Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.484

Ornamental fish in pet stores in Greece: a threat to biodiversity?

I. PAPAVLASOPOULOU[1], L. VARDAKAS[2], C. PERDIKARIS[3], D. KOMMATAS[2] and I. PASCHOS[4]

[1] MSc course 'Aquaculture', Department of Veterinary Medicine, University of Thessaly and Department of Aquaculture & Fisheries, Technological Educational Institute of Epirus, Greece
[2] Institute of Marine Biological Resources & Inland Waters, Hellenic Centre for Marine Research, 19013 Anavissos, Attica, Greece
[3] Department of Fisheries, Regional Unit of Thesprotia, Region of Epirus, 46100 Igoumenitsa, Greece
[4] Department of Aquaculture & Fisheries, Technological Educational Institute of Epirus, 46100 Igoumenitsa, Greece

Corresponding author: louisvard@gmail.com

Handling Editor: Stelios Katsanevakis

Received: 30 May 2013; Accepted: 25 September 2013; Published on line: 6 December 2013

Abstract

The aquarium trade has been recognized as an important pathway for the introduction of invasive species around the world. This study investigates the availability of ornamental fish species in ten large-size, centrally positioned aquarium stores that control a large share of imports and the Hellenic market chain, and aims to provide a provisional checklist on the aquarium fish trade in Greece. For each recorded species, additional data concerning various aspects (e.g. natural environment, native range, established as aliens, conservation status and threats to humans) were collected from Fishbase, the IUCN red list and scientific literature. Overall, 326 fish species belonging to 64 families were reported according to the store labels. The majority of the species recorded were freshwater (66%), originating mainly from South America and Asia, while most of the marine species (26%) had primarily an Indo-Pacific native distribution. Among the freshwater fishes, Cichlidae and Cyprinidae were the dominant families with 64 and 27 species, respectively, while the family Acanthuridae dominated within the marine fishes with ten species. The vast majority of both freshwater and marine species (>90%) were tropical. Concerning the presence of alien species, 62 ornamental species have been established outside their natural range, with 22 of them positively confirmed as aliens in European waters. Moreover, 25 species were listed in the critically endangered (CR), endangered (EN) and vulnerable (VU) categories of the IUCN red list. Even more surprisingly, for 192 species recorded, data were missing to assign their conservation status or had not been assessed at all. Finally, the majority of the species (84%) were harmless to humans. However, 35 species (11%) were recognised as potentially harmful (i.e. venomous, ciguatera poisoning, traumatogenic) and two were found to be poisonous if consumed. In conclusion, the aquarium fish sector in Greece is practically uncontrolled given the presence of: a) threatened species, b) species potentially harmful to humans and c) species capable of establishing non-indigenous populations, if released into the wild.

Keywords: alien species, ornamental fish, origin, aquarium trade, threatened species.

Introduction

The introduction of non-indigenous species in several parts of the world is regarded by many scientists and policy-makers as a significant threat to biodiversity (Kolar & Lodge, 2001; Dudgeon *et al*., 2006; Corfield *et al*., 2008). One of the major potential vectors of introduction of non-indigenous aquatic species (Katsanevakis *et al*., 2013) is through the importation of live aquarium species. The aquarium trade has been linked to over 150 species invasions in natural ecosystems around the world (Fuller, 2003; Siguan, 2003; Padilla & Williams, 2004). Severe ecological impacts are evident on native species (Ceccherelli & Cinelli, 1997), whereas the extinction of native fish populations by predation and/or resource competition has also been documented (Pimentel, 2010). However, the aquarium trade has received lesser attention from environmentalists, conservationists, ecologists, and policy makers as opposed to the attention given to the trade of terrestrial endangered species (Naylor *et al*., 2001; Chapman *et al*., 2003; Padilla & Williams, 2004). This could be attributed to the established set of conservation priorities by international bodies, governments and the public's general views about the natural environment and accordingly their focus on 'flagship' species belonging to higher taxa primarily (i.e. primates, mammals and birds).

Apart from the impacts on recipient areas, the aquarium trade may also have negative effects on the donor areas during collection. Although approximately 90% of the freshwater aquarium fish are cultured in captivity (Tlusty, 2002), the vast majority of supplies in marine species are dependent on wild sources (Andrews, 1990) frequently involving illegal/destructive fishing practices (e.g. cyanide fishing in Southeast Asia), which severely damage endangered species and fragile aquatic ecosys-

tems. Other negative effects of the aquarium trade include the spread of new diseases and parasites, such as Koi carp herpes virus (KHV) (Haenen *et al*., 2004); bacterial pathogens harmful to humans (Weir *et al*., 2012); threats from unintentionally carried biota (Duggan, 2010) and from irresponsible discharge of the aquaria and tank water.

The ornamental trade accounts for a limited but steadily growing proportion of fish introductions to Hellenic waters (Zenetos *et al*., 2009). To date, three ornamental fish species have established viable populations in the freshwaters of Greece: the goldfish (*Carassius auratus* L.), the sailfin molly (*Poecilia latipinna* Lesueur, 1821) and the sunfish (*Lepomis gibossus* L.). So far, the former two species present a restricted distribution range in the Hellenic region, while the latter has spread to a large number of river basins in the northern part of the country (Economou *et al*., 2007). Currently, we have no knowledge of how these species affect the native fish fauna as no research surveys have been conducted to assess possible negative impacts. Despite the low number of ornamental fish species released in Greece, the possibility of other ornamental fish being introduced and established into the wild, either intentionally or unintentionally, still remains. Moreover, given that a number of introduced species of Indo-Pacific origin, recently reported in the eastern Mediterranean, belong to species kept in aquarium (Zenetos *et al*., 2012), a number of released sub-tropical/thermophilic fish species could become established and spread to the warmer southern parts of the country at least.

The main goal of this study was to provide a provisional checklist of ornamental fish species in Greece. Moreover, our aim was to collect qualitative base data concerning various aspects of the ornamental fish species recorded (e.g. natural environment, native range, established as aliens, conservation status and threats to humans) in order to provide data that may contribute to future precautionary actions against introductions of aquarium fish species into the wild.

Data collection and analysis

From January to December 2011, we conducted a spatial survey to document ornamental fish species in the pet trade in Greece. Specifically, ten large-size, privately owned aquarium stores, which have a relevant importance to the aquarium sector and control a large share of imports and the market chain in Greece were investigated; nine located in the two largest cities of Greece (Athens and Thessaloniki), and one large pet store located in a provincial town (Ioannina).

The scientific and/or common name of all fishes was recorded at each location. When there was a mismatch between a store label scientific name and the common name, we used the scientific name provided in FishBase (Froese & Pauly, 2012). On several occasions, some common names could not lead to a scientific name and thus these fish were excluded. However, at this point it is important to state that the identification of some species may be erroneous in our compilation due to inaccurate labelling during our store survey. This holds particularly true for some species (e.g. Loricariidae) that cannot be identified to species level without close morphological or genetic analysis. Moreover, we proceeded by means of questionnaires, which were completed by the managers and/or technical staff of these stores, involving questions regarding aquarium maintenance and ecological requirements of the species. Retail prices were also recorded when possible.

Following recording, data collected for each species was classified on the basis of: a) natural environment (classified to freshwater (FW), marine (M), freshwater-brackish (F-B), marine-brackish (M-B) and freshwater-marine-brackish (F-M-B)), b) native range (classified into continents and sub-continents for freshwater species, and oceans for marine species), c) basic climatic zones (tropical, subtropical, temperate); conservation status (classified as not assessed (NA), critical endangered (CR), near threatened (NT), least concern (LC), vulnerable (VU), data deficient (DD), lower risk (LR)) and possible threats to humans (harmless (H), toxins (T), venomous (V), traumagenic (TR), poisonous to Eat (PtE)). The classification was done accoreding to Fishbase, for consistency purposes. As for conservation status, the IUCN red list was equally utilised (IUCN, 2012), and in the case of data that could not be derived from Fishbase, scientific literature mining was conducted. Species that have established alien populations out of their natural range (globally and in European waters) were identified by searching either Fishbase or the EASIN database (Katsanevakis *et al*., 2012), respectively.

For the purposes of this study, species varieties were assigned to a species level when possible (e.g. goldfish var. oranda was assigned as *Carassius auratus*). Likewise, hybrids recorded in each store, were omitted from further analysis. Finally, in order to conduct some basic descriptive statistics, brackish species were assigned to an either freshwater or marine species group.

Results

Our survey recorded 326 fish species belonging to 64 families (Table S1) in ten aquarium stores. The mean number of species recorded per store was 61 (s.d. = 38.8). The majority of the species recorded were freshwater (214) representing 66% of the total number, while 85 (26%) were marine species and 27 (8%) originated from transitional aquatic ecosystems (Fig. 1).

Freshwater species were represented by 40 families,

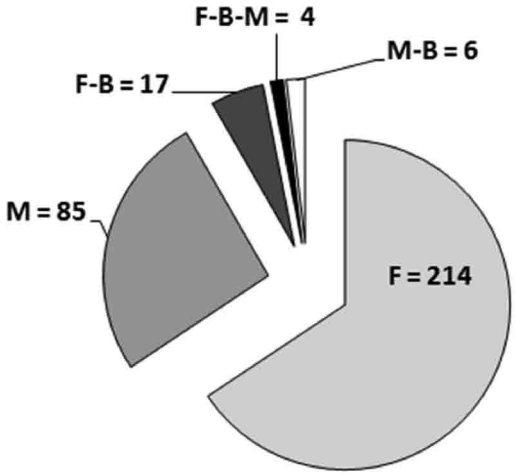

Fig. 1: Number of aquarium fish species in Hellenic aquarium stores according to their natural environment (FW: Fresh water; M: Marine; B: Brackish water).

whereas marine species by 24 (Fig. 2A, B). Among the freshwater fishes, Cichlidae and Cyprinidae were the dominant families, with 64 and 27 species respectively. Four families 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 (Fig. 2A). The family Acanthuridae dominated within the marine fishes with ten species, while the families of Balistidae and Gobiidae followed by five species. Four families (i.e. Apogonidae, Labridae, Pomacanthidae and Scorpaenidae) were represented by three species each and the remaining 17 families by a single species (Fig. 2B).

The vast majority of the species were tropical and the rest originated from sub-tropical regions, without any single species from temperate waters. This pattern was evident both in the freshwater species group (90%) and in the marine species group (93%). Moreover, the amount of sub-tropical species (22) in the freshwater group was higher compared to the marine group (4 species).

According to their native ranges, 87 freshwater spe-

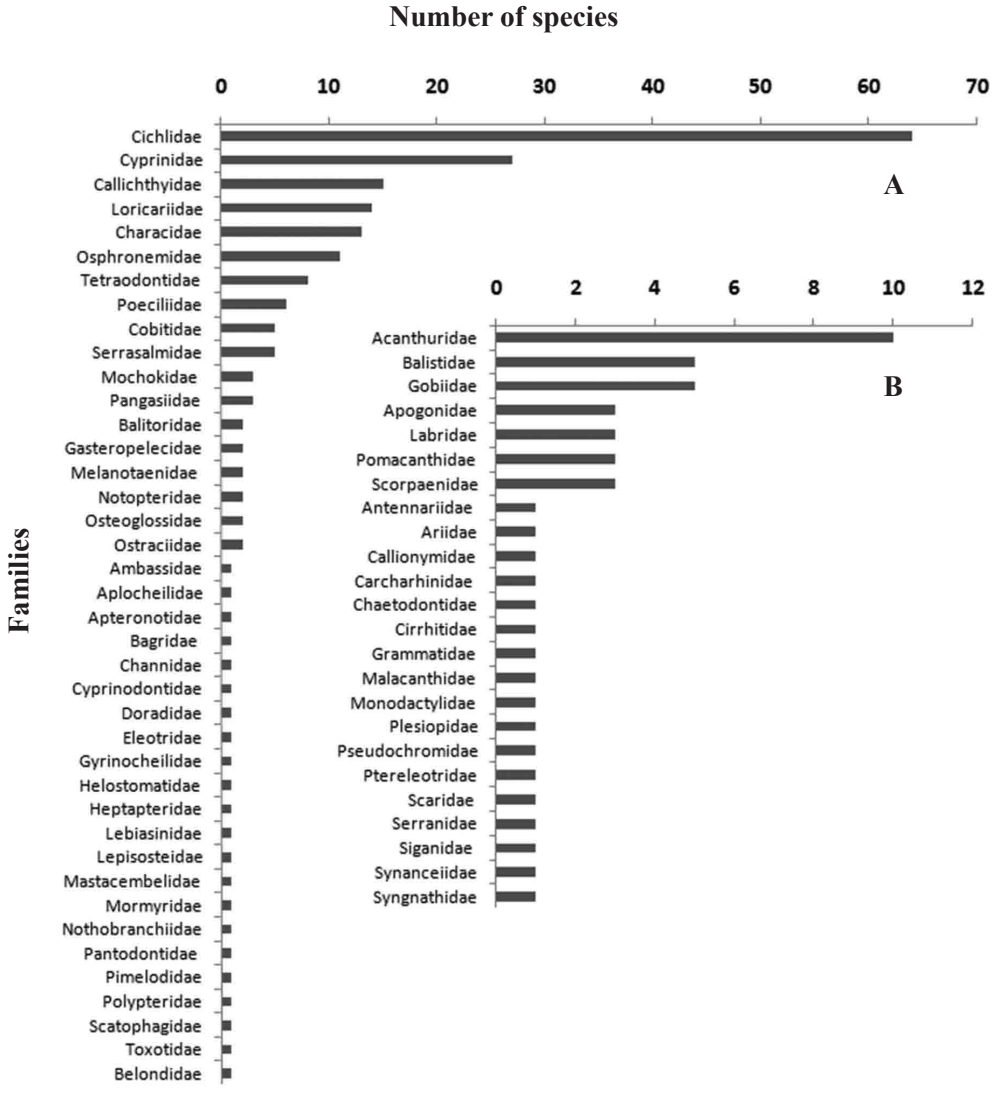

Fig. 2: Number of (A) freshwater and (B) marine aquarium species within each family in Hellenic aquarium stores.

cies (37%) were native to South America (Fig. 3A), while Asia was represented by 72 species (31%), followed by Africa with 45 species (19%). In addition, Central America was represented by 8 species while North America and Oceania with five species, respectively. In the marine group, 50 species (57%) had an Indo-Pacific native range, followed by 23 species (26%) that occur in the Pacific Ocean. The Indian and Atlantic Ocean were represented by six (7%) and five (6%) species, respectively (Fig. 3B). Moreover, a small number of marine species presented native distributional ranges occurring in more than one ocean, while only one species was circumglobal.

Twenty three species with over 50% frequency of presence were recorded in the aquarium stores, representing some of the most popular ornamental fish (Table 1). The majority of these species were characterized by small body size, impressive colour pattern and accessible retail price (mean retail price for 21 of these species at €5.2). Based on the data available for 136 species, the price of 71 species was below €10. However, the price-class with the highest number of species (34) was between €5 and €10.

The number of freshwater species positively established outside their native range was significantly higher compared to that of marine species (Table S1). In particular, 56 freshwater and six marine species were established as aliens in certain parts of the world and a search of the EASIN database revealed the presence of 22 of them in European waters (Table 2), matching the aquarium fish species recorded in the current survey.

According to their conservation status, two freshwater species were classified as critically endangered (CR), 12 vulnerable (VU) and 8 endangered (EN) (Table 3 and Table S1). Ninety-four species were classified as least threatened (nearly threatened-NT, Low concern-LC and Low risk-LR) (Table S1). Concerning the marine group, two species were classified as vulnerable and one as endangered (Table 3 and Table S1). The number of species in the NT, LC and LR categories reached 17 (Table S1). Not assessed (NA) and data deficient (DD) species were found to be 109 and 69 in the freshwater and marine groups, respectively (Table S1).

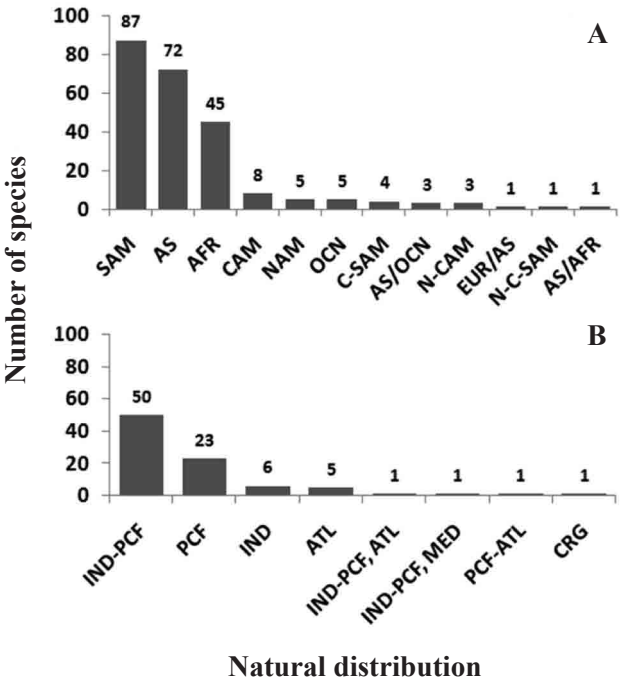

Fig. 3: Native distributional range of ornamental fish species recorded in Hellenic aquarium stores: (A) freshwater species in each continent-subcontinent (SAM: South America, AS: Asia, AFR: Africa, CAM: Central America, NAM: North America, OCN: Oceania, C-SAM: Central and South America, AS/OCN: Asia and Oceania, N-CAM: North and Central America, EUR/AS: Europe and Asia, N-C-SAM: North, Central and South America, AS/AFR: Asia and Africa) and (B): marine species in each ocean (IND-PCF: Indo-Pacific, PCF: Pacific, IND: Indian, ATL: Atlantic, IND-PCF, ATL: Indo-Pacific and Atlantic, IND-PCF, MED: Indo-Pacific and Mediterranean, PCF-ATL: Pacific and Atlantic, CRM: Circumglobal).

Table 1. Ornamental fish species with >50% frequency of presence in Hellenic aquarium stores and retail prices.

Species	Retail prices (€)	% presence	Species	Retail prices (€)	% presence
Paracheirodon axelrodi	3.50	80	*Danio rerio*	2.21	60
Puntius tetrazona	3.20		*Hyphessobrycon herbertaxelrodi*	2.50	
Trigonostigma heteromorpha	2.07		*Microgeophagus ramirezi*	12.18	
			Paracheirodon innesi	1.72	
			Pterophyllum scalare	4.00	
Astronotus ocellatus	13.78	70	*Chromobotia macracanthus*	7.87	50
Balantiocheilos melanopterus	6.00		*Corydoras aeneus*	13.28	
Carassius auratus	4.18		*Corydoras panda*	-	
Pelvicachromis pulcher	4.42		*Gymnocorymbus ternetzi*	3.69	
Poecilia reticulata	1.86		*Macrotocinclus affinis*	4.85	
Xiphophorus maculatus	3.00		*Moenkhausia sanctaefilomenae*	2.34	
			Pangasius sanitwongsei	-	
			Phenacogrammus interruptus	7.26	
			Trichogaster lalius	5.29	

Table 2. Ornamental fish species reported in Hellenic aquarium stores, which are registered as aliens in European waters in the EASIN database.

Scientific name	Environment	Impact	Pathways	Remarks
Astronotus ocellatus	Freshwater	Low/Unknown	Not assessed	
Barbonymus schwanenfeldii	Freshwater	Low/Unknown	Not assessed	
Carassius auratus	Freshwater	Low/Unknown	Release (Pets, Terrarium-Aquarium species)	*Carassius auratus auratus* is also present in the EASIN database as a high impact (sub) species.
Hemichromis bimaculatus	Freshwater	Low/Unknown	Not assessed	
Hyphessobrycon rosaceus	Freshwater	Low/Unknown	Not assessed	
Macropodus opercularis	Freshwater	Low/Unknown	Not assessed	
Maylandia lombardoi	Freshwater	Low/Unknown	Not assessed	
Melanochromis auratus	Freshwater	Low/Unknown	Not assessed	
Osphronemus goramy	Freshwater	Low/Unknown	Not assessed	
Poecilia latipinna	Freshwater	Low/Unknown	Release (Pets, Terrarium-Aquarium species)	
Poecilia reticulata	Freshwater	High	Not assessed	
Poecilia sphenops	Freshwater/Marine	Low/Unknown	Release (Pets, Terrarium-Aquarium species), Escape (Aquaculture)	
Poecilia velifera	Freshwater	Low/Unknown	Not assessed	
Pomacanthus imperator	Marine	Low/Unknown	Release (Pets, Terrarium-Aquarium species), Corridor (Lessepsian migrant)	First introduction in Israel on 1999 (Golani *et al*., 2010; Bariche *et al*., 2013).
Pterophyllum scalare	Freshwater	Low/Unknown	Not assessed	
Pterygoplichthys gibbiceps	Freshwater	Low/Unknown	Not assessed	As synonym of *Glyptoperichthys gibbiceps*.
Puntius tetrazona	Freshwater	Low/Unknown	Not assessed	
Pygocentrus nattereri	Freshwater	Low/Unknown	Not assessed	
Scatophagus argus	Marine	Low/Unknown	Release (Pets, Terrarium-Aquarium species)	First introduction in Malta on 2007 (Zammit & Schembri, 2011).
Synanceia verrucosa	Marine	Low/Unknown	Release (Pets, Terrarium-Aquarium species), Corridor (Lessepsian migrant) and Escape (Aquaculture) as a secondary source	First introduction in Israel on 2010 (Edelist *et al*., 2011; Bariche *et al*., 2013).
Xiphophorus helleri	Freshwater	High	Not assessed	
Xiphophorus maculatus	Freshwater	High	Not assessed	

Table 3. Freshwater and marine ornamental fish species assigned as critically endangered (CR), endangered (EN) and vulnerable (VU) conservation status in Hellenic aquarium stores.

Species	IUCN Red List Status
Freshwater	
Acanthurus lineatus, Acanthurus nigrofuscus	**CR**
Amphiprion ephippium, Amphiprion frenatus, Amphiprion ocellaris, Amphiprion percula, Amphiprion perideraion, Ancistrus dolichopterus, Ancistrus tamboensis, Ancistrus temminckii	**EN**
Thorichthys meeki, Tilapia buttikoferi, Toxotes jaculatrix, Trichogaster chuna, Trichogaster labiosa, Trichogaster lalius, Trichogaster leerii, Trichogaster microlepis, Trichopodus pectoralis, Trichopodus trichopterus, Trichopsis pumila, Trigonostigma heteromorpha	**VU**
Seawater	
Amphiprion polymnus	**EN**
Trigonopoma pauciperforatum, Trimma cana	**VU**

The majority of the species (276) were assigned as harmless to humans. However, 35 species (11%) were positively grouped as potentially harmful (i.e. venomous, involved in ciguatera poisoning or traumatogenic) (Table S1). Moreover, two species were found to be poisonous if consumed.

Discussion

Although the number of fish species recorded in the retail aquarium sector in Greece was comparable, in some cases, to that recorded in store surveys in other countries, it was considerably lower when compared to the overall diversity based on importation records (e.g. Western Europe, Japan, Australia, South Africa and particularly in the USA, with 1,802 marine ornamental species from 125 families entering the country on an annual basis; Davenport, 1996; Rhyne *et al*., 2012). Similarly, the number of freshwater crayfish species available to the aquarium stores in Greece was considerably lower, compared for instance to the German market (Papavlasopoulou *et al*., 2013). Species diversity observed in the aquarium sector of Greece may be attributed to various factors. The restricted number of stores investigated during this study may hinder the actual number of species on the Greek market. Undoubtedly, several medium-small sized, privately owned aquarium stores exist in Greece, where additional fish species, not recorded in the present study, may occur. However, we consider that the ten selected aquarium stores cover the largest proportion of ornamental fish diversity in the Greek aquarium trade, since these stores have a relevant importance on the Hellenic aquarium market, largely controlling the imports and the market-chain. It is accepted that other factors such as the long tradition in fish keeping, the developed aquaculture-based ornamental fish sector, the strong position in the international chain of trade networks as well as improved living standards and the presence or emergence of a dynamic middle class may be more important for species diversity in regional pet markets. In fact, it is estimated that more than 11 million USA households possess at least one aquarium (Padilla & Williams, 2004) representing 10.8% of pet owners (Tlusty, 2002). Nevertheless, the Hellenic aquarium fish market has made considerable progress and currently a major part of domestic sales is controlled by a few high standard retail chain stores.

The number of freshwater species offered is primarily attributed to the ease of maintaining home aquaria with freshwater, the moderate to wide environmental and feeding preferences, and the relatively low price of individuals originating from controlled reproduction. For instance, farming of goldfish, gouramis and tropical livebearers (guppy, swordtail, platy, molly) is an established industry in countries such as Singapore (Sales & Janssens, 2003), Thailand (particularly for the Siamese fighting fish; Monvises *et al*., 2009; Kipouros *et al*., 2011) and Japan (particularly for koi carp), all of them with a long history of domestication through a fully controlled fry production and artificial selection processes. Moreover, many freshwater aquarium fish (e.g. cichlids and cyprinids) are capable of spawning in aquarium conditions and although fry production requires a certain level of technical competence, this feature can be an important criterion for fish selection by aquarists. On the other hand, the keeping of marine ornamental fish requires a particular level of care, more expensive basic and auxiliary equipment and most of the species are collected in the wild (Ng & Tan, 1997) with traditional and in many cases mortality-increasing techniques (i.e. cyanide fishing particularly in Southeast Asia; Wood, 2001), which affects the final prices.

The vast majority of the species in the current survey were tropical due to the increased biodiversity and endemism in the tropics (Wabnitz *et al*., 2003), the impressive colour patterns of these species and in many cases the peculiarity of body forms and living modes. This is particularly evident in the freshwater fishes group originating from the Amazon river system (including more than 2,500 species; Junk *et al*., 1997), explaining (along with the proximity to North American markets) the dominance of South American species, within the freshwater group. The tropical origin of the marine species can also be attributed to the attractiveness of the reef-associated species, as well as to the long fishing tradition of capturing ornamental fish involving coastal communities along the entire equatorial belt, from the Indian Ocean to Oceania, Western Pacific and the Caribbean (Wood, 2001; Bruckner, 2005).

Despite the revenues and jobs generated by the aquarium/ornamental fish trade (reviewed in Tlusty, 2002), it has been identified as a major driver for non-native fish introductions into the wild, particularly for the freshwater species (Copp *et al*., 2005; 2010; Duggan *et al*., 2006; Corfield *et al*., 2008). Also, in the USA, 26% of human-mediated alien fish diversity was attributed to the aquarium trade (Fuller *et al*., 1999) and 115 freshwater aquarium species have been reported as introduced into the wild (Padilla & Williams, 2004). Based on our data, 26% of the freshwater species and 7% of the marine species had established alien populations outside their native range. Concerning the European waters, 22 aquarium species recorded during the current survey were confirmed as aliens. In Greece, goldfish and sailfin molly are the only fish of positive aquarium origin established in Hellenic freshwaters. Goldfish establishment in various lakes is attributed either to escapes or to unintentional releases via the admixture of goldfish fry to common carp fry (Economidis *et al*., 2000; Perdikaris *et al*., 2010). The sailfin molly has been introduced into Lake Vouliagmeni (Attica, central Greece) most likely due to intentional release by aquarium owners (Econo-

mou *et al*., 2007). However, the presence of sub-tropical ornamental species in pet stores raises questions about the possibility of the establishment of such fishes into the wild, either accidentally or intentionally. For instance, the sunfish is a highly invasive freshwater species already established in northern Greece and it is suspected that it originally found its way to natural habitats through accidental or deliberate releases by aquarists (Zenetos *et al*., 2009). However, the introduction of the sunfish in a large number of river basins in Greece (Economou *et al*., 2007) still remains unclear since no specimen was recorded during our study, raising doubts about its original pathway. However, introduction through angling cannot be excluded, as this was a common route in other countries (Copp & Fox, 2007). Significant increase of non indigenous marine species introduced with the aquarium trade was also reported in the last decade in European Seas (Katsanevakis *et al*., 2013). Species such as *Synanceia verrucosa* (Edelist *et al*., 2001), *Pomacanthus imperator* (Golani *et al*., 2010) and *Scatophagus argus* (Zammit & Schembri, 2011) have already been reported in the eastern Mediterranean. With respect to the already known invasive species, four of the species recorded in the current survey (i.e. *Carassius auratus*, *Poecilia reticulata*, *Pterois volitans* and *Xiphophorus helleri*) are included in the Global Invasive Species Database (http://www.issg.org/database). However, at least all the rest of the species listed as aliens in Table 2 should be thoroughly assessed for their invasiveness risk.

A relatively non-addressed dimension of the ornamental fish trade is the collection and selling of threatened species. Our data revealed that 25 species are listed in the CR, EN and VU categories of the IUCN red list. More surprisingly, for 192 species (ca. 58.5%) recorded in the present survey, either the relevant data were missing in order to assess their conservation status or they had not been assessed at all. Interestingly, among the most popular ornamental species in Greece, one species is listed as CR (*P. sanitwongsei*); one species as EN (*B. melanopterus*) and four species (*P. tetrazona*, *C. auratus*, *C. macracanthus* and *M. affinis*) have NT conservation status. The uncontrolled trade of ornamental fish resources is highlighted in the case of the ornamental fish export countries such as India, where at least thirty endemic freshwater species are listed as threatened in the IUCN Red List (Raghavan *et al.,* 2013).

Another interesting aspect that also emerged from this survey is related to the presence of species potentially harmful to humans. For instance, ten venomous species were identified, posing significant risk, at least to aquarists. For instance, in the case of *Pterois* spp., members of this genus have already passed through the Suez Canal (e.g. *Pterois miles*; Bariche *et al*., 2013) and are currently spreading to the SE part of the Mediterranean, indicating the possibility of establishment in new areas via aquarium releases.

Data collection and monitoring of the ornamental fish trade in Greece is practically non-existent, as no official datasets exist. However, efforts to monitor ornamental fish species should involve both experts and 'citizens-scientists' involved in aquarium keeping. The contribution of the latter group is particularly valuable, as demonstrated in the case of recording the occurrence of alien marine species in Greece (Zenetos *et al*., 2013). Such co-ordination is essential given the unprecedented growth of regular and internet-based trade of aquatic organisms.

Based on the current survey, the documented biodiversity of aquarium fish on the Hellenic market is significant, although, only certain low price freshwater species and, in most cases, small-sized dominate the trade. Nevertheless, commercially desirable species for potential domestic culture (as a feasible alternative to wild harvest) and species in need of protection in the wild were identified. Finally, research efforts to scrutinize species with establishment/invasion potential in the wild, adequate policies and trade restrictions along with the implementation of non-indigenous fish species prevention and public awareness programs should be urgent priorities in the near future.

Acknowledgements

The authors would like to thank the owners and employees of all the pet stores visited, for the valuable information, which helped us to achieve our study aims and the three anonymous reviewers for their detailed and constructive comments.

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