ORNAMENTAL AQUACULTURE

Small scale of production does not automatically mean small scale of impact

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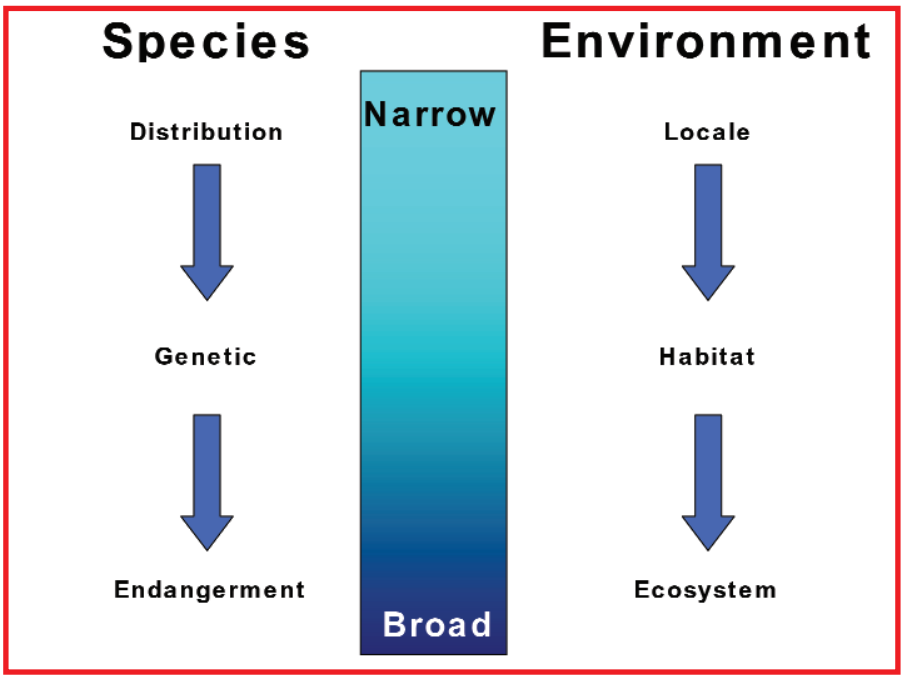
The mantra of ornamental aquaculture

A prevalent belief is that aquaculture production of ornamental species is good - it prevents environmentally harmful collection techniques, and the fish tend to be more suitable for continued holding in captivity. For a large part, this simplified view is correct. But as ornamental aquaculture expands, complexity increases such that a simplistic mantra - *ornamental aquaculture is good* - is insufficient. The ornamental aquaculture industry is in fact heading down the path already traveled by food-fish aquaculture; significant growth with little understanding of the environmental risks and benefits. In the case of food-fish aquaculture, rapid growth in the 1980s brought significant public concern regarding the unchecked growth of the industry, and subsequent environment degradation. It has taken over a decade to more completely understand interactions of food-fish aquaculture and the environment, but the negative perceptions generated in the 1980's still persist. Ornamental aquaculture, has developed significantly with little analysis of the ecological risks and benefits. Ornamental aquaculture is likewise poised on the cusp of rapid expansion, and the potential environmental impacts of this sector need to be fully understood prior to this expansion.

Currently, only 2 to 3% of marine species are produced in aquaculture operations, and represent approximately one-quarter of the total number of marine species that can be successfully cultured. However, recent improvements in aquaculture technology, particularly in feeds for nutritionally sensitive larval stages, and a global concern regarding the state of the environment and wild stocks will spur on the development of captive rearing of marine species. Poised on the brink of a growth phase, the marine ornamental aquaculture sector is in an enviable position. It can draw on the wide range of successes and difficulties encountered in both the freshwater ornamental and food-fish aquaculture sectors of the industry to develop a code of conduct that can be enacted upon prior to experiencing difficulties from growing too rapidly. Thus, it is important to understand the relationship between environmental impacts and ornamental production to help direct the marine ornamental industry toward best practices. Discovering the underlying relationships between ornamental aquaculture and environmental impacts can also be used to create best practices for the freshwater industry to assure that the industry maintains a positive environmental ethic as it continues to mature.



The range of impacts discussed within this paper. For both species and environments, positive and negative impacts can range from narrow to broad.

Does size matter?

The mantra that *ornamental aquaculture is good* is prompted in part by the size of the production operation. Ornamental fish farms are generally smaller than their food-fish counterparts, particularly on the basis of production weight. The United States Environmental Protection Agency, in designing effluent guidelines for aquaculture waste production, determined that warm-water aquaculture operations that produce less than 45,454 kg / year are not subject to an extensive permitting and application process. This EPA ruling manifests itself under the assumption that the size of an aquaculture facility is proportional to its impact. The EPA also accounted for the "cost-to-revenue" ratio in determining whether it should impose limitations and standards for the smaller sized production facilities. Smaller facilities do have less of a water quality impact (biochemical oxygen demand measured over five days, total suspended solids, fecal coliform, pH) than do larger facilities, and it is these impacts in which the EPA was most concerned. But is the assumption that smaller facilities have less impact correct for all impacts? Here the scales of environmental impact of ornamental aquaculture are summarized, to determine if the "small scale" ornamental production necessarily equates to lower levels of environmental impacts.

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Michael Tlusty, Ph.D. is a research scientist at the New England Aquarium who specializes in aquaculture. In addition to working with Project Piaba, Michael also conducts research on defining environmental impacts of aquaculture, and methods to make aquaculture more environmentally friendly. He also directs a small research hatchery where he the relationship between stress, nutrition, and disease in American lobsters.

Scope and scale of impacts

A discussion of environmental impacts of aquaculture must start with specification of the impacts. The term impact, by definition, is neutral. Thus, the environmental impacts of aquaculture can be positive, as when shellfish culture improves water quality through the removal of particulate matter, or negative, as when the shellfish feces and pseudofeces accumulate underneath the culture systems and create anoxic zones in the benthos. While much of the directionality of the impacts are determined by specific on farm, *in-situ* practices, ornamental aquaculture needs to be assessed for the overall directionality of its impacts.

The environment being referenced in "environmental impacts" is a broad ranging category. Two main subcategories are identified for the purpose of this discussion, "species" and a narrow definition of "environment". Species includes impacts dealing with conspecifics, and all non-specific flora and fauna impacted by the aquaculture operation. Environment refers to the physical and geochemical surroundings in which the species in question lives. It is important to distinguish impacts from these two subdivisions as the origin of positive or negative impacts. In the case of a negative impact, the remediative measures necessary for correction will likely differ for each division. Factors having a negative impact on species will not be similar to those influencing impacts to environments, and will require different remediation techniques.

Finally, the scale of impact needs to be addressed. For both species and environments, the range of impact can occur from narrow to the broad (Figure 1). Narrow impacts to species include changes in performance or distribution of a particular species or genome. Medium impacts involve change to the genetic structure of a population or genome, while a broad impact would influence the presence or absence of the population or genome. Similarly, narrow environmental impacts will affect the locale, medium impacts will affect habitats, while broad scale impacts will affect ecosystems. In both cases, broad scale impacts are considered more severe and should be a goal if the impact is positive, or avoided if the impact is negative. Narrow scale impacts are less severe, and easier to remediate if negative, and have less value if positive.

Positive and negative impacts

While the negative impacts of aquaculture tend to be the focus of popular news reports, aquaculture, particularly of ornamental species, can and does have numerous positive impacts. Positive impacts need to be applauded and encouraged, and this is where the ornamental aquaculture industry can have a significant impact. By understanding and avoiding actual and potential negative impacts, the industry can create a code of conduct that will allow it to be a significant positive force in the global preservation and conservation of species and habitats.

Positive impacts to species

The aquaculture production of ornamental species has its origins in the concern that wild populations are being fished unsustainably, and is ultimately rooted in as a positive impact to species. Many of the first marine species produced in aquaculture operations, such as clownfish (*Amphiprion* spp.), are not listed by CITES(Convention on International Trade in Endangered Species) indicating they are neither threatened nor endangered. Thus aquaculture production of these species is a positive impact, although narrow by definition, as the populations are "healthy", or high in numbers, and has little effect on the genetic distribution of the species. A second narrow positive impact to species is that often, the individuals produced in aquaculture operations are more robust, and more adapted to captive conditions. Thus overall health and survivorship of animals entering the pet trade can be greater in aquaculture produced compared to wild caught animals. Fewer animals die as a result of captive ownership decreasing the total numbers of available fish to enter the pet trade.

A medium range positive impact to species includes aquaculture production for enhancement. Enhancement is a management tool utilized when the distribution of a species becomes reduced, population numbers decrease, or more critically and broadly, the species becomes threatened or endangered. Work is being conducted on the Pacific threadfin, *Polydactylus sexfilis*, a food fish, with a secondary goal of being transferable to marine ornamental species.

Finally, aquaculture production of ornamentals has many broad scale positive impacts to species, and a number of species have benefited from captive propagation. In some cases, aquaculture production was so successful that not only did the species recover, but its recovery was to a point where the species could be traded once again in the ornamental fish pet industry. The giant clam (*Tridacna gigas*) is one of the few marine species for which this is true. However, there are a large number of freshwater species that rely heavily on aquaculture production including the golden dragon fish or Asian arrowana (*Scleropagus formosus*) which is endangered, and the red-tailed shark (*Epalzeorhynchus bicolor*) which is extinct in the wild (for further information on the classification of threatened and endangered species, see The World Conservation Union (IUCN) web site at www.redlist.org).

Overall, the incorporation of aquaculture production of marine ornamentals into the pet industry supply can be very beneficial as this will help focus attention on the animals that are better suited for captivity. It will prevent the selling of species such as moorish idols (*Zanclus cornutus*) that have selective diets, and thus do not feed well in home aquaria. When animals are reared in captivity, it is a given that they can continue to be maintained under captive conditions.

Postitive impacts to the environment

Impacts to the environment are less firmly rooted in the history of ornamental aquaculture production than are impacts to species. Local scale positive impacts can occur through increasing water quality in a number of ways. First, land based facilities have the opportunity to expel waste water than is of significantly higher quality than that taken in. through advanced filtering techniques. The stringent water quality needs of many marine ornamental species render this scenario a distinct possibility. Second, giant clams (*Tridacna* spp.), are farmed for use by the ornamental industry, and mollusks, being filter feeders, can remove nitrogenous wastes from a water body through their filter feeding capacity. Thus, the cage culture of giant clams in the coastal environment will assist in improvinge water quality. Finally, aquaculture operations, particularly those associated with meandering river systems, may further improve water quality by managing water flow in a stagnant or low oxygen system, as well as increasing oxygen concentration through release of water from well-aerated ponds, and diluting instream contaminants. Moderate scale positive impacts to the environment focus on the enrichment hypothesis. In certain areas, particularly in nutrient poor water bodies, a minor increase in nutrient loading can increase production

Species	Scientific name	Status
Bala shark	*Balantiocheilos melanopterus*	Endangered
Combtail	*Belontia signata*	Low risk
Betta	*Betta macrostoma*	Vulnerable
Betta	*Betta simplex*	Vulnerable
Dwarf botia	*Botia sidthimunki*	Critically endangered
Red rainbow	*Glossolepis incisus*	Vulnerable
Celebes rainbow	*Telmatherina ladigesi*	Vulnerable
Boeseman's rainbow	*Melanotaenia boesemani*	Endangered
Pygmy rainbow	*Melanotaenia pygmaea*	Low risk
Cherry barb	*Puntius titteya*	Low risk
Black ruby barb	*Puntius nigrafasciatus*	Low risk
Asian arrowana	*Scleropagus formosus*	Endangered

Threatened or endangered freshwater ornamental fish currently produced in freshwater aquaculture operations. Low risk indicates Low risk / conservation dependent (WCMC 2000).

An aquaculture success story - the arowana was once endangered, aquaculture has made it now possible for second generation captive bred animals to be sold in the pet trade. Photo: Svein A Fosså

to the point of greatly increasing primary production of the habitat. There is a fine demarcation between increased nutrient loading which increases system productivity, and that at which deleterious impacts such as eutrophication occur. While the enrichment hypothesis has not been quantitatively examined, the low stocking densities and small size of ornamental aquaculture operations is likely to occur at the appropriate scale in which enhancement of the environment will occur.

Broad scale positive environmental impacts include the creation of new habitat, or significant preservation of existing habitat. The best example of the creation of new habitat through ornamental aquaculture production is the coral farming industry. The collection of live rock and coral is destructive to the integrity of coral reef ecosystems, thus the interest of producing it with aquaculture technology. Coral is farmed by placing suitable substrate in the ocean, and allowing coral to settle upon this new substrate. In Florida, the permitting regulations state that live rock aquaculture has to be conducted in a location where there is no hard bottom, no natural reef, and no seagrass present. Thus, this aquaculture production creates habitat and ecosystems and increases complexity and biodiversity of relatively biologically unproductive areas.

Negative impacts to species

While there are many examples of positive impacts to species and environment by the ornamental aquaculture industry, there are also equivalent examples of negative impacts. The following examples of negative impacts to species and environments need to be carefully considered as the ornamental aquaculture industry continues to develop further. Where possible, these impacts need to be avoided in order to ensure that the industry maximally benefits the various species and environments.

Narrow negative impacts to species include factors such as increasing the fishing mortality of the species in question. While aquaculture is touted as being a way to decrease the demand for wild caught species, there are three cases in which the aquaculture production of animals can increase the number of animals being harvested from the wild. First, if the initial aquaculture production adds to the popularity of the species in the ornamental pet trade, then the increased demand may not keep pace with the increase in aquaculture production. Thus, the supply deficit will need correction through increasing wild harvests, until a time in which aquaculture production increases to meet the new demand. The banggai cardinalfish, *Pterapogon kauderni*, became popular for many reasons, aquaculture production of this species was one factor adding to its overall popularity. While the species was initially being produced via aquaculture in small to moderate amounts, demand increased above what the industry could supply. Thus, the increased demand for "sustainable aquaculture produced fish" could only be met by an increased harvest of wild animals. Second, if the aquaculture operation cannot maintain a viable broodstock population, then reproductively mature individuals may be collected to maintain production. One of the main arguments against the production of seahorses in aquaculture facilities is that the repeated removal of breeding individuals serve to provide no net benefit to the wild population. Finally, the production of animals in aquaculture operations will generally increase the supply of animals on the market. Overall, this will depress market prices, which will eventually trickle down to the fishermen. Resultantly, in order for the fishermen to maintain a steady economic income, they will have to increase the number of animals they catch and sell. The depressed market price for a target species may result in a broadening of the negative impacts, as it becomes beneficial for fishermen to switch species rather than continue catching the same target species. Project Seahorse (www.seahorse. mcgill.ca) has identified this as one potential drawback to the aquaculture production of sygnathids. Their concern is that aquaculture production will broaden the impacts to species by increasing the number of species entering the trade, and that these species will more likely be rare or threatened. While there are no specific examples to support or refute this concern, it is significant enough that this issue needs to be accounted for as the culture of more new species become developed and commercialized.

The broadest negative impact to species, displacement or extinction of native populations can occur as a result of interactions with escaped species that are being farmed outside of their native range. In North America, approximately 185 species of non-indigenous fish have been introduced with many og them forming viable populations. It is estimated that 65% of these species originated from ornamental fish farms.

Negative impacts to the environment

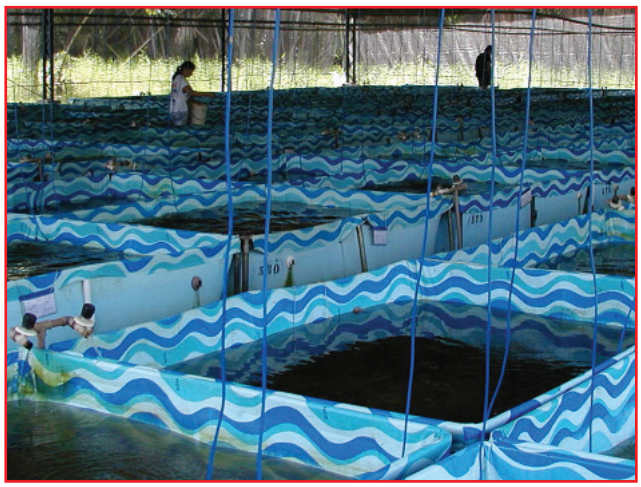
Much of the current opposition to aquaculture of food fish species is the increased nutrient loading leading to benthic impacts (increased organic matter, anoxic sediments, decreased faunal abundance and diversity) and possible eutrophication. It is unlikely that marine aquaculture operations would get to a size sufficient to negatively impact the environment through increased nutrient loading to the water column and

Piabeiros - ornamental fishermen of the Rio Negro, Amazonas, Brazil. Fish are held in small live wells immediately behind the Piabeiro. Water is exchanged manually by the Piabeiro during rest stops. Photo: M Tlusty.

benthos. None the less, misplaced small operations have the ability to significantly degrade the local environment. There is a tremendous lack of information regarding the environment surrounding ornamental (marine and freshwater fish farms) and thus the exact nature of localized impacts from ornamental aquaculture operations can only be speculated upon at this time. On a broader scale, both freshwater and marine ornamental aquaculture production have the potential to negatively impact ecosystems far removed from the production facility. Much of the current production of ornamental fish occurs outside the species original native range. The production of South American freshwater fish in Singapore and Florida, and Marine species in England and Michigan, USA (www.tropicorium.com) are primary examples. When production outside the country of origin occurs, it decreases the importance of the collection of these fish from the wild. Many of the local communities rely on fishing either solely or for a majority of their economy. If an aquaculture facility produces a species far from it's native range, there will be minimal chance of effectively including the original fishing community within the production chain of the species. In such cases, the fishermen will be forced to find alternate income sources, resulting in a devaluation of the fishing areas, and often the emergence of other industries deleterious to the overall health of the ecosystem.

Cardinal tetras - still wild caught. Producing these animals in aquaculture outside of Brazil would eliminate a primary source of income for remote inhabitants of the Amazon basin, and would open the rainforest to destructive economic practices. Photo: Bioquatic Photo.

Two ornamental fisheries are primary examples of this potential broad scale negative impact to the environment. First is the marine ornamental fishery in Eritrea. Here, the fishery focuses on 75 species, exporting 60,000 fish per year. While the fishery only accounts for 2% of the Eritrean economy, it provides a valuable income for remote coastal populations, as well as providing economic and social value for the coral reefs. The concern is that many of the species in this fishery can be produced in aquaculture operations outside of Eritrea, removing an important force in preserving the coastal reef ecosystem. The second example is the freshwater ornamental fishery focusing on the cardinal tetra (*Paracheirodon axelrodi*) in the Rio Negro, Amazonas, Brazil. Here, the economic reliance on the fishery is greater than in the Eritrean example, as approximately 60% of the municipal of the Barcelos economy is derived from this fishery. The ecological value of this fishery is also great, in that the fishery relies on an intact flooded-forest ecosystem. Thus this fishery, through protecting its fishing grounds, prevents further development of other economic opportunities such as forestry and mining in this area of the Amazonian rain forest. Currently, the US and Czechoslovakian aquaculture industries are increasing the aquaculture production of the cardinal tetra. If this is successful, the fate of the cardinal tetra will be the same as that of the neon tetra (*P. innesi*), with virtually all individuals being produced in aquaculture operations, and none originating from wild fisheries. The subsequent impact on the Amazonian rainforest cannot be fully predicted, but would be vast, including major shifts of the local economic base to environmentally destructive and unsustainable industries. This further loss of critical rain-forest habitat and general decrease in the economic viability of the rural societies will lead to the out-migration of families from rural communities to urban centers. Ultimately, these impacts will cascade to more deleterious social, cultural, and economic stressors contributing to a worsening demise of native and rural cultures.



An exporter of ornamental fish in Manaus, Brazil. Photo by Pat Spindler

Summary

Ornamental aquaculture's positive and negative impacts to species and habitats can be wide ranging. However, what needs to be explicitly stated is that while the ornamental aquaculture sector may be minor in terms of biomass produced and value, when compared to the food fish sector, it can prove to have extremely broad impacts. The broad impacts may even exceed those of food fish production as far more species are involved in ornamental aquaculture which are commonly cultured in broader geographic areas far removed from their original native ranges.

Overall, the commonly stated mantra of *ornamental aquaculture is good* is for the most part correct. In this discussion, most of the concrete examples were of positive impacts, while negative impacts relied more heavily on theory and hypotheses. However, as the ornamental industry progresses in time, and continues to develop new species for aquaculture production, it will be increasingly necessary to explore more narrow and broad ranges of potential negative impacts. It is only through further careful and conscientious development that the aquaculture production of ornamental species will over time attain maximum benefit on a global scale.

For further reading, see

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