1

The Marine Ornamental Species Trade

Matthew R. Palmtag

Florida Gulf Coast University, Fort Myers, FL, USA

Abstract

Marine aquarium keeping is one of the world’s most popular pastimes. Aquatic life is supplied through the marine ornamental species trade which consists of businesses that collect or culture livestock, transport, maintain, and trade until it reaches the consumer. Over 46,000,000 organisms representing 2500 species are traded annually with a value exceeding US$ 300,000,000. The Philippines and Indonesia supply the majority of livestock, with most specimens being consumed by the USA, Europe, and Japan. Unfortunately, irresponsible parties have caused coral reef destruction through negligent collection practices. Trade professionals and environmental advocates have employed a variety of measures to counteract the malpractice. Production of ornamentals through aquaculture is a leading solution that could reduce destruction by decreasing the need for wild livestock and providing an alternative profession for collectors. To achieve this economic–environmental balance, aquaculture capabilities require improvement through scientific research; additionally the technology must be accessible to countries that depend on collection.

Keywords Aquaculture; collection of marine ornamentals; environmental impact; sustainability

1.1 Introduction

The marine ornamental species trade is a global industry that provides wild-caught and aquacultured marine life for consumers. Marine ornamental livestock is supplied to consumers through an international network of artisans, aquaculturists, entrepreneurs, and businesses. Consumer groups primarily consist of home aquarists and public aquaria who maintain marine ornamental livestock for the purposes of aesthetic display, hobby, educational purposes, and pet companionship. This chapter is an overview of the history, economics, organisms, organization, and environmental implications of the marine ornamental species trade.

Home aquarists are the largest consumer of marine ornamental species. They are a diverse group in respect to the species and assemblages of organisms that they desire and care for. Some keep a few small fish, such as clownfish or damselfish (family Pomacentridae), in a small aquarium (e.g., 40 L). Others keep large predatory fish, such as sharks or moray eels, in enormous home aquarium (e.g., 4000 L). Many aquarists maintain a “fish only tank”, which is typically adorned with a community of fish and decorative rocks. There is also the “specialty tank”, aquarist who cares for an individual or group of organisms that require special conditions, such as seahorses or jellyfish. Today, the most popular version of the marine home aquarium is the “reef tank”. The “reef tank” simulates a natural reef environment, typically a tropical coral reef, and features a diverse assemblage of invertebrates as well as fish.

1.2 History
Fascination with marine life and the practice of keeping aquatic life in captivity can be traced to ancient civilizations. Evidence suggests that before 2000 BC the Assyrians, Egyptians, and Chinese cared for captive fish for the purpose of maintaining a readily available food source, as well as for religious reasons. In ancient China and Egypt, captive fish began to take on an additional decorative role and likely became status symbols (Nash, 2011). Wealthy Romans continued this trend during the first century BC. They constructed elaborate sea-side pools, vivarie piscinae, to maintain live seafood. The pools eventually acquired the added purposes of entertainment, social status symbols, homes for aquatic pets, and served as social gathering sites (Higginbotham, 1997). The Chinese forged the path for the aquatic ornamental species trade. Historic Chinese literature suggests that they identified ornamental phenotypes of carps (Carassius auratus), now known as “goldfish”, between 265 and 316 AD (Matsui, 1971). Goldfish were domesticated between 618 and 906 AD; culturing them became popular in Chinese society and they were also used as a tradable commodity (Fossa, 2004). In the 1500s, goldfish were exported to Japan and later to Europe in the 1700s, where they were kept in fish bowls and quickly became a ubiquitous pet (Klee, 1987).

In the 1840s British naturalists collected local marine life, such as sponges (porifera), and maintained them in glass containers for observation (Johnston, 1842). Soon afterward, the first public marine aquarium exhibit was introduced at the Zoological Gardens of Regent’s Park in London. The aquaria in this exhibit may have been the first to resemble a contemporary “reef tank”, as they housed an infrastructure of rock and sand with a diverse assemblage of temperate reef dwelling organisms including fish, mollusks, crustaceans, gastropods, echinoderms, anemones, and algae among others (The Aquatic Vivarium). Goldfish made their way into the homes of Americans during the 1850s and articles written for home aquarists in 1857 indicated that the hobby thrived (Klee, 1987). Global expansion of the freshwater aquarium hobby stimulated demand for more and different types of exotic organisms, especially fish. During the late 1800s and early 1900s, an increasing diversity of ornamental species were collected and exported from South America and South Asia, including the chanchito (Australoheros facetus) and paradise fish (Macropodus operculus) (Smith, 1902). Fish were imported to North America and Europe by steam ship and rail and maintained in metal cans during transit (Klee, 1987). Steam ships and trains provided less than ideal accommodations to sustain sensitive species. Air travel and improved airport
infrastructure of the 1930s facilitated transport, as well as the volume and number of species available in the trade. By 1935, aquarium publications reported the prevalence of over two hundred species in the freshwater aquarium trade (Innes, 1935).

The expanding interests of home aquarists eventually encompassed the marine environment, and the marine ornamental species trade was born. Sri Lanka, already serving as a hub for freshwater ornamental exportation, became the world’s first commercial site for marine ornamental species export from the 1930s through the 1950s. Collection and export locations expanded to the Philippines and Hawaii in the 1950s and 1960s. The trade was improved by the use of polyethylene bags to package live organisms for shipment, which significantly reduced the weight and cost of freight (Lim et al., 2003). A handful of species, such as clownfish and damselfish, made their way into the homes of aquarists (Innes, 1966).

By the mid-1950s public aquaria were maintaining and propagating coral. Soon home aquarists were doing the same, and coral too became a staple of the trade (Delbeek, 2001). Live rock (limestone encrusted in a benthic assemblage of invertebrates) also became a popular commodity; it had the dual purpose of decoration, as well as assisting with filtration of the aquarium (Carlson, 1999). Invertebrates other than coral, such as crabs, clams, mussels, oysters, snails, and anemones, also became popular (Axelrod & Shultz, 1978). The growth of the trade in the late 1960s and 1970s was catalyzed by the commercial development of synthetic sea salt, which allowed legions of enthusiasts who did not live near the sea the opportunity to maintain a marine aquarium (Moe, 1992). Steady technological advances in filtration, lighting, temperature control, water chemistry analysis, and husbandry techniques continued to increase the accessibility and popularity of the hobby throughout the 1970s and 1980s (Carlson, 1999).

1.3 Economics of Trade

Recent studies conducted from 1997–2012 estimated that more than 2500 species comprise the marine ornamental species trade. These consist of more than 1800 fish and over 700 invertebrate species, including but not limited to cnidarians, mollusks, arthropods, echinoderms, annelids, and poriferans (Wabnitz et al., 2003; Rhyne et al., 2012). The most recent global estimate indicates that 46,000,000 individual organisms are collected and sold annually to approximately 2,000,000 hobbyists worldwide, with a corresponding value exceeding US$ 300,000,000 (Wabnitz et al., 2003). The Philippines, Indonesia, Solomon Islands, Sri Lanka, Australia, Fiji, the Maldives, and Palau, export the overwhelming majority of livestock. The USA is the most prolific importer and consumer; other major importers include the United Kingdom, the Netherlands, France, Germany, Taiwan, Japan, China, and Italy (Wabnitz et al., 2003).

1.4 Species of Trade

The marine ornamental species trade is composed of an incredible diversity of organisms, but popular taxonomic groups represent the majority of species traded. More than twenty million fish are traded annually, with pomacentrids (damselfish and clownfish) representing nearly half by volume (Rhyne et al., 2012). Coral and live rock have shown the most rapid growth in popularity in recent history, with over ten million corals and
millions of kilograms of live rock being exported annually (Wabnitz et al., 2003). A total of 140 species of stony corals (order Scleractinia) dominate the coral trade while approximately 400,000 individual soft corals, representing 61 species, are also traded each year (Wabnitz et al., 2003) (Table 1.1). Sea fans also represent a small proportion of the trade.

About 500 species of invertebrates other than coral are popular; roughly ten million individuals are traded each year. These include mollusks (gastropods, bivalves, and cephalopods), echinoderms (starfish, urchins, and sea cucumbers), actinarians (sea anemones), crustaceans (shrimp, crabs, and lobsters), polychaetes (feather dusters and Christmas tree worms) and poriferans (sponges). Of this group, cleaner shrimp of genus *Lysmata*, boxing shrimp of genus *Stenopus*, and sea anemones of genus *Heteractis* compose about 15% of all non-coral invertebrates traded (Wabnitz et al., 2003). Certain invertebrates are included in aquaria for aesthetics, however, many are chosen for the service that they provide for the aquarium. Often referred to as the “cleanup crew”, these invertebrates may graze on nuisance algae, sift the substrate, filter, scavenge, prey upon nuisance species, clean parasites from cohorts, or provide habitat (Calado et al., 2003; Rhyne et al., 2009).

### 1.5 Organization of Trade

The journey of a marine ornamental from its native habitat to the home aquarium requires the services of a variety of players aligned in a complex chain. Approximately 90% of all marine ornamentals in the trade are captured from the wild, a practice that
requires the skills and experience of artisan collectors. Live rock and sessile or slow moving invertebrates are typically collected by finding and removing them from their location. The collection of fish and fast moving invertebrates requires snorkeling gear or underwater breathing devices, as well as tools such as nets, slurp guns, traps, hook and line or sedatives. Collectors either work for, or sell their catch to, a wholesaler, who stockpiles and prepares livestock for export. The wholesaler acts as an exporter or sells the livestock to one. Export normally requires government-mandated permits specific to the locale and import destination, veterinary inspection, treatment of livestock to prepare it for an international flight, and packaging (Olivier, 2003).

Exporters ship livestock by air to importers in destination countries; in some cases the exporter and importer are housed within one company. When a shipment arrives at its destination, importers unpack the livestock, inspect its health, and acclimatize it within a temporary holding facility (Wabnitz et al., 2003). At this point, various importers may repackage the livestock for shipment to another destination, sell it to a wholesaler, or sell directly to a retail outlet (Olivier, 2003). Parties acting as wholesalers also acclimate the livestock and either sell it to a retail outlet or directly to home aquarists via the internet (Larkin & Degner, 2001). Public aquaria and retailers can purchase livestock directly from wholesalers and sometimes from importers. Home aquarists typically can purchase livestock only from a retailer with a physical store or an importer, wholesaler, or retailer that peddles livestock through the internet (Zajicek et al., 2009).

Transshipping, which transpired in the 1970s, is an alternative pathway to trade reducing the number of middlemen involved. A transshipper amasses livestock orders from a consortium of retailers (and sometimes wholesalers) at the import destination, places the order with an exporter, and distributes the order to the consortium upon its arrival (Olivier, 2003). The purchasers of transshipped livestock are often required to pick the shipment up from the airport with no guarantee that the shipment will arrive alive. Destination site retailers and wholesalers save money by avoiding the markup that importers charge (and wholesalers), but lose the timely acclimation and husbandry benefits that they provide. While handling costs are reduced, the amount of time livestock spends packaged in transit increases, which has led to increased acclimation time, disease, and mortality (Olivier, 2003). In recent years, governments and transshipping companies have made progressive efforts to reduce the mortality rates associated with transshipping. Governments have employed quality control laws and licensing to discourage irresponsible practices. Likewise, transshipping companies have sought greater responsibility by guaranteeing the live arrival and quality of their livestock (Olivier, 2003).

1.6 Environmental Impact

The collection of wild marine ornamentals has taken a damaging toll on the environment. Destructive collection practices and nonexistent or ineffective fisheries management have led to a significant amount of coral reef habitat destruction and overfishing (McManus et al., 1997). This outcome has also affected the reputations of collectors as a whole, even though the majority are conservation-minded collectors who harvest ornamentals sustainably (Dawes, 2003). A significant minority of collectors have resorted to highly damaging collection techniques that improve their catch per unit effort while imperiling the reefs that reward them with their bounty. One of the most
notorious techniques involves *in situ* sedation of fish by means of a variety of chemicals, including plant extracts, bleach, and most notably, cyanide (Bruckner, 2001). Cyanide, banned globally for this purpose, the most popular sedative is linked by abundant evidence to coral bleaching and mass mortality of non-targeted species. The effects of cyanide extend far beyond the reef; fish captured using cyanide suffer greatly increased mortality rates (Rubec, 1986). The use of cyanide fuels a sinister cycle of habitat destruction and accelerated demand to replace livestock lost due to high post-collection mortality.

Physical destruction of reefs and ill-managed removal of livestock is another hazardous result of irresponsible collection. Some collectors have dismembered corals to capture fish that have taken refuge in them (Pet-Soede & Erdmann, 1998). Fishing nets, which are typically used in an environmentally friendly manner, can become entangled in coral and lead to mortality. Another practice is to beat a coral with a blunt object to drive sheltered fish from its protection (Wood, 2001). The harvest of live rock and coral often requires the force of a hammer, chisel, crow bar, or screw driver and results in a direct loss of habitat (Bruckner, 2001). Coral and live rock harvest can be sustainable but if not managed properly, these sites may become cloaked in turf algae, eliminating much of the productivity of the once thriving ecosystem (McClanahan, 1995). Sustained removal of select species, particular sex, or life stage can compromise the reproductive capability of the species or stress non-target species causing imbalance to the local ecosystem (Sadovy & Vincent, 2006).

The majority of coral reefs are classified as threatened. The greatest threats result from coastal development, climate change, destructive food fishing methods, pollution, terrestrial runoff, and ocean acidification. The effects of the marine ornamental trade are miniscule by comparison, yet significant nonetheless (McManus *et al.*, 1997). The gravity of the situation may lead one to believe that elimination of the trade would improve the well-being of coral reefs. Trade professionals and scientists that study coral reefs and the trade, present counter arguments. They point out that public aquariums and conscientious aquarists play a pivotal role in gaining the attention of the general public and educating them about anthropogenic impacts on coral reefs (Tlusty *et al.*, 2013). Ending the trade could popularize a black market that promotes destructive collection techniques and leaves no potential for managed sustainable harvest (Shuman *et al.*, 2004). Marine ornamentals are the most valuable consumer goods that exist in a coral reef; well-managed, sustainable collection provides communities with an incentive for protecting the resource and sustainably using it (Wabnitz *et al.*, 2003). In the absence of a viable trade, many communities could turn to catastrophically destructive practices such as excavating coral reefs to produce building materials (Teitelbaum *et al.*, 2010).

The marine ornamental industry together with environmental protection advocates, have supported a variety of measures to counteract the negative impacts that negligent parties have caused. Environmental protection organizations have conducted grassroots efforts to educate collectors about the consequences of irresponsible practices and have provided instruction on how to capture and care for livestock using environmentally-friendly methods (Rubec, 1986). Several countries have employed collection management plans with varying success. These efforts have included specified collection zones, marine protected areas, no-catch zones, collection area rotations, bans, quotas, size limits, sex restrictions, access limitations, collection equipment restrictions, and exportation limits. These actions have been successful in some areas while ineffective in
others. Failure has often been due to noncompliance, coupled with the inability of governing bodies to enforce restrictions (Sadovy & Vincent, 2006). Another strategy has been the education of consumers regarding destructive fishing techniques and the corresponding environmental impacts. Organizations, such as The Marine Aquarium Council (MAC) have facilitated this effort by providing the consumer with the opportunity to promote and support sustainable practices (Shuman et al., 2004). MAC certifies livestock at the retail level under the following stipulations: livestock was collected at a locale that designed and adhered to a certified management plan, and livestock was captured, maintained, and transported throughout the chain of custody using practices that minimize mortality and are deemed environmentally sustainable and humane (MAC, 2001a, b, c).

1.7 Marine Ornamentals Aquaculture

Expansion of the marine ornamental aquaculture industry can impart sustainability to the trade. Aquaculture has the potential to reduce the trade’s dependence on wild collection through the sustainable production of livestock (Figures 1.1 and 1.2) (Palmtag & Holt, 2007). Reduced need of wild livestock could decrease the prevalence of destructive collection practices by incentivizing the use of sustainable collection which provide a competitive environmentally friendly product. The aquaculture industry has its detractors as some methodologies are not sustainable. Additionally, aquaculture production in import locations could reduce or eliminate the need for collectors, resulting in unemployment and reduced motivation for some local communities to protect the livestock’s habitat, potentially resorting to more destructive uses of the reef.

Figure 1.1 Candy basslet (Liopropoma carmabi). (a) Adult pair of candy basslet; and (b) 58-day-old larvae raised by Todd Gardner at Atlantis Marine World in Long Island, New York in 2010. (See insert for color representation of the figure.)
Many scientists and trade professionals argue that the industry has far more benefits than disadvantages. Sustainable aquaculture practices are well-developed and prevail in many countries throughout the world (Frankic & Hershner, 2003). It is improbable that aquaculture could fully replace the wild collection trade: under the appropriate conditions, sustainable production of marine ornamentals could be carried out simultaneously in popular collection areas (Teitelbaum et al., 2010). This dynamic could provide new employment opportunities, improve awareness of sustainable practices, and enhance the economic infrastructure originally developed exclusively for wild collection (Pomeroy et al., 2006). Aquacultured livestock suffer significantly less mortality than wild harvested, which reduces the need to resupply ornamentals that have succumb to stress due to wild collection. Aquaculture production

Figure 1.2 Fire shrimp (*Lysmata debelius*) raised by Matthew R. Palmtag and Dr. Joan Holt in the late 1990s at the University of Texas Marine Science Institute in Port Aransas, Texas, USA. (a) 68-day-old post-larvae; (b) 83-day-old newly metamorphose juvenile; and (c) adult shrimp. (See insert for color representation of the figure.)
could also preserve genetic attributes of endangered populations, preserve species, and serve stock enhancement capabilities (Tlusty et al., 2013).

The first cultured marine ornamentals were reared in the 1950s and 1960s, soon followed by the first documented marine ornamental aquaculture company Tropicornium, a coral aquaculture enterprise in Romulus, Michigan, USA (Innes, 1966; Delbeek, 2001). One of the defining achievements that catalyzed the development of the marine ornamental aquaculture industry was Martin Moe’s success in rearing clownfish (Amphiprion ocellaris) in captivity in the early 1970s. Moe then spearheaded the first commercial production of marine ornamental fish with the inception of Aqualife Research Corporation in Walkers Cay, Bahamas in 1972 (Tellock, 1996). Several marine ornamental aquaculture ventures have come and gone since the 1970s, and many thrive today. One of the greatest disparities between the contemporary freshwater and marine ornamental fish trades has been the corresponding success of the aquaculture industry component. Approximately 90% of freshwater ornamental species traded are produced through aquaculture while less than 10% of marine species are cultured. The limited success of the marine ornamental aquaculture industry can be attributed to a variety of causes; two of the foremost are the complex nutrition of early life stages and the husbandry requirements of many popular species (Olivotto et al., 2011). The progress that has been achieved and the obstacles that lie ahead are the focus of this book.

The collective efforts of research scientists, aquaculture professionals, professional and home aquarists over the last six decades have resulted in the successful culture of hundreds of marine ornamental species (Townsend, 2011). Many of these species have been raised with limited success; therefore the majority of them are not commercially viable. Lagging far behind the relative success of the freshwater ornamental aquaculture industry, it is fair to say that the marine component remains in its early stages (Holt, 2003). Yet, the industry thrives through a variety of means. Many proprietors culture marine ornamentals in intensive closed systems in “more economically developed countries (MEDC)”. Several extensive operations also exist worldwide; these ventures utilize ponds in tropical locations to support the feeding and husbandry requirements of the livestock. Another means is to farm ornamentals extensively in their natural habitat; this is a popular and effective method often used for clams, coral, and live rock. A cottage industry exists where an individual or a family produces marine ornamentals intensively or extensively at their homes. A hybrid method also exists, where premarket size larval and juvenile livestock are collected and then raised in captivity until they reach marketable size (Lecchini et al., 2006).

Some exciting new developments involving aquaculture have been introduced to the trade recently. Several aquaculture businesses produce novel phenotypes through artificial selection. This is not a new concept; the freshwater aquaculture industry has practiced this for more than a thousand years (Fosså, 2004). Production of artificially selected marine ornamentals has arisen with the relatively recent capability to culture marine ornamentals in captivity. On another front, improved accessibility and technological advances of submersibles and deep-diving, self-contained breathing devices have enabled collectors and deep water enthusiasts to introduce deep-dwelling species to the trade. The availability of these species to the aquarist are often limited and they typically command an expensive price; some consumers are willing to offer as much as US$ 30,000 for one specimen (Kaneshiro, 2012). To date, a handful of marine ornamental aquaculturists have successfully cultured several of these species (T. Gardner, pers. comm.).
1.8 Conclusions

Aquarium keeping is one of the world’s most popular pastimes and it continues to grow in popularity, especially in the marine component (Livengood & Chapman, 2007). The continued viability of the marine ornamental species trade will undoubtedly depend on the ability to operate in a sustainable manner. Marine ornamental aquaculture has an opportunity to play an instrumental role in achieving a balance between economic feasibility and environmentally sound practice. Research has and will continue to play a key role in developing the capability of the industry to produce a greater number of species and improve efficiency and sustainability. This balance cannot be reached by the enterprises operating in MEDCs alone. To strike a global economic–environmental balance, effective methodologies established through sound scientific research must be published and then employed by the communities that depend on collecting wild livestock (Palmtag & Holt, 2001; Pomeroy et al., 2006).

Acknowledgements

I am grateful to my wife Dr. Rebecca Waggett for her diverse array of assistance. I thank Dr. Joan Holt for her consummate mentorship and support with this project. I express gratitude to colleagues Dr. William Sanders and Todd Gardner for their assistance with editing, and I thank Florida Gulf Coast University for their continued support.

References


Palmtag, M.R. & Holt, G.J. (2001) *Captive Rearing of Fire Shrimp (Lysmata debelius)*, Texas Sea Grant College Program. Sea Grant Texas, Texas, USA.


