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ORNAMENTAL FISH TRADE: OVERVIEW AND EMERGING QUESTIONS.

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Ornamental fishkeeping has become one of the most popular hobbies globally. The entire industry is valued approximately US\$ 15-30 billion per year and the international market may involve more than 100 countries. Over a billion of wild-caught or captive-bred fish belonging to more than 6,000 species are sold annually. Yet, few laws or regulations are in place to control the aquarium fish market. The industry should aim at promoting sustainability through the development and deployment of best practices and standards, particularly taking into account the welfare of traded fish.

Introduction

Ornamental fishkeeping probably started with goldfish (*Carassius auratus*) stocked in ponds, in China, in the 10th century during the Sung Dynasty. In 1136, Emperor Hiau-Tsung started to breed and keep these fish in a more controlled environment and new varieties were created. Few centuries later, goldfish were no longer a luxury item, but common among all people. In 1616, goldfish was imported to Japan, followed by Europe from the late 16th century. Afterward, ornamental fishkeeping continued to rapidly spread across the globe by sailors, who marketed goldfish in addition to the spices and other commodities they traded (Rhyne et al., 2017). In 1856, German Emil Robmaber wrote a revolutionary essay entitled “Sea in a Glass”, which is recognized as the beginning of the aquatic hobby as we know it today. During the second part of the 20th century, several inventions revolutionized ornamental fishkeeping, among which flake foods, water chemistry, filtration, aeration, and lighting, which made it possible for anyone to enjoy fish. Meanwhile, faster and more advanced transportation allowed an increasing number of exchanges throughout the world.

Today, ornamental fishkeeping is one of the most popular hobbies globally, particularly in developed countries, such as the United States of America (USA), Japan, Australia, Germany, France, Belgium, the Netherlands, the United Kingdom (UK), and Italy. In total, several million households now possess at least one aquarium. For marine species, there are about two million private and approximately 1000 public aquariums worldwide (Biondo, 2018). Many cities around the world are planning to build new aquariums and private demand is increasing as well. There is a growth potential for the aquarium industry, as only 50 per cent of the top 100 cities, hosting more than three million people, have a public aquarium (Biondo, 2018). The entire value of the industry inclusive of retail sales, associated materials, wages and non-exported product is estimated around US\$ 15 - 30 billion per year, and the international market may involve more than 100 countries (Teletchea, 2016). The USA, Japan, Singapore, the UK, Germany, France, the Netherlands, and Italy are the largest importing countries. Indo-Pacific countries, such as Indonesia, the Philippines, Sri Lanka and the Maldives, Brazil, Israel, Czech Republic, the USA are among the top exporting countries. The United States alone is purported to account for half of the trade in marine ornamental fishes (Rhyne et al., 2017). Besides, Singapore is known to be a hub for the global trade where fish imported from various parts of Asia are then re-packed and exported mainly to the US and the European Union.

Over a billion fish traded

Over a billion fish are traded internationally each year. Nine fish out of ten are coming from freshwaters, the remaining, around 30 million, are issued from marine waters (Teletchea, 2016). These fish belong probably to more than 5000 freshwater and about 1800 marine species, even though the number of fish species that are traded is often much lower and heavily skewed towards the same families. Based on a survey realized in ten large-size, privately owned aquarium stores in Greece, Papavlasopoulou et al. (2014) recorded 326 fish species belonging to 64 families. The mean number of species recorded per store was 61. Two-thirds were freshwater species, one-quarter were marine, and less than 10% originated from transitional aquatic ecosystems. Among the freshwater fishes, Cichlidae and Cyprinidae were the dominant families with 64 and 27 species, respectively (Papavlasopoulou et al., 2014). Four families (Callichthyidae, Loricariidae, Characidae, Osphronemidae) were represented by 11-15 species, 12 families were represented by 2-8 species and the remaining 22 families were represented by a single species. Among the marine fishes, the family Acanthuridae dominated with ten species, followed by Balistidae and Gobiidae with five species. Four families (Apogonidae, Labridae, Pomacanthidae and Scorpaenidae) were represented by three species each and the remaining 17 families by a single species (Papavlasopoulou et al., 2014). Similarly, Rixon et al. (2005) recorded 308 freshwater fish species during a survey of 20 pet and aquarium stores located in North America. The most common were goldfish, followed by Siamese fighting fish *Betta splendens*, guppy *Poecilia reticulata*, neon tetra *Paracheirodon innesi*, koi carp *Cyprinus carpio*, white cloud mountain minnow *Tanichthys albonubes*, green swordtail *Xiphophorus hellerii*, and southern platyfish *Xiphophorus maculatus* (Rixon et al., 2005). Only for marine fish, Rhyne and Tlustý (2012) found that only 20 species represented more than half of the total number of individuals imported to the USA, with six species with more than 400,000 fish each: blue green damselfish *Chromis viridis*, sapphire devil *Chrysiptera cyanea*, threespot dascyllus *Dascyllus trimaculatus*, whitetail dascyllus *Dascyllus aruanus*, anemonefish *Amphiprion ocellaris* / *Amphiprion percula* together and goldtail demoiselle *Chrysiptera parasema*. Conversely, only 10 or fewer specimens were imported for 326 species that year (Rhyne and Tlustý, 2012).

Wild-caught vs captive-bred?

Historically, all aquarium fish traded were wild-caught. Yet, within the past decades, an increasing number of ornamental fish species have been bred in captivity. This implies that, as recently demonstrated for foodfish, such a dichotomy, either wild-caught (fisheries) or captive-bred (aquaculture), is not relevant since numerous species are produced using a spectrum of methods (Teletchea, 2016). Therefore, in order to better describe the ornamental fish production and notably highlight its dependence on fisheries, a new classification initially developed for foodfish was applied to the hundred most popular aquarium fish species sold in Europe and North America. This classification includes six levels of domestication: capture of wild animals in nature, i.e. fisheries (level 0), first trials of acclimatization to the culture environment (level 1 of domestication), part of the life cycle closed in captivity (level 2), entire life cycle closed in captivity with wild inputs (level 3), entire life cycle closed in captivity without wild inputs (level 4), and selective breeding programmes used focusing on specific goals (level 5). The levels of domestication of freshwater aquarium fish species ($n = 50$) ranged from 0 to 5, with 20 species classified at the level 5, among which the goldfish, the Siamese fighting fish, and the guppy (Figure 1). This result illustrated that probably 90% of the tropical freshwater fishes are captive bred (Raghavan et al., 2013). Inversely, only three freshwater species were classified at the level 0 (1 species) and 1 (2 species), namely the golden otocinclus *Macrotocinclus affinis*, and the leopard pleco *Pterygoplichthys gibbiceps* and the amazon sailfin catfish

Pterygoplichthys pardalis, respectively. The levels of domestication of marine fish species ($n = 50$) ranged from 0 to 3 (Figure 1). Nearly half of the species ($n = 23$) were classified at the level 0, among which the palette surgeonfish *Paracanthurus hepatus* or the yellow tang *Zebrasoma flavescens*. Inversely, 10 species belong to the level 3, among which the banggai cardinal fish *Pterapogon kauderni*, and the clown anemonefish *Amphiprion ocellaris*.

In conclusion, nearly 75% of the hundred most popular aquarium species studied were classified at the levels 0 to 3, implying that their trade is based either partly or entirely on the capture of wild specimens. The farming of these species thus represents most often initial experiments with no foreseeable lasting results. This is particularly true for the marine aquarium aquaculture industry, which is in its infancy with limited specific research and multiple restricting bottlenecks (Teletchea, 2016). Rhyne et al. (2017) provided an overview of the main bottlenecks, such as appropriate foods for larvae, and opportunities, such as selective breeding, of marine ornamental fish aquaculture. The Food and Agriculture Organization of the United Nations (FAO) and the World Associations of Zoos and Aquariums (WAZA) consider that less than 30 marine ornamental fish species are being captive bred in significant volumes (Biondo, 2018). A list of captive bred marine ornamental fish species is available at The Marine Breeders Initiative (MBI) website: www.mbisite.org. They are also reports of between 100 and 300 marine species bred in captivity, largely on a hobbyist or research scale, even though less than 10% have reached a commercial scale with significant volumes (Biondo, 2018).

Lack of regulations

Despite the volume and tremendous diversity of fishes traded, few laws or regulations are in place to control the aquarium fish market (Biondo, 2018). For example, there is no legislation or official reporting system in place that requires the declaration of ‘species’ or their ‘numbers’ prior to export (Raghavan et al., 2013). Hence, even though some individual exporters do provide data on the details of the cargo (species and numbers), others simply list aquarium fish exports under the general label ‘live ornamental fish’ or ‘tropical freshwater fish’. The practice of shipment reporting only by weight or value represents an impediment to assessing the origin and number of individuals by species. For example, around 291 species of African freshwater fishes are traded without any quantification (Raghavan et al., 2013). Most exporting countries have either no specific management plans, or when such plans do exist, they are rarely enforced and implemented based on weak scientific baseline studies or monitoring activities (Biondo, 2018). Also, very few marine ornamental fish species, among which seahorses (*Hippocampus* spp.), are protected or monitored by the Convention on International Trade of Endangered Species (CITES) (Biondo, 2018). At last, the importation of live aquarium species is one of the major potential vectors of introduction of non-indigenous aquatic species, which is considered as a major threat to biodiversity (Papavlasopoulou et al., 2014). Globally, over 150 species invasions in natural ecosystems has been linked to the aquarium trade (Papavlasopoulou et al., 2014). In the USA only, 26% of human-mediated alien fish diversity was attributed to the aquarium trade and 115 freshwater aquarium species have been reported as introduced into the wild (Papavlasopoulou et al., 2014). To reduce the risk of invasions due to the intentional release of fish by hobbyists, it has been proposed that the sale of species that routinely outgrow home aquarium should be stopped (Rhyne et al. 2017).

In conclusion, the aquarium fish trade should become more sustainable through the development and deployment of best practices and standards. Several ornamental fish trading organizations functioning globally are actively engaged in both development of the industry and making ornamental fish trade more sustainable, such as Marine Aquarium Council (MAC;

<http://www.aquariumcouncil.org/>), Ornamental Aquatic Trade Association (OATA; <http://www.ornamentalfish.org/>), Ornamental Fish International (OFI; <http://www.ofish.org>) and International Air Transport Associations (IATA; <http://www.iata.org/>).

Welfare issues

Most information available on the welfare of ornamental fish comes from the hobbyist literature or online (Stevens et al., 2017). In contrast, there is a conspicuous lack of scientific literature on this specific topic, particularly in comparison with the work realized on foodfish (Stevens et al., 2017). There is also a lack of legislation addressing precisely ornamental fish, even though fish trading organizations promote high welfare standards and set out codes of conduct. They also provide training courses and advocate for improvements in fish handling and welfare; yet the global trade has no regulatory body.

Ornamental fishes, like any captive animals, are exposed to various stressors, which may alter their welfare and result in poor growth, disease and potentially death. These stressors include inadequate water quality (e.g., salinity, pH, nitrogen compounds, dissolved oxygen, carbon dioxide), handling, transportation, confinement, poor social (e.g., density) and physical environment, and diseases. All efforts should be made to reduce chronic (long-term) stress, while acute stress, such as transport and handling, cannot be avoided. The most common physiological method to quantify stress in fish is to measure cortisol, both within the fish or in the water for enclosed tank. Yet, behavioural measures of stress are most commonly used as they are easier and simpler to observe, among which are flashing (scratching body surface on objects), gasping at the water surface, changes in ventilation, feeding behavior or swimming activities. Concerns are also raised about nutrition as feeding an ornamental fish in our modern society represents a symbolic action more referred to humans than to fish physiological needs; therefore, human psychology affects the ornamental fish feeds quality much more than the fish physiology (Sicuro, 2018). At last, some of the newer varieties of aquarium fish (level 5 of domestication) are rejected because people claimed to see a trend in the direction of increasing abnormality and monstrosities in the fishes. In Germany, as part of their animal Welfare laws, the government produced, in 1999, provisions aimed at banning any animal breeding that could lead to “pain, suffering or damage” to the animal. In both Europe and the USA, more and more hobbyists are indeed expressing their dislike about man-made fishes (Teletchea, 2016).

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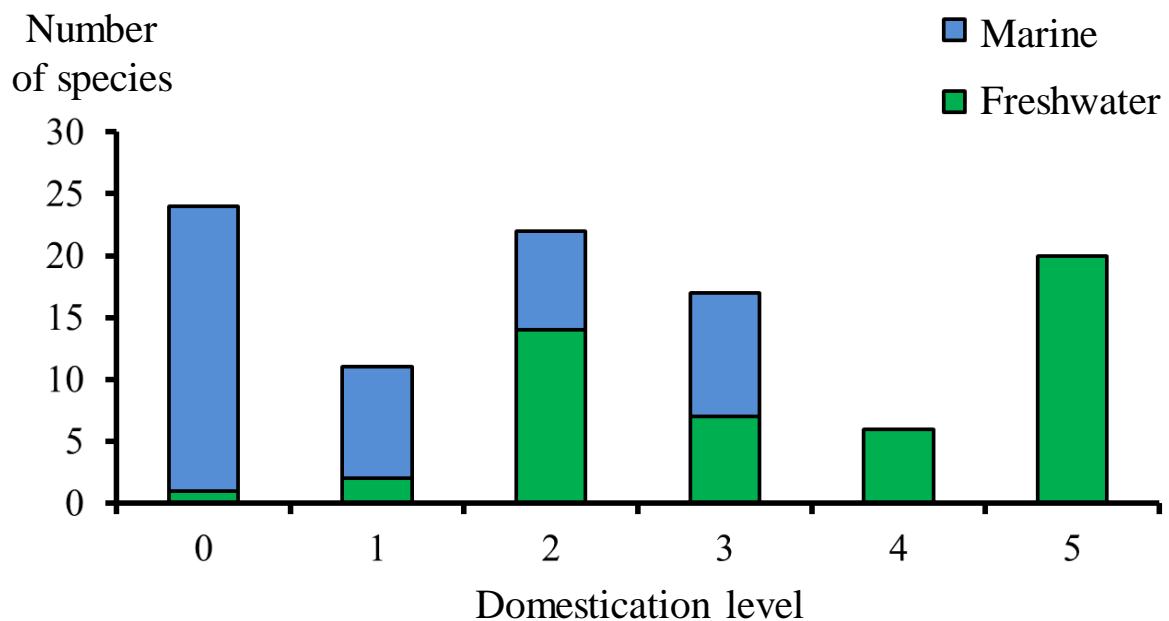
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Figure 1



Number of aquarium fish species per domestication level ($n = 100$). Importantly, reaching a given level for a species does not imply that the entire production is based on this level (modified after Teletchea, 2016).