Biological Conservation 169 (2014) 225–237

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Review

Conservation and management of ornamental coral reef wildlife: Successes, shortcomings, and future directions ☆

Laura E. Dee [a], Stephanie S. Horii [a], Daniel J. Thornhill [b,*]

[a] Bren School of Environmental Science & Management, University of California, Santa Barbara, 2400 Bren Hall, Santa Barbara, CA 93106, USA
[b] Department of Conservation Science and Policy, Defenders of Wildlife, 1130 17th Street NW, Washington, DC 20036, USA

ARTICLE INFO

Article history:
Received 23 August 2013
Received in revised form 12 November 2013
Accepted 14 November 2013

Keywords:
Aquarium trade
Coral reef conservation
Coral reef fisheries
Ornamental fisheries
Sustainable fisheries management

ABSTRACT

Trade in ornamental coral reef wildlife supports a multi-million dollar industry but in some places threatens vulnerable coral reef species and ecosystems due to unsustainable practices and lack of effective regulation. To supply this trade, fishers sometimes deplete fish populations and rely on practices, such as cyanide fishing, that harm coral reef organisms and habitats. The number of countries involved, dispersed fishing localities, and the diversity of species in trade present considerable impediments to conservation and management. For instance, traditional fisheries management techniques such as stock assessments and total catch limits may not be feasible for ornamental fisheries, which are characterized by limited data on population dynamics, stock status, and collection effort, as well as instances of illegal, underreported, and unregulated fishing. A number of strategies to monitor, regulate, and manage the trade have been implemented with varying efficacy. In order to learn from previous attempts and identify promising approaches, we reviewed selected management practices and regulations from diverse settings, with attention to the effectiveness of each approach. Strategies reviewed include international agreements, marine protected areas, rotational closures, banned-species lists, quotas, cyanide detection, gear restrictions, size limits, licensing and limited entry into the fishery, and regulations on imports. Moratoriums on certain species, no-take reserves, tiered quota systems, and import and export restrictions, among others, provided examples of management successes. Further conservation and management improvements could be achieved through a wider application of successful strategies identified here and utilization of data-limited methods from food fisheries.

Contents

* Corresponding author. Tel.: +1 (202) 772 0227; fax: +1 (202) 682 1331.
E-mail address: thornhill.dan@gmail.com (D.J. Thornhill).

0006-3207/$ - see front matter © 2013 The Authors. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.11.025

1. Introduction

1.1. The ornamental coral reef wildlife trade and its ecological consequences

The trade in ornamental coral reef wildlife, which includes the aquarium, jewelry, and curio trades, supports a multi-million dollar industry (Grey et al., 2005; Wabnitz et al., 2003); however, collection practices and a lack of effective regulation and management may threaten vulnerable coral reef species (Thornhill, 2012;Tissot et al., 2010). Many species are targeted to supply this trade, primarily based on their size and aesthetics. Examples include brightly-colored juvenile or male fishes; stony corals with attractive skeletons or large, colorful polyps; and mollusks with colorful, ornate shells. The effects of the collection and trade in ornamental wildlife are less studied than other threats to coral reefs – including climate change, ocean acidification, overfishing, and nutrient pollution – in part due to the complexity of the trade, which targets hundreds of fish and invertebrate species (Rhyne et al., 2012;Wabnitz et al., 2003). Nevertheless, collection has reduced certain populations, introduced invasive species, and in rare cases caused localized extirpations (reviewed in Thornhill, 2012). For example, one of the most-studied ornamental species, the yellow tang (*Zebrasoma flavescens*) in West Hawaii, has declined in some collection areas, but is stable or recovering within reserves (Tissot and Hallacher, 2003; Tissot et al., 2004; Williams et al., 2009). In the Sulawesi Archipelago of Indonesia, endemic Banggai cardinalfish (*Pterapogon kauderni*) have declined in abundance to the point of localized extirpations, and are now considered endangered (International Union for the Conservation of Nature, 2012; Kolm and Berglund, 2003; Vagelli, 2008). Invertebrates collected for trade also exhibited population declines; for instance, densities of symbiotic giant anemones in the Cebu region of the Philippines declined over 80% (Shuman et al., 2005). Even stony corals (order Scleractinia), the foundation of coral reef ecosystems, are collected. Their collection can reduce coral cover and alter species compositions and population demographics (Knittweis and Wolff, 2010; Ross, 1984). Yet many ornamental fisheries have continued for decades and have not collapsed. Despite the potential impacts of collection, the stock status and sustainable harvest levels of most ornamental species remain largely unknown and unmonitored.

Beyond the unevaluated status of targeted species and potential population declines, destructive practices, including cyanide fishing, are sometimes used to collect coral reef wildlife for trade. Cyanide is dispensed onto coral colonies in order to anesthetize and easily capture fish (Rubec et al., 2001). Within minutes, these toxins kill an estimated 50% or more of exposed species, with additional deaths occurring hours to days later (Hanawa et al., 1998; Rubec et al., 2001). Non-targeted species like corals, anemones, and other habitat forming species are also exposed and can be injured or killed. In particular, cyanide blocks respiration in corals, causing coral bleaching and mortality (Cervino et al., 2003; Jones and Steven, 1997). The current prevalence of cyanide fishing is unknown. Cyanide fishing occurs in at least 15 countries, including major exporters like Indonesia and the Philippines, though its use is apparently less prevalent today than 20 years ago (Bruckner and Roberts, 2008). Other prevalent fishing methods also injure and kill both targeted and non-targeted species, including abrasive nets, spears, and crushing of corals to capture fish (Gonzales and Savaris, 2005; Thornhill, 2012).

The coral reef wildlife trade can also affect importing countries through the introduction of exotic and invasive species (Semmens et al., 2004). The most prominent example is the introduction of lionfish (*Pterois volitans* and *P. miles*) from the Indo-Pacific into the Caribbean and western Atlantic (Betancur et al., 2011). Since the 1990s, lionfish spread along the U.S. east coast and throughout the Caribbean (Betancur et al., 2011). These predators eat large quantities of native fishes resulting in reduced recruitment of Atlantic coral reef fishes, competition with native predators such as grouper, reduction of grazers like surgeonfish and parrotfish, and concomitant ecological changes (Albins and Hixon, 2008; Lesser and Slattery, 2011).

The broader ecological consequences of collection for the trade are understudied from both fisheries and ecological perspectives. The coral reef wildlife trade targets species ranging from the foundation of coral reefs (e.g., corals and live rock for aquariums and home décor) to top predators (e.g., sharks for teeth, jaws, and other curio items; Grey et al., 2005; Knittweis and Wolff, 2010; Ross, 1984). One concern is that characteristics that make fish and invertebrate species attractive to aquarium enthusiasts can also lead to disproportionate impacts on the reef when these species are removed. For example, hobbyists' preferences for species that consume algae or parasites could drive reductions of these species on the reef, potentially with trophic effects (e.g., Edwards and Shepherd, 1992; Rhyne et al., 2009; but see Tissot et al., 2004). The diversity of species and complexity of interactions on coral reefs make understanding population dynamics of coral reef wildlife and predicting the ecosystem-level consequences of their removal difficult.

1.2. Management challenges

The coral reef wildlife trade exhibits both notable similarities and differences from other capture fisheries, including characteristics that can impede resource management. Organisms from nearly every trophic level are collected, making identification and monitoring of collected species exceptionally challenging. The life history, demographic, and population data required for traditional stock assessments are typically unavailable (Fujita et al., in press; Honey et al., 2010). Even countries with higher management and enforcement capacity, such as the U.S., generally do not conduct stock assessments for ornamental species. In general, stock assessments for many species in the trade may be difficult because rare species are targeted. For rare species, accurate estimates of population size are difficult to obtain because their probability of detection in surveys is quite low (e.g., see Chadès et al., 2008). It is therefore difficult for managers to monitor populations and reefs, enforce regulations, document catches, and develop accurate population models.

Many locations have few (if any) regulations addressing the coral reef wildlife trade. In countries where regulations exist, enforcement is hindered by inaccurate reporting of landings (e.g., Walsh et al., 2004; Rhyne et al., 2012) and illegal collection (Barber and Pratt, 1997). Similar to issues with trans-boundary fisheries (McWhinnie, 2009), roving collectors are common in Southeast Asian fisheries and have little incentive to protect coral reef resources in a given area, because they may never return to the