

## The Pet Trade as a Source of Invasive Fish in Taiwan

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**ABSTRACT:** In this study, ornamental fish available for purchase at pet stores in Taiwan were compared to those documented as having invaded the island's ecosystems. In total, 293 pet fish species belonging to 48 families were recorded. The top five families that included the most pet fish species were the Cichilidae (79 species), Callichthyidae (38), Characidae (37), Cyprinidae (20), and Loricariidae (16). Among the 48 families, five families, documented as having invasion records, are the Cichilidae, Cyprinidae, Loricariidae, Belontiidae, and Poeciliidae. Except for the Cichilidae, the proportion of invasive species to total species of other four families were at least equal to or greater than 10%, with the Belontiidae displaying the highest proportion at 66.6%. The Belontiidae also demonstrated a significantly higher rate of documented invasive species than did the other families. Families with a greater number of recorded pet fish species also presented a significant positive correlation with their documented invasive species if the 20 families with only a single surveyed species were excluded. Forcing retailers to foster home program, urging aquariums to display how to eliminate fish escaping from captivity, and instituting a higher custom duty or higher purchasing tax were proposed to eliminate future introductions of pet fish species.

**KEY WORDS:** Pet trade, Fish invasion, Taiwan, Island.

### INTRODUCTION

From 1976 to 1996, the global pet trade, including aquarium and ornamental species, grew 14% annually (FAO, 1999). The total export value of ornamental fish and invertebrates in 1996 exceeded US\$200 million (Padilla and Williams, 2004). One-third of the 100 worst invasive species, listed by the IUCN, originate from aquarium or ornamental release (Padilla and Williams, 2004). Currently, aquarium release has become one of the top five pathways for introduction of non-native invasive species worldwide (Ruiz et al., 1997), however, little attention has been given to this commerce by scientists and policymakers.

Invasive species are considered the second leading cause for species extinction in the world (Wilcove et al., 1998). The major hazard for aquatic biodiversity today is also the invasion of exotic species (Allan and Flecker, 1993; Kolar and Lodge, 2001). Significant negative impacts from exotic fish

introductions have long been documented (Ross, 1991; Huston, 1994). These negative impacts include displacing native species (Townsend and Croel, 1991), carrying pathogens (Stewart, 1991), preying on native species (Liang et al., 2005), causing changes in nutrient cycling (Townsend, 1996), and presenting dangers to humans (Stewart, 1991).

The pathways by which pet fish are introduced into nature in Taiwan include the intentional discarding of unwanted species, accidental escape from families and breeding farms, and ritualistic release of species during religious practices (Severinghaus and Chi, 1999). Discarded, released, or escaped pet fish are usually healthy adults, which also have a greater probability of surviving and reproducing in the wild. Thus, pet fish represent a major source of ecological destruction that may be particularly invasive if continually permitted to be released into the wild.

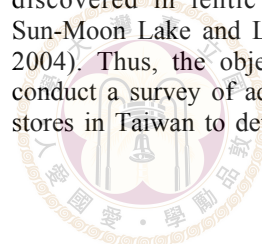
Recently, a reservoir fish survey reported that 19 of the 30 collected fishes were exotic species, and over 50% of these species originated from pet fish (Chang and Tsai, 2004). Similar situations were also discovered in lentic waters, such as those in Sun-Moon Lake and Lang Lake (Chang and Tsai, 2004). Thus, the objective of this study was to conduct a survey of aquarium and ornamental fish stores in Taiwan to determine if those invasive pet

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fishes that are present in the wild are originating from Taiwanese pet stores. By analyzing the results of the survey, the fish families and species located in pet stores can be compared with the documented invasive species to identify those fish families and species with higher invasive potential on the island. Finally, recommendations for reducing and eliminating future pet fish introductions are provided.

## MATERIALS AND METHODS

A survey of 67 pet fish stores, including 34 in Taipei City, 3 in Taichung City, and 33 in Kaohsiung City, was conducted from June to October 2004. The common name, numerical abundance, and market price of each fish in each store were recorded by a team of at least three individuals. The surveyed pet stores targeted were located at major trading locations and included chain stores, wholesale stations, and warehouses, to maximize the survey efficiency. Accurate verification of the species list obtained from the pet trading sites required great labor for the following two reasons. First, the common name listed in the pet store is designed to attract customers, and so it likely differs from the commonly used one, and needs to be verified with taxonomic references. Second, the same species may have been assigned different common names due to variations in their coloration, appearance, and pattern of the body parts. Species identification and verification were based on Page and Burr (1991), Axelrod et al. (1998), and Axelrod (1995). Fish pictures and descriptions on the websites of FishBase (<http://www.fishbase.org>), FishIndex (<http://species.fishindex.com>), Badman's Tropical Fish (<http://badmanstropicalfish.com>), and Aquatic Community (<http://www.aquaticcommunity.com>) were also used to confirm the fish species identification. Species lists of invasive pet fish were generated from Chen et al. (2003), Liang and Chen (2003), and the website of the Natural Resources and Ecological database of the Council of Agriculture, Taiwan (<http://ngis.zo.ntu.edu.tw/exotic/>).

## RESULTS

Fish with 836 commercial names were found in the 67 pet stores visited. They were identified as being 293 species in 48 families (Table 1). Among these, Over 95% were freshwater species, while a few (4.2%) were saltwater species like Tetraodontids. Twenty families were found to be

represented by more than one species; while only a single species was recorded for the other 28 families. If the species of surveyed pet fish were clustered by geographical distribution, the first three assemblies originated from Africa, Central and South America, and Asia, while there were limited numbers from Oceania, North America, and Europe (Fig. 1). The top five families that included the most pet fish species were the Cichlidae (79 species), Callichthyidae (38), Characidae (37), Cyprinidae (20), and Loricariidae (16).

After excluding the 28 families with only one species recorded, Spearman's correlation revealed that families with greater numbers of species also had significantly increased documented numbers of invasive species in Taiwan (Spearman's  $\rho = 0.54$ ,  $p < 0.05$ ,  $n = 20$ ). Sixteen pet fish species (5.4%) of five families have been documented in wild habitats, while those fish species in the other 43 families have so far not been observed in the wild in Taiwan (Table 1). However, except for the Cichlidae, the proportions of invasive species to total species for the four other families with pet fish species existing in the wild were at least  $\geq 10\%$ , with the Belontiidae displaying the highest proportion of 66.6%. The Belontiidae showed a significantly higher rate of imported species appearing in the wild, when using either the average over the 48 surveyed families or the 10% rule as the criterion (one-sided binomial test,  $p < 0.01$ ).

For those 16 species existing in the wild, 12 (75%) species can be purchased in pet stores (Table 2). All six species in the Belontiidae and two species in the Loricariidae are currently available commercially. For the other three families, at least one species (50%) can presently be bought in a pet store.

## DISCUSSION

Correlation analysis revealed that pet fish families with more imported species displayed greater numbers of species appearing in the wild. More imported species appearing within a particular family presents a higher possibility of escape, or being discarded or released from their captive environment. Thus, a simple rule for administrative agencies to manage pet fish invasion is to target those families with higher numbers of imported aquarium and ornamental fishes.

The average invasive proportion of pet fish for all 48 families was 2.9%. However, if those families with no invasive species records were excluded, the invasive proportion increases to 24.6%. The 10% rule proposed by Williamson and Fitter (1996)

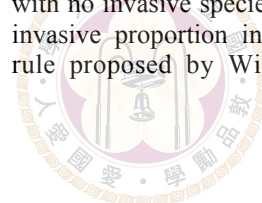


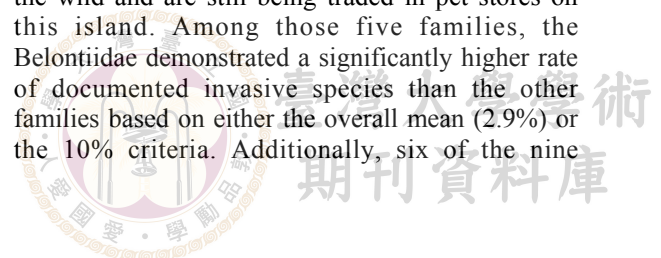
Table 1. Pet fish families and numerical abundance of species in each family. The numerical abundance of documented invasive species and commercial availability in pet stores is also listed for each family.

Family	Surveyed pet fish species	Documented number of invasive species within family		Number of commercially available and documented invasive pet fish species
		number	(%)	
Cichlidae	79	4	(5.1%)	2
Callichthyidae	38	0		0
Characidae	37	0		0
Cyprinidae	20	2	(10.0%)	1
Loricariidae	16	2	(12.5%)	2
Belontiidae	9	6	(66.6%)	6
Pimelodidae	9	0		0
Poeciliidae	7	2	(28.6%)	1
Tetraodontidae	7	0		0
Polypteridae	6	0		0
Pomacanthidae	6	0		0
Cyprinodontidae	5	0		0
Melanotaeniidae	5	0		0
Alestiidae	4	0		0
Lepisosteidae	4	0		0
Anostomidae	3	0		0
Osteoglossidae	3	0		0
Serranidae	3	0		0
Hemiramphidae	2	0		0
Monodactylidae	2	0		0
Acanthuridae	1	0		0
Achiridae	1	0		0
Acipenseridae	1	0		0
Anabantidae	1	0		0
Apterontidae	1	0		0
Arapaimidae	1	0		0
Atherinidae	1	0		0
Bagridae	1	0		0
Batrachoididae	1	0		0
Catostomidae	1	0		0
Chacidae	1	0		0
Chaetodontidae	1	0		0
Citharinidae	1	0		0
Cobitidae	1	0		0
Coiidae	1	0		0
Doradidae	1	0		0
Gasteropelecidae	1	0		0
Gobiidae	1	0		0
Gymnotidae	1	0		0
Helostomatidae	1	0		0
Malapteruridae	1	0		0
Osphronemidae	1	0		0
Ostraciidae	1	0		0
Potamotrygonidae	1	0		0
Pseudomugilidae	1	0		0
Scorpaenidae	1	0		0
Siganidae	1	0		0
Siluridae	1	0		0
Total	Total	Total (mean %)		Total
48	293	16(2.9)		12

indicates that 10% of imported species appear in the wild, and 10% of those appearing in the wild survive in the wild, and 10% of those surviving exotic species may eventually become pest species. According to the pet fish survey in this study, some families, such as the Cichlidae, Cyprinidae, Loricariidae, Belontiidae, and Poeciliidae, do present a high potential of surviving in the wild habitats of Taiwan once they have escaped or been discarded or released from their captive environments; however, most imported pet fish have

not yet appeared in the wild. Thus, the evidence generated from this study to support the 10% rule is still inconclusive.

Regulation and great attention should be placed on those 12 pet fish species which have appeared in the wild and are still being traded in pet stores on this island. Among those five families, the Belontiidae demonstrated a significantly higher rate of documented invasive species than the other families based on either the overall mean (2.9%) or the 10% criteria. Additionally, six of the nine



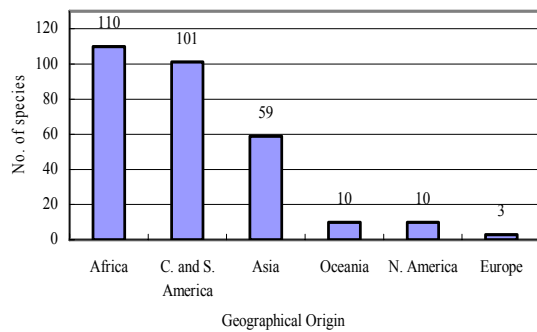


Fig. 1. Distribution of geographical origins of pet fish species in Taiwan. (C. and S. America, Central and South America; N. America, North America).

Table 2. Documented invasive pet fish species in Taiwan. Species marked with an asterisk (\*) could be purchased in a pet store based on the 2004 study.

Family	Documented invasive species
Cichlidae	<i>Cichlasoma salvinii</i> * <i>Cichlasoma citrinellum</i> * <i>Cichlasoma managuense</i> <i>Geophagus brasiliensis</i>
Cyprinidae	<i>Barbodes schwanenfeldii</i> * <i>Barbodes pierrei</i>
Loricariidae	<i>Hypostomus plecostomus</i> * <i>Pterygoplichthys multiradiatus</i> *
Belontiidae	<i>Trichogaster leeri</i> * <i>Trichogaster microlepis</i> * <i>Trichogaster labiosa</i> * <i>Trichogaster trichopterus</i> * <i>Colisa fasciatus</i> * <i>Colisa lalia</i> *
Poeciliidae	<i>Poecilia reticulata</i> * <i>Xiphophorus hellerii</i>

documented invasive species are commercially available in pet stores according to the survey results. These invading species are mainly the gourami species of the Belontiidae, which are distributed mainly in lentic, pool habitats of Asian countries such as Malaysia, Indonesia, Thailand, India, Bangladesh, and Nepal. The gourami are omnivores, and reproduce by making and guarding bubble nests on the surface of the water or on aquatic vegetation. Based on the knowledge of the Belontiidae, caution should particularly be exercised, especially Asian pet fish species with flexible feeding habits and specialized eggs or young-protection behavior.

Due to the great economic benefits globally, the pet trade industry will likely keep growing in the future (Padilla and Williams, 2004). Therefore, cooperation with the industry is necessary for educating buyers, sellers, and the public to prevent pet fish from being discarded or released. An effective way to decrease additional releases of pet fishes into the wild is to force retailers to establish

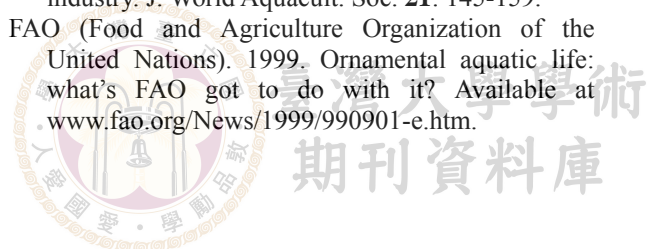
foster home programs for the disposal of unwanted fish (Courtenay and Stauefer, 1990). Displays on how to eliminate fish escaping from captivity placed at public aquariums, wholesalers, and chain stores is another useful action to prevent additional introduction of exotic fish species into the wild. More-extreme ways like instituting a higher custom duty or higher purchasing tax should be considered by the administrative agencies (Padilla and Williams, 2004). Overall, reducing the invasion of pet fish will require the industry to be strongly committed to the protection of aquatic biodiversity, and policymakers must recognize that without effective regulation of the aquarium and ornamental fish trade there is a potential and real threat to aquatic communities of Taiwan.

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## 臺灣販售觀賞魚種與入侵魚類關係之探討

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### 摘 要

為了瞭解臺灣地區寵物販售物種與外來魚種入侵之相關程度，於 94 年 6 月至 10 月在台北、台中及高雄等三處都會區進行觀賞魚類販售物種調查，結果共發現 48 科 293 種外來魚類，多數為淡水魚類，其中包含魚種最多的前五科依次為 Cichilidae (79 種)、Callichthyidae (38 種)、Characidae (37 種)、Cyprinidae (20 種)和 Loricariidae (16 種)。48 科魚種中，已有五科具有入侵魚類紀錄，各科入侵魚種數量比例多數等於或大於 10%。在有入侵魚種紀錄之科別中成功比例最高為 Belontiidae (66.6%)。若科內引入魚種數量增加，則野外入侵紀錄之數量也有顯著提高之統計關係存在。依據調查結果，本研究提出可以請販售商設立回收中心與提供降低寵物逸逃資訊以減少外來魚種入侵。政府單位則應研究以提高進口關稅與營業稅額之方式，予以控制。總之，減少與抑止外來寵物魚種之入侵，需要產、學、政、商等各單位之共同合作，方能有所成效。

關鍵詞：魚類入侵、觀賞魚類、臺灣。

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