NGO) and development agencies that enforcement is a repressive activity that should not be funded in developing countries, even when local communities and DFP practitioners alike agree that strict enforcement is a necessity. Of course, the solution to DFPs clearly must be a balanced and integrated one and beefed-up enforcement capacities and activities must play an important role.

The use of alternative income generation schemes to lure fishers from DFPs has proven difficult and failures seem to outnumber successes. One problem is the lucrative nature of most DFPs; it is often difficult to devise alternative income generation schemes that earn nearly as much as DFPs. Seaweed farming, or mariculture, is one scheme that has shown considerable earnings potential, although in one case the relatively large amount of free time afforded seaweed farmers resulted in "recreational cyanide fishing." Mariculture of target species for both the live reef fish aquarium trade and food fish trades also shows promise. Unfortunately, larger companies often undertake these activities with little benefit to the local fishers otherwise involved in DFPs.

Mixed results have also been achieved in the case of training fishers in non-destructive techniques to replace DFPs. In the live reef fish trade, there have been some successes in converting cyanide fishers to the use of nets for aquarium fish and hook-and-line for live reef food fish, particularly in the Philippines. But few such efforts have yet been implemented in other Southeast Asian countries where cyanide fishing is a problem, such as Indonesia and Vietnam. While training in non-destructive techniques prevents damage to the reef itself, it does not in itself prevent overfishing. For example, hook-and-line fishers have wiped out grouper spawning aggregations in Palau nearly as efficiently as would be the case with cyanide. Likewise, training and regulations in the Philippines to switch fishers from muro-ami—where rocks are pounded along the reef to drive fish into a trap net—to pa-aling—where the fish are chased with hundreds of bubbling air hoses instead—may prevent damage to the reef. But pa-aling still removes up to 50 percent of the standing fish biomass on a reef in one net operation. In short, approaches to reducing destructive fishing need to be coupled with more comprehensive measures to prevent overfishing.

One relatively new solution to reduce DFPs, and cyanide fishing in particular, involves the use of "eco-labelling" or certification to ensure that fish and corals exported for the aquarium trade are harvested at sustainable levels without the use of destructive methods. This approach is being widely advocated by private sector and non-government groups in the United States, the world's largest importing country for the aquarium trade. If combined with tighter regulations to prevent the export of "undesirable aquarium species"—those that do not survive in aquaria due to dietary or habitat requirements or behavioral incompatibilities—certification has the potential to greatly reduce both cyanide fishing and unnecessary mortality of exported fish and invertebrates. It depends, however, on the growth of consumer demand for "environmentally-friendly" fish and other reef species, and willingness on the part of governments of consumer countries to regulate—and possibly restrict—the import of non-certified reef species. Unfortunately, in the case of blast fishing, the majority of the catch is destined for low-value local markets where certification is not an applicable strategy.

Relevant Actions Taken to Address the Issue

Governments, researchers, national and international conservation NGOs and development aid agencies are now realizing the full extent of the DFP problem and are mobilizing to combat DFPs. Research is focusing on both the effects of DFPs, the extent of reef damage caused by DFPs, and methods to enhance recovery from this damage. International NGOs and aid agencies are helping many MPAs beef up enforcement activities and involve the private, marine tourism sector in prevention of DFPs. Government agencies are becoming more actively involved

Photo: Jeffrey Jeffords, divergallery.com

Fish collector employs cyanide in reef fish collection, Capone Islands, Philippines

as well. The U.S. National Marine Fisheries Service is increasing efforts to remove derelict fishing gear in the Hawaiian Islands. The International Marinelife Alliance's Destructive Fishing Reform Initiative, carried out in partnership with a wide variety of other NGOs and government agencies throughout the Asia-Pacific, is using a combination of education for both fishers and government agencies, enforcement, and monitoring of the live reef fish trade to combat cyanide fishing (and prevent its introduction into new source countries), overfishing and other abuses in the live reef fish trade. The Marine Aquarium Council in the United States is leading an effort to establish a certification system for aquarium organisms in international trade.

Management and Policy Implications

DFPs present an immediate and expanding threat to coral reefs throughout the world, with SE Asian reefs in the epicenter of global marine biodiversity at highest risk. Management solutions are urgently needed to address this problem, which threatens to severely degrade a large percentage of the world's most diverse reefs *within this decade*. Priority recommendations for action are included below.

Specific Recommendations for Action

- ***Focus immediate policy and funding initiatives on stronger enforcement against DFPs***. Most countries have laws against DFPs, but glaring legal loopholes must be closed and persistent problems with corruption in the legal system addressed. Specific regulations banning possession and use of key components of DFPs such as blasting caps and cyanide would greatly facilitate enforcement. Hookah compressors should be banned for the capture of live reef food fish (which can be captured with hook-and-line), but may be necessary for aquarium fish collectors even when using best practices. The wholesale ban of compressors is therefore problematic. Banning their use would be unfair to aquarium fishers trying to do the right thing, while allowing compressors creates a loophole for those fishers still using cyanide to catch fish. Policymakers must keep in mind how the nuances between the food fish and aquarium trades have the potential to create incompatibilities in policy. Perhaps even more importantly, enforcement institutions must be educated on the tremendous damage caused by DFPs, while patrol time both inside and outside of MPAs must be greatly increased. Firsthand experience from conservation agencies and suggestions from destructive fishers themselves show that stronger enforcement is an essential prerequisite for curbing DFPs.
- ***Expand and strengthen the world's MPA network***. MPAs are one of the most effective tools against destructive fishing, though properly focused funding assistance is still needed in many tropical developing country MPAs to move beyond "paper park" status.
- ***Fund applied research on restoration of DFP-damaged reefs***. Current reef restoration efforts are largely focused on extremely high-cost rehabilitation of damage from ship groundings. There is an urgent need for inexpensive, low-technology restoration techniques for the vast areas of blast and cyanide damaged reefs prevalent in areas of the Indo-West Pacific. Local community involvement in restoration efforts can both build local support and provide a potential source of livelihood.
- ***Develop and support "ecolabelling" certification systems to provide market incentives against DFPs***. Significant progress has been made by the Marine Aquarium Council and its partners towards developing a certification system sustainable for collection of reef organisms for the aquarium trade, but the system has yet to function in the real world, and it is unclear if and when it will become a major driver of the aquarium fish market. Similar systems might conceivably be applied to live reef food fish and

lobsters, but more study is needed to determine if it is possible to mobilize consumers in Asian markets against DFP-caught products or not. A more promising route for Asian markets may be to pressure and work with industry players themselves to develop an industry code of conduct that could be independently monitored.

Useful References and Resources

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The Marine Ornamental Trade

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Statement of Issue

THE international trade in marine ornamentals from coral reefs is increasing in many countries and expanding to most coral reef regions. Although the ornamental trade may provide alternative sources of income for some communities, there are still major environmental and management concerns over this trade, including: the use of destructive fishing and collection practices, especially the use of cyanide to stun and then capture fish alive; overexploitation; targeting of rare or endemic species which can bring the highest prices; collection of organisms from deeper reefs; the removal of reef substrate or "live rock"; the collection of inappropriate species that do not survive well in aquaria; high mortality rates associated with improper handling and transport; and the health impacts on human collectors from excessive diving and the use of hookah rigs.

Many developing countries are currently ill equipped to manage this rapidly growing industry. However, many of these animals and products are destined for hobbyists in developed countries, where awareness and concern about the use of reef animals is growing. Increased awareness in both hobbyists and importing countries may be used to generate market incentives for the sustainable management of reef organisms.

At the 9th ICRS, presentations and posters from several symposia addressed different aspects of the marine ornamental trade, including the nature of the trade, environmental impacts, case studies, and strategies and options for addressing the impacts and managing the industry.

State of Knowledge

Extent and Nature of Trade

Over forty countries have a marine aquarium fishery based on coral reef species. It is estimated that over 1000 different species of fish and invertebrates, as well as live reef substrate or "live rock," are presently involved in the trade. At least 20 million fish are captured annually to supply hobbyists primarily in the United States, European Union, Japan and Canada. Invertebrates are an important component of the trade, constituting about 20 percent of the total export. Some of the major exporting countries include the Philippines, Indonesia, and Fiji. In the Pacific region, the live reef fish trade is increasing in importance, for both food fish and aquarium fish. While this trade has the potential for increasing benefits to local Pacific Island communities, experience has shown that the live reef fish trade can be destructive to reef resources if it is not managed and regulated appropriately. Regional differences exist with regard to the collection of coral; throughout most of the Caribbean, coral is viewed as essential fish habitat, and the collection of coral and life rock is prohibited.

Photo: Paul Holthus

Ornamental fishers and boat on shore

CITES and the Marine Ornamental Trade

All stony corals, live rock and *Tridacna (giant clams)* are listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Exports of Appendix II listed species require permits from the exporting countries that state that the export will not be detrimental to the survival of the species or its role in the environment. However, many exporting countries may not have the resources to fully implement the non-detrimental findings. These permits provide a means to monitor the trade through the annual reports by exporting and importing countries. CITES data indicate the trade in live coral and live rock has increased annually at a rate of 12-30 percent with most originating in Indonesia and Fiji and over 80 percent imported by the United States. Several of the most traded live coral genera are slow growing, and may be vulnerable to overexploitation. More studies are

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needed on the life history characteristics, abundance and distribution of species in trade.

Database for the Marine Ornamental Trade
UNEP-World Conservation and Monitoring Centre and the Marine Aquarium Council are collaborating in the creation of the Global Marine Aquarium Database (GMAD) that will form the first comprehensive quantitative analyses of the trade in all marine ornamental organisms. Information is being collated from exporters involved in the trade. This database will be especially useful for describing the nature and volume of trade in non-CITES animals.

Culturing of Marine Ornamentals
The artificial propagation of marine ornamental species has the potential to supply some of the market demand, alleviating some pressure on wild stocks. In South Africa, propagation of corals was conducted by experimenting with current flow, feeding and light to obtain the optimum growth conditions. The twelve most suitable hard corals were selected for culture from the 36 species tested. In the Solomon Islands, light traps and crest nets have been used to capture juvenile fish. The feasibility of harvesting postlarval coral reef fishes and rearing them in captivity for the aquarium trade is being tested for more than 60 species.

Progress is being made in coral and fish propagation, but cultured ornamentals will remain a minor component of the trade for the foreseeable future. Captive breeding of reef organisms is only about 2 percent of the market for fish and slightly more for corals. Aquaculture of marine ornamentals is growing very slowly due to biological and technical constraints, higher costs of cultured animals, and low demand for cultured products by consumers.

Inappropriate Species in Trade
Although improvements have been made in the husbandry of coral reef animals, there are a large number of species collected and sold for the marine aquarium trade, which continue to have low to dismal chances of surviving in aquaria. Included in this group are most azooxanthellae anthozoans, many filter-feeding invertebrates, and certain fishes. The main reasons that these animals do not survive in aquaria are related to diet and the inability of aquaria to supply sufficient amounts or types of nutrients. Expert hobbyists, retailers and researchers have documented many of these animals, which are inappropriate for the trade; a report compiling all these observations was presented, which includes several hundred species.


Photo: Chuck Savall

A pair of orange, white, and black Clark's Anemone Fish in their green host anemone, Fiji

Case Studies From Different Countries

Brazil: In Brazil, there is high concern for the local extinction of many reef species from the capture of ornamental animals and coastal development. Recent studies point to high rate of endemism (up to 20 percent) in reef fishes.

Fiji: Fiji is one of the major exporters of live reef substrate (live rock), fish and invertebrates for the marine aquarium trade. Careful and systematic collection can result in reduced environmental impacts. The challenge that faces responsible exporters is to educate collectors in sustainable reef management.

Maldives: In the Maldives, about 114 species of live tropical fish are exported, with 20 species making up about 75 percent of the exports. In 1999 more than 160,000 fish were exported, mostly to Europe, earning about US$ 300,000. The trade includes species that are very rare in the Maldives, as well as quasi-endemic species. Collection is depleting many favored species in the country, a concern for the biodiversity of reefs.

South Africa: The marine aquarium trade in South Africa has expanded greatly during the past decade. Most animals are collected from the wild (less than 2 percent are maricultured). Poaching is common, and corals are commonly chiseled off reefs that are already degraded by pollution. Many specimens die during transportation and handling, or from placement in unsuitable aquaria. The future of a sustainable supply of corals for the aquarium trade lies in artificial propagation through mariculture, and efforts are underway to culture local corals for the trade.

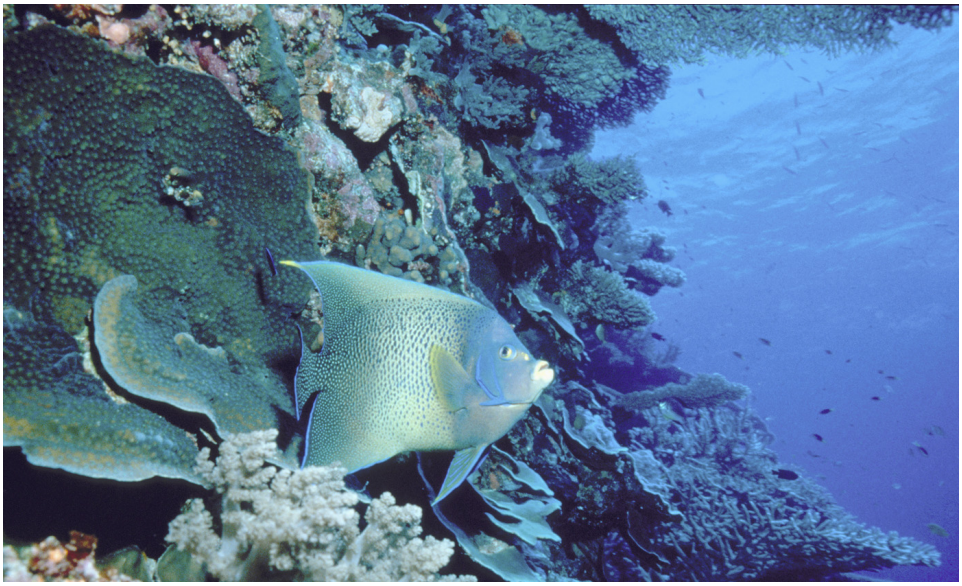

Photo: Great Barrier Reef Marine Park Authority

Angelfish, Great Barrier Reef, Australia

Sri Lanka: For many years the marine ornamental export trade in Sri Lanka was not monitored or regulated, and there were concerns about possible environmental impacts of the fishery. A collaborative program involving resource managers and the ornamental industry was initiated to develop a conservation management plan. Population censuses, along with user assessments, were brought together to produce a plan for the conservation and management of marine ornamental resources that is acceptable to all stakeholders and thus more likely to succeed.

U.S Hawai'ian islands: In Hawai'i, the collecting of reef fish for the aquarium trade has caused multiple-use conflicts between collectors and other users, especially the tourism sector. Intensive monitoring between control areas and collection areas reveals that 8 species targeted by collectors were significantly less abundant (up to 60 percent less) in collection sites. In response to this environmental impact, and with input from the local community, 30 percent of the west Hawai'i coastline was closed to aquarium collecting in 1998. However, latest surveys indicate that impacted areas still have significantly lower abundances.

Shifting the Burden of Proof of Sustainable Use

There has been heightened interest in the trade in coral reef organisms in both importing and exporting countries. Market incentives that reward and encourage responsible use of coral reef resources and discourage destructive practices are being explored as possible strategies to address the negative environmental impacts of the trade. Eco-certification schemes and creative regulations on imports can shift the burden of proof onto the commercial users who profit from the use of these resources, and encourage sustainable management in source countries.

Eco-certification Schemes

If conscientious and increasingly sophisticated marine aquarium hobbyists insist on sustainably collected marine organisms, exporting countries may have an opportunity to maximize their potential in this market. The Marine Aquarium Council (MAC) is an independent, international multi-stakeholder non-profit organization that is developing an eco-certification scheme by bringing together representatives of the aquarium industry, hobbyists, conservation organizations, government agencies, public aquariums, international organizations and others, who have shared interests in the future of the marine aquarium industry, and the marine organisms and habitat it is based on. By creating standards and educating and certifying those engaged in the collection and care of ornamental marine life from reef to aquarium, MAC is providing one potential solution to the problems surrounding the trade. Export countries can benefit in many ways from marine ornamental industry if environmental guidelines are followed. The main challenge is to ensure sustainable reef management by educating collectors, others in the industry and the ultimate buyer.

Importing Countries Must Assume Some Responsibility

Importing countries, whose citizens are driving the demand for aquarium animals, must share some responsibility along with the exporting countries for creating market incentives for sustainable products. The United States, one of the major importers of coral and coral reef animals, is exploring innovative trade measures to ensure that coral reef products were not taken using destructive collection practices, and that corals were collected from areas under sustainable management.

Relevant Actions Being Taken to Address Issue

The Marine Aquarium Council (MAC) is progressing on developing an eco-certification system, which was launched

in late 2001. The MAC Core Standards have been released and are available on its website. The MAC Core Standards consist of three components: Ecosystem and Fisheries Management: Collection, Fishing, and Holding; Handling, Husbandry and Transport.

Reef Check is developing and testing a monitoring protocol for MAC certification. The newly formed MAC Science and Monitoring Advisory Committee will review the monitoring system. The committee will provide ongoing support to MAC on science, research, assessment, and monitoring of coral reefs and marine aquarium organisms in relation to certification, sustainability and environmental impacts.

The Philippines has established cyanide detection centers for the testing of live food fish and aquarium fish destined for export.

The U.S. Government continues to work domestically and internationally to improve the ability of customs officials to properly identify corals in trade through training workshops and the development of a coral identification module for Indo-Pacific corals in trade. The book includes photos, descriptions and a key to corals in trade and has been adopted as the standard identification guide for CITES parties. In 2001, two international workshops were held in Fiji and Indonesia, with support from the United States, to promote the sustainable management, monitoring, and identification of corals and coral reef animals in the trade.

Management and Policy Implications

Promoting best management practices, such as through certification schemes and development of management conservation plans that involve resource users, may be the most effective way to ensure sustainable use of resources.

Specific Recommendations for Action

- Develop management and conservation plans that involve resource users, and thus are more likely to succeed. Ecological no-take reserves should be included in the plans.
- Support industry standards and eco-certification systems, such as the MAC system, that promote best practices and the sustainable management of reef resources.
- Develop policy and legislation to improve reef management and conservation in relation to trade, in both exporting and importing countries, and that encourage certification.
- Raise consumer awareness about environmental issues and the role that consumer choice can play in encouraging sustainable management, and encourage hobbyists to demand certified products.
- Develop and implement appropriate monitoring plans for the aquarium trade.
- Encourage exporters to contribute their data to the Global Marine Aquarium Database to ensure that comprehensive information on the trade is available.
- Discourage the collection and trade in inappropriate species that do not survive in aquaria.
- Discourage the collection and trade of rare or endemic species, or those from deep reefs where monitoring and management are difficult.
- Support scientific research that better defines sustainability and encourage scientists to participate in developing monitoring standards.
- Promote the development of viable culturing of ornamentals, and encourage in situ culturing.
- Promote management, oversight and certification schemes that also include diving safeguards for human collectors from excessive diving, and equitable distribution of profits.

Useful References and Resources

This paper is based upon presentations and posters at the 9th International Coral Reef Symposium, including Mini-Symposia "A Sustainable Trade in Marine Ornamentals: Linking Reef Science, Conservation and Use," "Destructive Fishing Practices," and "Status Reports." Authors and titles of presentations can be found at: www.nova.edu/ocean/9icrs/.

Marine Aquarium Council (MAC) Web site. www.aquariumcouncil.org

CITES Web site: www.cites.org

ICLARM Web site: www.cgiar.org/ICLARM/

UNEP-WCMC Web site. www.unep-wcmc.org

U.S. Coral Reef Task Force Web site, and report on *The International Trade in Coral and Coral Reef Species: the Role of the United States*. Web site: www.coralreef.gov

Secretariat for Pacific Community Web site: www.spc.org.nc/

Traffic Web site: www.traffic.org

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Conservation Biology of Coral Reef Fishes

Terry J. Donaldson [1] and Yvonne Sadovy [2]

Statement of Issue

MANY coral reef fishes are particularly susceptible to overexploitation, not only because of their typical life history traits but also because of their direct and indirect dependence on coral reef habitats, which are also under threat. The presentations at the 9th ICRS reflected the research and concerns of biologists working on a broad range of reef fishes and reef environments regarding the impacts of exploitation and natural impacts on reefs and reef fish communities. Particular emphasis in many of the talks was placed upon the difficulties of detecting and measuring changes in reef fish communities, especially for particularly large or rare species. Moreover, the general lack of information on the biology and habitat requirements of commercially exploited species represents a serious impediment to understanding both natural and anthropogenic impacts. There appears to be a growing consensus that special vigilance is needed to manage and conserve reef fish assemblages.

Three themes were elaborated during this mini-symposium at the 9th ICRS: (1) the increasing and sometimes intensive exploitation of reef fish, often for export, and their vulnerability to such exploitation; (2) the role of habitat, especially at particular life history phases, and (3) the needs and difficulties of monitoring reef fish assemblages.

Photo: S. Zumbrunn

Nassau Grouper in Grand Cayman

State of Knowledge

Exploitation of Reef Fishes

Exploitation of reef fishes appears to be increasing, with a pronounced growth in international trade adding pressure to limited resources. In addition to traditional fisheries, pressure is growing on species being taken in new, non-traditional fisheries, such as the marine aquarium trade, the live reef food fish trade and the trade in fish fry for mariculture. The live reef fish trades may be quite selective in terms of both species and are attractive for aquaria or suitable for food in terms of taste, texture, and size – aquarium size or 'plate' size.

In the Philippines, the live reef fish trade harvests coral trout, *Plectropomus leopardus*, in significant numbers, targeting especially those that are close to first sexual maturation (that is, preferred plate size in restaurants – 30-35 centimeters total length). Ironically, cyanide is often used to "catch" such fish alive; cyanide is used to stun the fish and allow their easy collection. In Australia, this same species represents over 90 percent of all live exports of reef fishes. There is some concern in Australia that the lucrative live reef fish trade will cause excessive expansion of the live fish fishery through reactivation of existing, but dormant, fishing licences, such is the economic promise of this trade. In Sri Lanka, about 200,000 fish are exported each year for the marine aquarium trade, with particularly heavy pressure on certain desirable species (for example, *Labroides dimidiatus*, a wrasse, which represents about 10 percent of the trade in terms of numbers). Both collectors and biologists are expressing concern about the status of some of the more intensively exploited species.

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Critical Role of Habitat

Some fisheries focus heavily on particular life history phases, such as spawning aggregations or nursery areas, where catchability is particularly high, or fish easy to find. Aggregation sites and other specific habitats need to be included in Marine Protected Areas (MPAs), although for some species spawning aggregations may not be spatially predictable enough from year to year to benefit from site-based management. Other approaches include temporal closures. Fry fisheries, which target tiny juveniles of species such as the rabbitfish and groupers, may place excessive pressure on resources, and take high levels of bycatch. These fry fisheries are particularly challenging to monitor and manage.

The importance of alterations to habitat, such as from bleaching or habitat destruction, for reef fish assemblages needs to be recognized and addressed. The massive bleaching event of 1998 severely affected many areas of the Indo-Pacific with some islands of the Indian Ocean suffering 90 percent coral mortality. Surveys in two locations following this bleaching event indicated increased levels of planktivores and herbivores, while corallivores showed clear declines from pre-bleaching levels. There were also changes in species richness. Regrettably, coral-dwelling species adversely affected by coral bleaching, and thus experiencing declines in population levels with a corresponding loss of habitat, may also be threatened with harvest by the live reef fish trade. In the Caribbean, the importance of mangrove and seagrass beds for juveniles of a number of reef species was demonstrated by a study that showed declines in adults of certain species following loss of, or destruction to, nursery areas. The design and management of MPAs need to incorporate key life history phases or habitats such as nurseries or spawning areas.

Monitoring Reef Fish Assemblages

A strong focus of many of the presentations was the difficulty of, and urgent need for, monitoring reef fish assemblages, especially in the case of heavily exploited, or vulnerable species. A particularly acute problem is the monitoring of large and relatively rare reef fishes and there is a need to incorporate age-structured data to distinguish the effects of fishing from natural demographic differences between areas. Some large reef species, such as the Humphead wrasse, *Cheilinus undulatus*, and the Bumphead parrotfish, *Bolbometopon muricatum*, have shown alarming declines in some places. Because these species are wide-ranging and naturally scarce, 'traditional' spatial scales and methodologies of underwater visual census are evidently not well-suited to such species. It is clear that

Photo: Coastal Resources Center, URI

Traditional fish trap, Balikpapan Bay, East Kalimantan, Indonesia

dedicated and specially designed surveys are needed. To address this problem, scientists have moved beyond more conventional methods of assessing reef fish populations (that is, through underwater visual census and fishery data) by seeking anecdotal information and the opinions of those knowledgeable about the resource, such as local communities, collectors and traders, through the use of questionnaires or interviews and seeking out export records and logbooks. Fishers have also been directly involved in dive surveys. These 'alternative' approaches to data gathering reflect the difficulties in monitoring reef fishes and the general shortage of fishery data collected in reef fisheries. Often, several sources of information are combined as a crosscheck and to form a wider picture. Overall, however, the dearth of information, even on heavily exploited and valuable species, and the special difficulties of monitoring large or rare species, were perceived to be serious impediments to management and conservation initiatives for vulnerable reef species.

Relevant Actions Being Taken to Address the Issue

Approaches to address some of the problems identified were proposed, are under development or are being implemented. Alternative methods for monitoring large and wide-ranging species are being developed and there was increasing interest and confidence expressed in the use of traditional knowledge for better understanding reef fisheries. There is a growing focus on the need to protect and manage reef fish spawning aggregations; the Society for the Conservation of Reef Fish Aggregations (SCRFA) was established in summer 2000 and formerly constituted during the 9th ICRS. Monitoring of reef fisheries and non-traditional fisheries, such as marine ornamentals and juveniles destined for mariculture grow-out in SE Asia, have yet to receive serious attention in most places.

Management and Policy Implications

Collection of information on the past history and current status of reef fish resources is essential for identifying especially vulnerable species and better understanding the effects of different fishing practices. Specific conservation issues include the protection and management of reef fish spawning aggregations and critical nursery areas. The dearth of information on reef fish fisheries, particularly in the Indo-Pacific, seriously undermines management and conservation initiatives and is a key area that needs to be addressed in developing fishery management plans and monitoring protocols at the country level.

Specific Recommendations for Action

- Develop monitoring protocols for large and wide-ranging and rare reef fishes.
- Improve or implement species-specific monitoring systems for reef fisheries; many are not monitored or species are lumped. Many non-traditional fisheries, such as those for the marine aquarium trade, are often not monitored at all.
- Protect critical life history bottlenecks, such as nursery areas and spawning aggregations.
- Increase reliance on, and incorporation of, traditional knowledge in the understanding of reef fishery histories and status where appropriate.
- Protect stressed areas, such as bleached areas, to enhance recovery potential.
- Scrutinize 'mariculture' activities that depend on wild-caught juveniles (as opposed to hatchery produced) for grow-out – these activities are not necessarily sustainable solutions to overfishing or destructive fishing practices.

Useful References and Resources

This paper is based upon presentations at the 9th International Coral Reef Symposium, Mini-Symposium B3, *Conservation Biology of Coral Reef Fishes.* Authors and titles of presentations can be found at: www.nova.edu/ocean/9icrs/.

IUCN Grouper/Wrasse Specialist Group with links to IUCN and other sites of interest: www.hku.hk/ecology/GroupersWrasses/iucnsg/index.html

Sale, P. F. *Coral Reef Fishes: New Insights into their Ecology.* Chapman and Hall (2001 publication)

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