Domestication level of the most popular aquarium fish species: is the aquarium trade dependent on wild populations?

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Keywords

Aquarium fish, aAquarium trade, conservation, domestication, sustainability, wild fish.

Abstract

The aquarium fish trade has strongly increased in the past decades to become one of the most popular hobbies globally. Historically, all aquarium fish traded were wild-caught. Then, an increasing number of fish species have been produced in captivity. The main goal of the present study is to apply the concept of domestication level to the hundred most popular aquarium fish species in Europe and North America. The levels of domestication of freshwater aquarium fish species (n= 50) ranged from 0 to 5, with 20 species classified at the level 5 (selective breeding programmes are used focusing on specific goals) and only three species at the level 0 (capture fisheries) and 1 (first trials of acclimatization to the culture environment). In contrast, the levels of domestication of marine fish species (n= 50) ranged from 0 to 3, implying that the production of all marine aquarium fish species is based either entirely or partly on the capture of wild-caught specimens. Based on this new classification, the main advantages and drawbacks of fisheries and aquaculture are discussed.

1. Introduction

The international aquarium fish trade has strongly increased in the past century, particularly since the early 1980s, to become one of the most popular hobbies globally (Andrews, 1990; Dufour, 1998; Wabnitz et al., 2003; Anonymous, 2007; Livengood and Chapman, 2011; Strecker et al., 2011). Today, it is estimated that million households possess at least one aquarium, particularly in the United States of America, European countries (Germany, France, Belgium, Italy), Japan, China, Australia and South Africa (Andrews, 1990; Wabnitz et al., 2003; Livengood and Chapman, 2011; Rhyne and Tlusty, 2012; Papavlasopoulou et al., 2014). For instance, about 11 million American households have at least one aquarium representing almost 11% of pet owners (Tlusty, 2002 ; Rixon et al., 2005; Papavlasopoulou et al., 2014). Likewise, about 11% of French households have an aquarium with a mean of 10 fish, which represent around 30 million aquarium fish kept, i.e., half of all pets in France (Hignette, 2003; Nedellec, 2010). The entire industry inclusive of retail sales, associated materials and wages is valued at approximately US$ 15 to 30 billion per year (Andrews, 1990; Tlusty, 2002; Whittington and Chong, 2007; Moorhead and Zeng, 2010; Raghavan et al., 2013) and the international market probably involves more than 100 countries (Cheong, 1996; Whittington and Chong, 2007). The principal sources of freshwater fish species are the United States of America, Singapore, Brazil, Israel and more recently Czech Republic, while those of marine fish species are chiefly Indonesia, Philippines, Sri Lanka and Singapore (Andrews, 1990; Dufour, 1998; Lim et al., 2003; Monteiro-Neto et al., 2003; Whittington and Chong, 2007; Nedellec, 2010). The top importing regions are the United States of America, European countries (Germany, United Kingdom, France, and Italy), Japan and more recently China (Cheong, 1996; Dufour, 1998, Wood, 2001; Monteiro-Neto et al., 2003; Wabnitz et al., 2003; Livengood and Chapman, 2011; Townsend, 2011; Cohen et al., 2013).

It is estimated that over 6 000 aquarium fish species are now traded internationally each year, among which three quarters (ca. 4 000) live in freshwaters and one quarter (ca. 1 500-1 800) in marine waters (Whittington and Chong, 2007; Rhyne and Tlusty, 2012; Raghavan et al., 2013). The global market has probably reached a billion fish annually, which would be a multiplication by six of the total number of fish sold globally in the late 1980s (Andrews, 1990; Whittington and Chong, 2007;

Raghavan et al., 2013). More than ninety per cent of the aquarium fish traded belong to freshwater fish species (Livengood and Chapman, 2011; Raghavan et al., 2013), whereas the total number of marine fish range between 20 to 24 million per year (Wabnitz et al., 2003). Another strong difference between freshwater and marine aquarium fish is that the former are chiefly farm-bred (ca. 90%) whereas the latter are mainly wild-caught (Andrews, 1990; Dufour, 1998; Tlusty, 2002; Hignette, 2003; Whittington and Chong, 2007; Livengood and Chapman, 2011; Raghavan et al., 2013). However, it has recently been demonstrated for foodfish that such a dichotomy, either farm-bred or wild-caught, is not relevant since numerous foodfish species are produced using a spectrum of methods and cannot be cleanly ascribed as fisheries or aquaculture (Teletchea, 2012; Klinger et al., 2013; Teletchea and Fontaine, 2014). In order to better describe the various strategies for foodfish production, a new classification comprising five levels of domestication with 1 being the least to 5 being the most domesticated was developed (Teletchea and Fontaine, 2014). Among the 250 species recorded in the FAO database in 2009, 39 belong to the level 1 (first trials of acclimatization to the culture environment), 75 to the level 2 (part of the live cycle closed in captivity, also known as capture-based aquaculture), 61 to the level 3 (entire life cycle closed in captivity with wild inputs), 45 to the level 4 (entire life cycle closed in captivity without wild inputs) and 30 to the level 5 (selective breeding programmes are used focusing on specific goals). Based on this new classification, it was highlighted that 70% of the 250 farmed foodfish species, actually belong to the first three levels of domestication, thus representing a transitory form of fish production dependent on the availability of the wild resource (Teletchea and Fontaine, 2014).

The main goal of the present study is to examine the domestication level of the most popular aquarium freshwater and marine fish species in order to assess the dependence of the aquarium trade on wild populations.

2. Material and Methods

The number of aquarium fish species traded worldwide is enormous (Andrews, 1990; Whittington and Chong, 2007; Maceda-Veiga et al., 2013; Raghavan et al., 2013). Even in a single retail store, tens of fish species can easily be found (Rixon et al., 2005; Strecker et al., 2011; Maceda-Veiga et al., 2013; Papavlasopoulou et al., 2014). Therefore, a choice has to be made. In the present study, the hundred most popular aquarium species (50 living in freshwaters and 50 in marine waters) in Europe and North America were selected (Wabnitz et al., 2003; Rixon et al., 2005; Nedellec, 2010; Livengood and Chapman, 2011; Maceda-Veiga et al., 2013, 2014; Papavlasopoulou et al., 2014). The choice of freshwater fish species was based chiefly on the studies of Rixon et al. (2005), Strecker et al. (2011), Maceda-Veiga et al. (2013, 2014) and Papavlasopoulou et al. (2014). For instance, Rixon et al. (2005) recorded 308 freshwater fish species during a survey of 20 pet and aquarium stores located in North America (Michigan, USA; Ontario, Canada) between October 2002 and July 2003. Among the 308 species, only 31 were found in more than half of stores, with the most common were goldfish Carassius auratus (Linnaeus, 1758) (100% occurrence), followed by siamese fighting fish Betta splendens Regan, 1910, guppy Poecilia reticulata Peters, 1859, neon tetra Paracheirodon innesi (Myers, 1936) (each in 19 pet stores), koi carp Cyprinus carpio Linnaeus, 1758, white could mountain minnow Tanichthys albonubes Lin, 1932, green swordtail Xiphophorus hellerii Heckel, 1848, and southern platyfish Xiphophorus maculatus (Günther, 1866) (each in 17 pet stores) (Rixon et al., 2005). The choice of marine species was based mainly on the studies of Wood (2001), Wabnitz et al. (2003), Monteiro-Neto et al. (2003), Moorhead and Zeng (2010), Kiron and Dhanasiri (2011) and Rhyne and Tlusty (2012). For instance, Rhyne and Tlusty (2012) reviewed all the shipment declarations and the attached commercial invoices for a one year period (May 2004 to May 2005) to evaluate the diversity of marine aquarium fish species imported in the U.S. Based on the analysis of 8,015 discrete invoices, they found that more than 11 million fishes belonging to 1802 species from 125 families were imported. Nevertheless, only 20 species represented more than half of the total number of individuals imported, with six species with more than 400 000 fish each: blue green damselfish Chromis viridis (Cuvier, 1830), sapphire devil Chrysiptera cyanea (Quoy & Gaimard, 1825), threespot dascyllus Dascyllus trimaculatus (Rüppell, 1829), whitetail dascyllus Dascyllus aruanus (Linnaeus, 1758), anemonefish Amphiprion ocellaris Cuvier, 1830 / Amphiprion percula (Lacepède, 1802) together and goldtail demoiselle Chrysiptera parasema (Fowler, 1918). Conversely, only 10 or fewer fish were imported for 326 species that year (Rhyne and Tlusty, 2012). Then, an extensive literature search was realized to determine for each selected species its domestication level based on scientific articles found using scholar google website (http://scholar.google.fr/), the Marine Breeders Initiative (Murray and Watson, 2014) or general websites using google.

3. Results

The levels of domestication varied strongly between freshwater and marine aquarium fish species (Fig. 1). Overall, 25 freshwater species were classified at the levels 4 and 5, whereas all marine species were classified at the levels 0 to 3.

3.1. Domestication level of freshwater aquarium fish species

The 50 most popular aquarium fish species belonged to 12 families (Tab. I). The two families with the highest number of species were Cyprinidae (n = 11) and Characidae (n = 11), followed by Poeciliidae (n = 6) and Cichlidae (n = 6). Inversely, five families were represented by a single species only, Alestidae, Cobitidae, Gyrinocheilidae, Helostomatidae, and Serrasalmidae.

The levels of domestication ranged from 0 to 5 (Tab. I). 20 species were classified at the level 5, among which the goldfish, the siamese fighting fish, and the guppy. Inversely only three species were classified at the level 0 (1 species) and 1 (2 species), namely the golden otocinclus Macrotocinclus affinis (Steindachner, 1877), and the leopard pleco Pterygoplichthys gibbiceps (Kner, 1854) and the amazon sailfin catfish Pterygoplichthys pardalis (Castelnau, 1855), respectively.

3.2. Domestication level of marine aquarium fish species

The 50 most popular aquarium fish species belonged to 17 families (Tab. II). The family with the highest number of species was Pomacentridae (n = 16), followed by Pomacanthidae (n= 9) and Acanthuridae (n = 6). On the opposite, all other families have only one single species, except Apogonidae, Labridae, Serranidae, each with two and Syngnathidae with three.

The levels of domestication ranged from 0 to 3, implying that the production of all marine fish species was based either entirely or partly on the capture of wild specimens (Tab. II). Nearly half of the species (n= 23) were classified at the level 0, among which the palette surgeonfish Paracanthurus hepatus (Linnaeus, 1766) or the yellow tang Zebrasoma flavescens (Bennett, 1828). Inversely, 10 species belong to the level 3, among which the banggai cardinal fish Pterapogon kauderni Koumans, 1933, and the clown anemonefish Amphiprion ocellaris Cuvier, 1830.

4. Discussion

Even though the number of fish species targeted in the present study is very small compared to the total number of aquarium species traded globally, they still represent together the bulk of the market in terms of volume (Andrews, 1990; Wood, 2001; Anonymous, 2007; Rhyne and Tlusty, 2012; Murray and Watson, 2014). Thus, the present study reflects relatively well the current state of the aquarium market in North America and Europe.

4.1. How many aquarium fish species are domesticated?

Domestication implies much more than merely keeping wild animals in farms or homes (Fosså, 2004; Teletchea and Fontaine, 2014). Indeed, domestication is a long and endless process during which captive individuals will become more adapted to humans and captive conditions and consequently progressively modified from their wild congeners. Domestication leads to permanent genetic modifications of a bred lineage, while taming or keeping wild fish in captive conditions is only conditioned behavioral modification of individuals. Consequently, to be considered as domesticated, the entire life cycle of the targeted fish species must be fully closed in captivity, independently of wild sources (Balon, 2004; Teletchea and Fontaine, 2014). Once one full life cycle is completed in captivity, the process of domestication can proceed further (Teletchea and Fontaine, 2014).

Based on these definitions, the first truly domesticated fish species was certainly the goldfish, for which the domestication was initiated by Chinese about 1500-2000 years ago (Fosså, 2004). Today, goldfish is one of the most popular aquarium fish species that display hundreds of fancy breeds (Balon, 2004; Nedellec, 2010). Several other aquarium freshwater fish species can also be considered truly domesticated today, i.e., those at the levels 4 and 5 (Tab. I). Depending on the species, captive or domesticated fishes have more or less strongly diverged from wild phenotypes through selective breeding, mutations and/or hybridization, such as the siamese fighting fish (Balon, 2004; Fosså, 2004). However, even for fish species that have reached the levels 4 or 5, large number of wild individuals can still be caught in nature, especially in South America and Africa where little aquarium fish farming is carried out (Andrews, 1990; Raghavan et al., 2013). Besides, there are numerous species for which the trade depends almost exclusively on wild-caught specimens, such as the clown loach Chromobotia macracanthus (Bleeker, 1852) or the almost 300 African freshwater species known to occur in the aquarium trade (Legendre et al., 2012; Raghavan et al., 2013).

Compared to the freshwater aquarium trade, the onset of marine aquarium trade is much more recent and probably occurred in the 1930s in Sri Lanka (Wood, 2001; Wabnitz et al., 2003). Trade expanded during the 1950s, with an increasing number of places (e.g. Hawaii and the Philippines) and accounts for about 10 per cent of the international aquarium fish trade in terms of value (marine and freshwater included) in the past years (Wabnitz et al., 2003; Cohen et al., 2013). During this period, probably over 100 species of marine fish have been bred in captivity in many countries, but of these, relatively few have reached a commercial scale (Wood, 2001; Townsend, 2011). One of the main bottlenecks to overcome in order to complete the entire life cycle in captivity of a marine fish species is the first feeding of larvae, as they are very small and thus they need tiny, live foods (Tlusty, 2002; Wabnitz et al., 2003; Olivotto et al., 2011). To date, captive larval rearing successes have been largely limited to small, experimental, or hobbyist scales. Additionally, very few scientific publications exist documenting aspects pertinent to the culture of aquarium reef fish species (Moorhead and Zeng, 2010). Consequently, the trade of virtually all marine aquarium marine species depends partly or entirely on wild-caught specimens (Wood, 2001; Wabnitz et al., 2003; Anonymous, 2007; Townsend, 2011; Murray and Watson, 2014). Nevertheless, there is, for some species, a partial control of the life cycle in captivity (level 2), which corresponds for instance to post-larval capture and culture or PCC for coral reefs, i.e., fish larvae are captured via means of light traps or crest nets and are then grown in captivity up to the commercial size (Hignette, 2003; Wabnitz et al., 2003). Besides, very few species are now commercially bred with the whole life cycle closed in captivity (level 3), such as bangaii cardinalfish, clownfish Amphiprion spp, and probably several gobies (Gobiosoma, Gobiodon, Amblygobius), dottybacks (Pseudochromis spp), jawfish (Opisthognathus), basslets (Gramma ssp) and various seahorses Hippocampus spp (Wood, 2001; Wabnitz et al., 2003; Anonymous, 2007; Olivotto et al., 2011; Townsend, 2011). In order to encourage marine aquaria hobbyists to get involved in the captive breeding of marine organisms and document their successes, a new tool was recently developed by the Marine Life Aquarium Society of Michigan (Murray and Watson, 2014). This project, called The Marine Breeders Initiative (MBI), is freely available at the following address www.mbisite.org/, and was used in the present study to establish the domestication level of marine species. However, successful breeding indicated in this database can mean anything from 'inducing spawning' to 'keeping the larvae alive for 60 days postlarval settlement', and so most successes do not lead to marketable sized organisms (Murray and Watson, 2014; see also:

http://www.reef2rainforest.com/2015/01/05/captive-bred-marine-fishes-state-of-the-art-2015/).

In conclusion, three-quarters of the hundred most popular aquarium species studied here were classified at the levels 0 to 3, implying that their trade is based either entirely or partly on the capture of wild specimens. The farming of these species, when it does exist, thus represents initial experiments with no foreseeable lasting results (Teletchea and Fontaine, 2014). This is particularly true for the marine aquarium aquaculture industry, which is in its infancy with limited specific research and multiple restricting bottlenecks (Moorhead and Zeng, 2010). Besides, as for foodfish, there is no dichotomy between wild and captive fish for most aquarium species traded globally and "farmed" should not be confused with "domesticated" (Fosså, 2004; Teletchea and Fontaine, 2014). Therefore, it is really important to distinguish how aquarium fish species are produced in captivity using either the classification proposed here or a similar classification developed by the CITES Coral Working Group for corals (Olivotto et al., 2011). This last classification contains four source codes for hard (also known as stony) corals: "w" for wild, maricultured, or farmed corals (maintenance or growth of wild coral clippings or fragments in marine-based aquaculture systems); "f" for aquacultured corals (first-generation cultured corals produced in aquaculture systems); "c" for captive-bred or cultured corals (second-generation cultured corals produced in closed systems); and "r" for ranched corals (rearing of whole corals or larvae taken from the wild in a controlled environment (Olivotto et al., 2011).

4.2. Should all wild-caught fisheries be stopped and all farmed fish species domesticated?

4.2.1. Fisheries

The capture of wild fish has an important economic status and is a major overseas income in numerous developing regions (Andrews, 1990; Anonymous, 2007; Livengood and Chapman, 2011; Rhyne et al., 2012). Besides, as very few aquarium species are exploited directly for other purposes, there is little doubt that aquarium animals are the highest value-added product that can be harvested, particularly in a coral reef (Wabnitz et al., 2003; Rhyne et al., 2014). At last, the collection of aquarium fish often represents in these regions, the only sources of revenues and employment (Tlusty, 2002).

The global capture of aquarium marine fish has been estimated at 100 tonnes (Anonymous, 2007). Thus, it is often considered that the collection of marine species for the aquarium trade has not driven any global extinction of species, which is probably true for the most widespread and/or abundant species (Wabnitz et al., 2003; Rhyne et al., 2012). However, there are some evidence of localized depletion of a number of target aquarium species in Sri Lanka, Kenya, the Philippines, Indonesia and Hawaii (Andrews, 1990; Wabnitz et al., 2003). One well-known example of such depletion is the banggai cardinal fish, occurring naturally only in Sulawesi, which quickly became heavily traded and overexploited once it entered the aquarium trade (Rhyne et al., 2012). Besides, one of the main problems with the trade of wild-caught aquarium fish is the destructive fishing practices that are commonly used to collect animals (Andrews, 1990; Dufour, 1998; Hignette, 2003; Moorhead and Zeng, 2010; Rhyne et al., 2012; Cohen et al., 2013). For instance, the use of cyanide destroys the habitat of the target fish species as well as of other organisms (Hignette, 2003; Kiron and Dhanasiri, 2011).

Summing up, if managed sustainably, the trade of wild-caught marine and freshwater fish species could support jobs in predominantly rural, low-income communities and so could provide strong economic incentives for conservation in regions where other options for generating revenue are limited (Wabnitz et al., 2003; Tlusty et al., 2006; Kiron et Dhanasiri, 2011; Rhyne et al., 2012; Murray and Watson, 2014).

4.2.2. Aquaculture

The farming of aquarium fish species has considerably developed in the last decades. Once the full life cycle of a fish species is controlled in captivity (levels 4 to 5), farming allows releasing the pressure on wild populations by supplying tank-bred fish year-round for the aquarium trade (Wood, 2001; Wabnitz et al., 2003; Olivotto et al., 2011). This is particularly critical for endangered or over-exploited species (Müller & Schlegel, 1844) (Wood, 2001; Tlusty, 2002).

Nevertheless, it is also possible that if the trade becomes more reliant on cultured fish, less attention might be paid to conserving the habitat in which they occur in the wild (Wood, 2001). Besides, aquaculture production, instead of replacing the capture of wild specimens, can sometimes accelerate a decline in the wild populations because captively-bred fish add to the popularity of a species and does not replace the reliance on wild collections (Tlusty, 2002). Moreover, if bottlenecks hamper closing the live cycle in captivity (level 2), the production would rely on the repeated collections of wild animals, and thus may actually contribute to the decrease of wild populations (Tlusty, 2002). Inversely, farming can be used either to restock or save rare or critically endangered species (Moorhead and Zeng, 2010). Public aquariums are probably the best place to support the development of such conservation programs (Koldewey et al., 2013; Tlusty et al., 2013). Today, both the North American based Association of Zoos and Aquariums (AZA) and the global World Association of Zoos and Aquariums (WAZA) address collection sustainability (Tlusty et al., 2013). One additional benefit of the aquaculture of aquarium fish is that it leads to the gradual production of hardier species, which are better adapted to captive conditions and survive longer (Wabnitz et al., 2003; Anonymous, 2007). For species that have reached the level 5, domestication allows the production of strains that are popular in the hobby, but do not occur in the wild (Tlusty, 2002). Most often, domesticated varieties are positively considered and indicative of man-made fish are regarded as an asset to the aquarium hobby (Fosså, 2004; Maceda-Veiga et al., 2014). At last, some of the most domesticated aquarium species became vertebrate model in science, such as the well-known zebrafish, Danio rerio (Hamilton, 1822) or the medaka, Oryzias latipes (Temminck & Schlegel, 1846) (Maceda-Veiga et al., 2014). Nevertheless, concerns are raised over some of the newer varieties of aquarium fish, because people claimed to see a trend in the direction of increasing abnormality and monstrosities in the fishes (Balon, 2004; Fosså, 2004). 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 (Fosså, 2004). More generally, in Europe, but also in the United States of America, more and more fishkeepers are expressing their dislike of man-made fishes (Fosså, 2004). Once a captive fish species is domesticated (levels 4 or 5), it can be produced anywhere in the world. Yet, aquacultural operations tend to be focused in the more prosperous consumer countries where there is sufficient capital investment required for the high cost of developing the necessary infrastructure (Wood, 2001; Tlusty, 2002; Murray and Watson, 2014). This chiefly explains why the production of aquarium fish species has been more prevalent in developed countries, such as in the United States of America, Israel or more recently the Czech Republic (Cheong, 1996; Wood, 2001). Producing fish close to consumer centers is becoming more profitable because transport costs are greatly reduced (Livengood and Chapman, 2011). However, establishment of aquaculture facilities way from the countries of origin deprives these countries of income and puts people out of jobs (Wood, 2001). Therefore, technology should be transferred to developing countries to enable them to set up their own facilities for culturing fish that have come from their native ecosystems (Wood, 2001; Olivotto et al., 2011).

Summing up, aquaculture of aquarium fish species can prevent over-harvesting, help saving critically endangered species, produce new varieties of domesticated fish well adapted to captive conditions, and provide employment (see also Fig. 3 in Tlusty et al., 2013).

5. Conclusion

The aquarium fish trade has strongly increased in the past decades. Historically, all fish traded were wild-caught. Then, as for foodfish, an increasing number of species have been reared in captivity, resulting in that today 90% of the freshwater fish are farmed. Some freshwater species have reached the level 5 and display numerous man-made varieties. In contrast, the bulk of the marine aquarium trade is based on wild-caught or recently farmed fish, thus only slightly changed from their wild counterparts. In the future, it is anticipated that more aquarium fish species will be domesticated.

Figure 1. Number of aquarium fish species per domestication level (white: freshwater, n = 50 species; black: marine, n= 50 species)

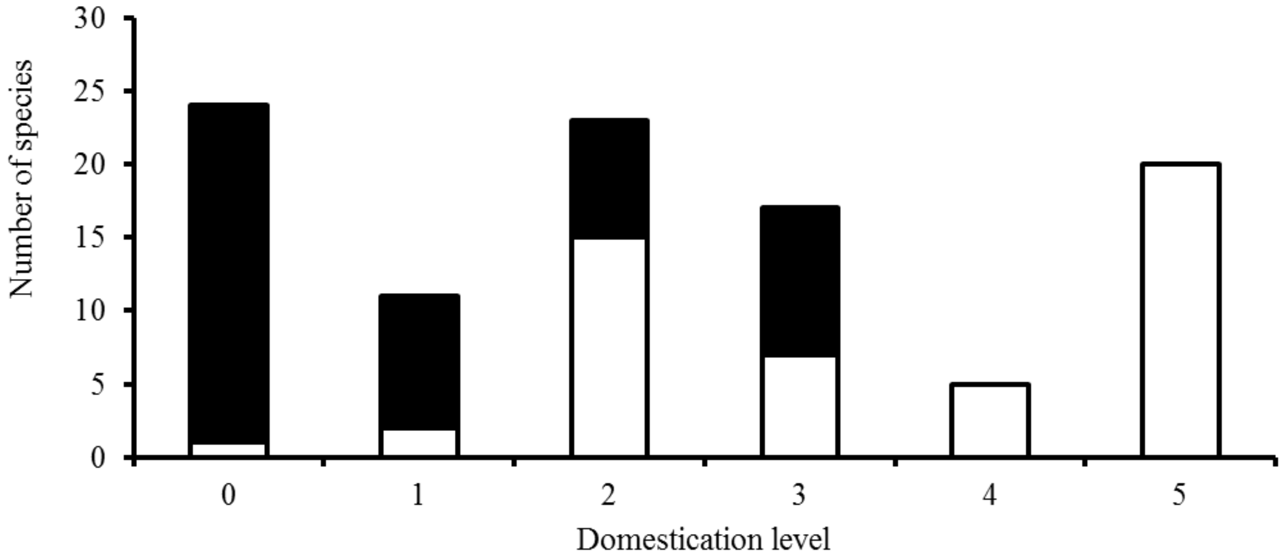

Table I. - Domestication level of the 50 most popular aquarium freshwater fish species classified according to their family. The main references used to establish the domestication level is indicated in the last column.

Family	Scientific names	Common names	Level	Main references
Alestidae	Phenacogrammus interruptus (Boulenger, 1899)	Congo tetra	2	Pecio, 2009
Callichthyidae	Corydoras aeneus (Gill, 1858)	Bronze corydoras	4	Huysentruyt et al., 2009
Callichthyidae	Corydoras paleatus (Jenyns, 1842)	Peppered corydoras	2	Pruzsinszky and Ladich, 1998
Callichthyidae	Corydoras panda Nijssen & Isbrücker, 1971	Panda corydoras	2	Sulistyowati and Arfah, 2005
Characidae	Gymnocorhymbus ternetzi (Boulenger, 1895)	Black tetra	5	David and Marimuthu, 2014
Characidae	Hemigrammus erythrozonus Durbin, 1909	Glowlight tetra	2	Pecio et al., 2007
Characidae	Hyphessobrycon eques (Steindachner, 1882)	Jewel tetra	3	Park et al., 2014
Characidae	Hyphessobrycon erythrostigma (Fowler, 1943)	Bleeding-heart tetra	3	[1]
Characidae	Hyphessobrycon herbertaxelerodi Géry, 1961	Black neon tetra	2	Liao, 2000
Characidae	Hyphessobrycon pulchripinnis Ahl, 1937	Lemon tetra	4	Cole et al., 1999
Characidae	Metynnis hypsauchen (Müller & Troschel, 1844)	Silver dollar	2	Liao, 2000
Characidae	Moenkhausia sanctaefilomenae (Steindachner, 1907)	Redeye tetra	3	Alanis et al., 2009
Characidae	Paracheirodon axelrodi (Schultz, 1956)	Cardinal tetra	3	Brito and Bazzoli, 2009
Characidae	Paracheirodon innesi (Myers, 1936)	Neon tetra	5	Balon, 2004
Characidae	Pristella maxillaris (Ulrey, 1894)	X-ray tetra	2	Liao, 2000
Cichlidae	Astronotus ocellatus (Agassiz, 1831)	Oscar	3	Rezvani et al., 2011
Cichlidae	Labidochromis caeruleus Fryer, 1956	Blue streak hap	2	Maleknejad et al., 2014
Cichlidae	Mikrogeophagus ramirezi (Myers & Harry, 1948)	Ram cichlid	2	Liao, 2000
Cichlidae	Pelvicachromis pulcher (Boulenger, 1901)	Rainbow krib	2	Liao, 2000
Cichlidae	Pterophyllum scalare (Schultze, 1823)	Freshwater angelfish	5	Kasiri et al., 2011
Cichlidae	Symphysodon aequifasciatus Pellegrin, 1904	Blue discus	5	Balon, 2004
Cobitidae	Chromobotia macracanthus (Bleeker, 1852)	Clown loach	2	Legendre et al., 2012
Cyprinidae	Balantiocheilos melanopterus (Bleeker, 1850)	Tricolor sharkminnow	4	Ghosh et al., 2003
Cyprinidae	Carassius auratus (Linnaeus, 1758)	Goldfish	5	Komiyama et al., 2009
Cyprinidae	Cyprinus carpio Linnaeus, 1758	Common carp, Koi carp	5	Balon, 2004
Cyprinidae	Danio rerio (Hamilton, 1822)	Zebra danio	5	Balon, 2004
Cyprinidae	Devario aequipinnatus (McClelland, 1839)	Giant danio	3	Dey et al., 2014
Cyprinidae	Epalzeorhynchos frenatum (Fowler, 1934)	Rainbow sharkminnow	4	Albernathy, 2004
Cyprinidae	Pethia conchonius (Hamilton, 1822)	Rosy barb	5	Swain and Jayasankar, 2013
Cyprinidae	Puntigrus tetrazona (Bleeker, 1855)	Sumatra barb	5	Tamaru et al., 1997
Cyprinidae	Puntius titteya Deraniyagala, 1929	Cherry barb	2	Sundarabarathy et al., 2004
Cyprinidae	Tanichthys albonubes Lin, 1932	White cloud mountain minnow	4	Sado and Kimura, 2005
Cyprinidae	Trigonostigma heteromorpha (Duncker, 1904)	Harlequin rasbora	5	[2]
Gyrinocheilidae	Gyrinocheilus aymonieri (Tirant, 1883)	Siamese algae-eater	2	Liao, 2000
Helostomatidae	Helostoma temminkii Cuvier, 1829	Kissing gourami	5	Ng and Tan, 1997
Loricariidae	Ancistrus dolichopterus Kner, 1854	Bushymouth catfish	2	Brysiewicz et al., 2011
Loricariidae	Hypostomus plecostomus (Linnaeus, 1758)	Suckermouth catfish	2	Liao, 2000
Loricariidae	Macrotocinclus affinis (Steindachner, 1877)	Golden otocinclus	0	[3]
Loricariidae	Pterygoplichthys gibbiceps (Kner, 1854)	Leopard pleco	1	Brion et al., 2013
Loricariidae	Pterygoplichthys pardalis (Castelnau, 1855)	Amazon sailfin catfish	1	Brion et al., 2013
Osphronemidae	Betta splendens Regan, 1910	Siamese fighting fish, bettas	5	Monvises et al., 2009
Osphronemidae	Trichogaster lalius (Hamilton, 1822)	Dwarf gourami	5	Zuanon et al., 2013
Osphronemidae	Trichopodus trichopterus (Pallas, 1770)	Three spot gourami	5	Ng and Tan, 1997
Poeciliidae	Poecilia latipinna (Lesueur, 1821)	Sailfin molly	5	Balon, 2004
Poeciliidae	Poecilia reticulata Peters, 1859	Guppy	5	Balon, 2004
Poeciliidae	Poecilia sphenops Valenciennes, 1846	Molly	5	Balon, 2004
Poeciliidae	Xiphophorus hellerii Heckel, 1848	Green swordtail	5	Balon, 2004
Poeciliidae	Xiphophorus maculatus (Günther, 1866)	Southern platyfish	5	Balon, 2004
Poeciliidae	Xiphophorus varietus (Meek, 1904)	Variable platyfish	5	[4]
Serrasalmidae	Pygocentrus nattereri Kner, 1858	Red piranha	3	Rahman et al., 2008

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