Management of Biological Invasions (2015) Volume 6, Issue 3: 253–261

Research Article

Aliens just a click away: the online aquarium trade in Italy

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Received: 2 December 2014 / Accepted: 22 May 2015 / Published online: 15 June 2015

Handling editor: Vadim Panov

Abstract

The aquarium trade moves thousands of species around the globe, opening the door to unwanted organisms being released into fresh and marine waters, with subsequent adverse ecological and economic impacts. Unlike ballast waters, the commerce of ornamental pets and the aquarium trade have only recently been recognized as major pathways for the introduction of fish, invertebrates and plants, with online commerce in particular being a thriving business. Here, we report the results of the first study on the online aquarium trade in Italy. We examined 54 online aquarium shops and collected data about the animals and plants sold. For each species, information about its native range, reproduction, feeding habits, pathways, impacts, status in Italy and price were gathered, in order to identify previously recorded or potentially invasive species for Italy. Freshwater fish and plants represent the most sold taxa, and mainly come from the Americas. Most animals are omnivorous, and the plants can reproduce through both reproduction modalities (asexual/sexual). Half of the traded plants have already been introduced outside their native range; however, the majority of the species sold have not yet been recorded in the wild in Italy. As expected, a high percentage of the sold species are reportedly introduced due to escape/release for ornamental purposes. Data on their impact is scanty and mainly concerns the already known invasive species and their ecological damage. Although the multilevel impact exerted by invasive species is recognized worldwide, in Italy the average price of invaders is quite low, thus favoring their purchase. In addition, considering the nation's growing number of aquarists, the probability of releasing potentially invasive species through the online trade is very high: more information, accurately presented information for buyers and stakeholders, and appropriate regulations may change this trade in order to reduce the risk of new invasions.

Key words: online aquarium trade, introduction pathway, biological invasion, Italy

Introduction

The introduction and spread of alien species are today considered to be amongst the main threats to biodiversity at different scales and to differing extents (Hulme et al. 2009). Indeed, a fraction of these introduced species, the invasive ones, cause substantial harm to biodiversity, human health and economy (Kettunen et al. 2008; Mack and Smith 2011; Mazza et al. 2014a).

Prevention of species introductions is considered to be the cornerstone of invasive species management (Vander Zanden and Olden 2008), but pathways of species introductions are diverse, dynamic over time, and vary both taxonomically and geographically (e.g., Moyle and Marchetti 2006; Ricciardi 2006). An understanding of the full spectrum of invasion pathways is necessary by both the global and European Biodiversity Strategy towards 2020, being crucial to improve policy actions (e.g. as underlined by the recently approved European Regulation on Invasive Alien Species 1143/2014), guide integrated management strategies, and enhance educational programs aimed at reducing the threat of future invasions (Lodge et al. 2006).

Aquatic ecosystems have been subject to some quite spectacular invasions. Compared to terrestrial systems, inland, marine and transitional waters are highly vulnerable to either the accidental or deliberate introduction of species and to their subsequent spread: this susceptibility is mainly the effect of intensive human uses, as has been well highlighted by the case study of Italy (e.g. Gherardi et al. 2008; Occhipinti-Ambrogi et al. 2011; Cuesta et al. 2014).

Today, great attention is paid to unintentional pathways of aquatic alien species introductions through ballast-water (Carlton and Geller 1993; Ruiz et al. 1997), transport via trailer boats (Leung et al. 2006; Rothlisberger et al. 2010), bait-bucket releases by anglers (Litvak and Mandrak 1993; Di Stefano et al. 2009), and escapes associated with aquaculture (Naylor et al. 2001; De Silva et al. 2009). Meanwhile, trade in aquarium and ornamental species is emerging as another important source for species likely to invade aquatic habitats (Padilla and Williams 2004; Strecker et al. 2011). In particular, an important aspect that has often been overlooked is the facilitation of biological invasions associated with the online trade of organisms (e.g. Derraik and Philipps 2010).

New market opportunities are thus opened: the online trade is poorly regulated and, being accessible to all, has increased considerably in recent years, making the purchase of invasive species just a mouse click away from any home (Padilla and Williams 2004). More than 150 species of vertebrates, invertebrates, plants and microorganisms (including pathogens) have invaded natural water bodies via the aquarium trade and ornamental aquaculture (Padilla and Williams 2004).

Our main aim is to assess the invasion risk posed by the online aquarium trade in Italy for the first time, by retrieving information on the sold species. As pinpointed by Chucholl (2013), it is crucial to collect data on traded species (and their biology) to forecast the possible 'new' invaders for Italy in order to develop efficacious and preventative management measures. The topic is pivotal and contemporary, because no restrictive regulations on this issue currently exist, both in Italy and in Europe (Shine et al. 2009; Hulme et al. 2009), with the latter having only recommended a Code of Conduct on Pets and Invasive Alien Species (Recommendation n. 154/2011).

Methods

Between January and May 2012, we conducted an extensive survey of online aquarium stores to document the number and species of animals and plants sold in the ornamental pet trade in Italy. For each sold item, we recorded the taxon at genus or species level, when possible, specifying the habitat, reproduction strategies, feeding habits (only for animals), native range and if the species has already been introduced outside it, the pathways of introductions, the possible impacts, the status in Italy and the price.

In particular, for freshwater, brackish water and partly terrestrial species (i.e., those that require freshwater systems to complete their life-cycle, but which also inhabit terrestrial environments) we indicated the native continent: Africa, Asia, North America, Central America, South America, Oceania, and Europe. For marine species, we used Pacific, Atlantic, Indian Oceans and Mediterranean Sea. Cryptogenic was used where the origin of a species was debated.

For reproduction strategies, we considered asexual reproduction when offspring arise from a single organism (such as vegetative propagation of plants and fragmentation of Cnidaria); sexual reproduction for the gonochoric or hermaphrodite species; and parthenogenesis when growth and development of eggs or embryos occur without fertilization.

For the feeding habits of animals, we modified the classification for fish proposed by Froese and Pauly (2012) as follows: herbivore, carnivore, omnivorous and symbiosis with zooxanthellae algae.

Finally, according to Hulme et al. (2008), we retrieved data on the most common introduction pathways (divided into more specific sub-categories) reported in the literature for the species we found in the Italian online shops: release (due to bio-control; angling; pets, terrarium-aquarium species); escape (aquaculture; ornamental planting; pets, terrarium-aquarium species); contaminant (trade of contaminated commodities); stowaway (shipping); corridor (inland canals); other (e.g. species introduced through minor pathways, other than the above mentioned as for smuggling, habitat management and medicinal use). Species for which reliable information on their pathway of introduction could not be found were classified as "unknown". No species was introduced through the sixth pathway (unaided) listed in Hulme et al. (2008). We divided the impacts of species into ecological, economic and social (e.g. human well-being) and, for the *status* in Italy, species were classified as native or alien (absent or occasional or established or invasive). In particular, the definition of the alien status for the plants follows Celesti-Grapow et al. (2009),

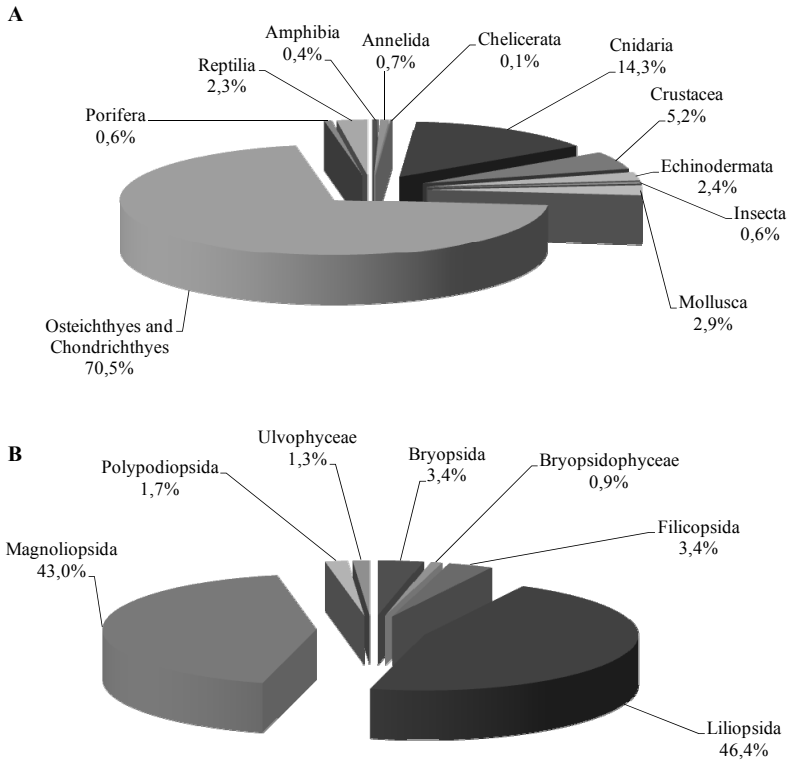

Figure 1. Frequency (%) of animal (A, n=902) and plant (B, n=235) taxa sold by online pet shops in Italy.

with the addition of the term "*emerging invasive*" to indicate the species exerting some kind of local environmental impact and with recent increasing distribution records in literature.

Data on biology, pathways of introduction and impacts was gathered by examining scientific literature and using international databases available online, such as DAISIE (http://www.europe-aliens.org/expertSearch.do), ISSG (http://www.issg.org/worst100_species.html), CIESM (http://www.ciesm.org/online/atlas/index.htm), NOBANIS (http://www.nobanis.org) and FishBase (http://www.fishbase.org/).

Species belonging to more than one category were tallied more than once. When no documentation was available for a given category or when the available information was dubious or anecdotal, we deemed it as "unknown".

Statistical comparisons of frequencies between plants and animals, among different habitats, reproduction strategies, feeding habits, native ranges and pathways were made using Wilks' test after Williams' correction (statistic: G). The selling prices were compared between invasive and non-invasive species using the Mann-Whitney test (statistic: U), reporting in the text medians with first-third interquartiles. The level of significance at which the null hypothesis was rejected is $\alpha = 0.05$.

Results

We found 54 online shops: 7% only had a website without details about traded materials/species, and these were not included in the analysis.

In the online shops, 1137 species were traded: 902 animals and 235 plants, with 14% and 9% identified only at genus level, respectively. Fishes (particularly Perciformes; 51%), and Liliopsida and Magnoliopsida, in particular *Echinodorus* and *Cryptocoryne* genera (Alismatales), were, respectively, the most sold among animals ($G=2369.86$, $df=10$, $P<0.001$; Figure 1A) and plants ($G=338.33$, $df=6$, $P<0.001$; Figure 1B).

Species were mainly freshwater (animals: 54.2%, $G=812.73$, $df=3$, $P<0.001$; plants: 97%, $G=473.74$, $df=3$, $P<0.001$; Figure 2) and come from Americas (animals: 43%, $G=454.34$, $df=4$, $P<0.001$; plants: 39%, $G=88.04$, $df=6$, $P<0.001$;

Table 1. List of invasive and potential invasive plant (P) and animal (A) species for Italy sold in the online shops. NA: North America, NCA=North-Central America, CSA=Central-South America, SA=South America.

P/A	Species	Origin	Pathway of introduction	Impact	Average price (€)	No. shops	Status in Italy	References	Notes
P	*Pistia stratiotes*	SA	ornamental	ecological, economic	3.6	1	emerging invasive	Celesti-Grapow et al. (2009)	
P	*Eichornia crassipes*	SA	ornamental	ecological, economic, social	6	2	emerging invasive	Celesti-Grapow et al. (2009)	
P	*Myriophyllum aquaticum*	SA	ornamental	ecological, economic, social	5	2	emerging invasive	Celesti-Grapow et al. (2009)	
P	*Bacopa monnieri*	Pantropical Subtropics	ornamental, other	ecological	3.8	2	absent	Celesti-Grapow et al. (2009)	potential invasive
P	*Hygrophila polysperma*	Asia	ornamental	ecological, economic	4.8	1	absent	Celesti-Grapow et al. (2009)	potential invasive
P	*Cabomba caroliniana*	SA	ornamental, shipping, trade	ecological, economic, social	5	3	absent	Celesti-Grapow et al. (2009)	potential invasive
A	*Xenopus laevis*	Africa	ornamental, research	ecological	6	3	invasive	Lillo et al. (2005)	
A	*Procambarus clarkii*	NCA	ornamental, culture, angling, biocontrol, smuggling	ecological, economic, social	10	2	invasive	Gherardi (2006)	
A	*Trachemys scripta*	NA	ornamental	ecological, social	16	1	invasive	Gherardi et al. (2008)	
A	*Gambusia holbrooki*	NA	biocontrol, ornamental	ecological	3	1	invasive	Gherardi et al. (2008)	
A	*Pomacea canaliculata*	CSA	culture, ornamental, smuggling	ecological, economic, social	2.9	1	absent	www.issg.org	potential invasive
A	*Xiphophorus maculatus*	NCA	ornamental	ecological	1.9	8	absent	www.fishbase.org	potential invasive
A	*Neocaridina davidii*	Asia	angling, ornamental	ecological	6.2	3	absent	Quante 2009	potential invasive

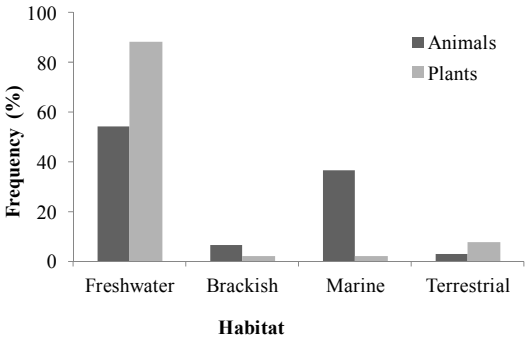

Figure 2. Frequency distribution per habitat of the alien animal (n=998) and plant (n=257) taxa sold by online pet shops in Italy. Species whose habitat includes two or more preferences were tallied more than once.

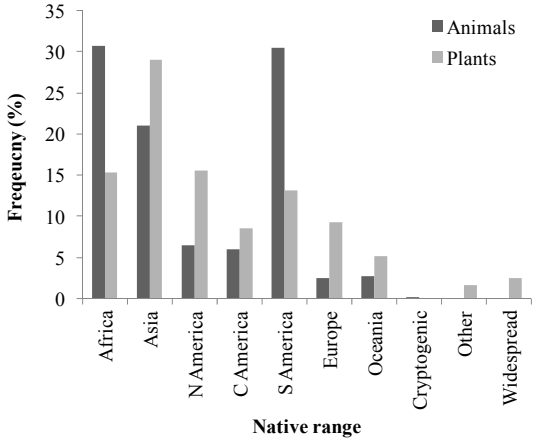

Figure 3. Frequency distribution per native range of the alien animal (n=618) and plant (n=366) taxa sold by online pet shops in Italy. Species whose native range includes two or more continents were tallied more than once.

Figure 3). For marine animal species, Pacific Ocean was the main donor area (55%, G=448.61, df=3, P<0.001); only five plant genera were marine, with a widespread distribution in oceans.

Traded animals are mostly omnivorous (52.1%; G=941.44, df=4, P<0.001) and gonochoric (76%, G=1398.20, df=3, P<0.001), while plants reproduce through both sexual and asexual modalities (87%, G=287.02, df=2, P<0.001).

Among the sold species, 184 animals (20%, G=337.63, df=1, P<0.0001) and 125 plants (53%, G=0.96, df=1, P>0.1) were already introduced outside their native range (but no data are available for 29% of the animal species).

As expected, release and/or escape for ornamental reasons were the main pathways of introduction for both animals (considering the subcategories separately for the analysis 88%, G=1130.03, df=9, P<0.001) and plants (77%, G=190.60, df=4, P<0.001).

No data for the impacts are reported for the majority of the species (77% of animals and 47.5% of plants), while for other species ecological impacts are the most documented (animals: 18%, G=263.22, df=3, P<0.001; plants: 29%, G=116.63, df=4, P<0.001).

95% of animal and 72% of plant species were alien for Italy, but never reported in the wild. The animal alien species present in our country were reported as occasional (0.3%), established (0.6%) and invasive (0.9%) (G=2743.15, df=5, P<0.001), while the plant alien species present were mainly established (4.3%) (occasional: 1.3%, and invasive: 2.1%, G=394.46, df=5, P<0.001).

Prices were variable and plants were usually cheaper (range: € 2–38 for plants, € 1–310 for animals). Invasive species resulted less expensive than the non-invasive ones in animals (U=4878.6, n=489, P<0.0001; invasive: 6.23 (3.26–9.63), non-invasive: 9.4 (6.8–18.65)), but not in plants (U=2259, n=159, P=0.05; invasive 4.93 (4.04–5.76), non-invasive 5.34 (4.25–6.8)).

Considering prices, impacts, availability in shops and species plasticity, we identified six potential new invasive species for Italy, three plants and three animals (Table 1).

Discussion

To the best of our knowledge, our study is the first that has investigated the role of the online ornamental trade for both animals and plants. The previous studies only considered one or a few taxa (e.g. crayfish in Chucholl 2013, plants in Lenda et al. 2014) or mostly land based stores (e.g. freshwater fish, mollusks and macrophytes in Rixon et al. 2005). It is noteworthy that the number of traded species we found mostly involved animals, in particular fish. Among them, Perciformes includes the families most appreciated by the aquarists (Cichlidae for freshwater and Pomacentridae for marine), while Siluriformes (mainly Loricariidae) are widely used as cleaner fish in hobby aquariums. Among plants, *Echinodorus* and *Cryptocoryne* genera are the most well-known aquatic plants, easy to care also for beginners because of their high plasticity and adaptability (they can grow partially out of the water and with low levels of light, and can reproduce easily; Rataj and Horeman 1977).

Freshwater species are the most traded, probably for two main reasons: the easy maintenance in aquaria and their cheaper price compared to marine species. As also found by Padilla and Williams (2004), the Americas and the Pacific Ocean are the main donor areas for the freshwater and marine species, respectively: several developing countries from these areas are known to be major exporters of ornamental specimens. The sold animals are mainly omnivorous, and plants can reproduce through both reproduction modalities (asexual/sexual): all these characteristics can favor their survival and spread in the wild, once released or escaped (e.g., the highly invasive crayfish *Procambarus clarkii* (Girard, 1852)), or the alga *Caulerpa* sp., Gherardi 2006; www.cabi.org).

Half of the traded plants in the online shops are already introduced outside their native range; the lower percentage of the recorded introduced animals could be an underestimate, because plants may be easier to sample and find than animals.

As expected from the literature, a high percentage of sold species is reported to have been introduced through escape/release for ornamental purposes. Aquarium keeping is a hobby that has become more popular in industrialized countries involving very popular pets such as tropical fish or turtles (Olivier 2001). Contrary to ballast waters, the commerce of ornamental pets and the aquarium trade have only recently been recognized as a major pathways for fish, invertebrates and plant introductions (Padilla and Williams 2004). Despite this, the pet trade, and in particular online commerce, is a thriving business, as confirmed by the present study.

Unfortunately, data on impacts is scanty, even for fish (as found also by Ribeiro and Leunda 2012), the most known and traded taxon, and mainly concern the already known invasive species worldwide and the ecological damage they have caused. Despite this, some species

continue to be widely sold, at low prices, without any information about their associated risk, such as the African clawed frog *Xenopus laevis* Daudin, 1802, invasive in Sicily (Lillo et al. 2005), or the red swamp crayfish *Procambarus clarkii* (Girard, 1852), highly invasive in Italy and in other parts of Europe (Gherardi 2006; Mazza et al. 2014b). Also the red eared slider, *Trachemys scripta elegans* Wied, 1839, is still sold online: the species is currently included in Annex B of EC Regulation n° 338/97 (9th December 1996), thus its importation is banned within the European Union, but the individuals imported before the law came into force can be kept and new births must be reported to the State Forestry.

Surprisingly, specimens of the *Caulerpa* genus are also available online. After the first invasion by the 'killer green alga', *C. taxifolia* (Vahl) C. Agardh, banned from the international aquarium trade and currently in regression in the Mediterranean Sea (Occhipinti-Ambrogi, unpublished data), the congeneric *C. racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman and Boudouresque is widely threatening the Mediterranean coasts of Spain, France and Italy (Ruiz et al. 2011). Other well-known harmful plants are still traded, such as the water lettuce *Pistia stratiotes* L., considered to be one of the most important pantropical aquatic weeds (Labrada and Fornasari 2002), and reported as an emerging invasive species in Campania (Brundu et al. 2012); the South-American water hyacinth *Eichhornia crassipes* (Mart.) Solms, an emerging invasive in Italy and highly invasive in Europe (Brundu et al. 2012), or *Myriophyllum aquaticum* Verdcourt and *Cyperus involucratus* Rottb., both recorded in several Italian localities in the last decade, with detrimental environmental impacts at least on a local scale (in particular, *M. aquaticum* is showing an increasing invasiveness; Lastrucci et al. 2006).

Another worrying concern emerging from our survey is the presence of species potentially harmful to humans. Like the ornamental trade in America and in Greece, Indo-Pacific lionfish *Pterois volitans* Linnaeus, 1758 is sold, despite being a venomous species that poses significant risk, at least to aquarists (Padilla and Williams 2004; Mazza et al. 2014a; Papavlasopoulou et al. 2014).

For the other species whose impact is still unknown, a precautionary approach should be adopted and information on their biology should be provided in detail. Moreover, a high relevant part of the traded species is recognized only at genus level, or is misidentified (no correspondence between photos and nomenclature, as reported also by Chucholl 2013), increasing the uncertainty of identification and the risks of potential impact, and thus raising management problems (uncorrected species could be released bypassing the few existing laws). For example, a generic species of *Procambarus* is sold for only € 5, but no information is available about its identity (it could be the parthenogenetic marmorkrebs or one of the several species belonging to this genus).

The majority of the sold species have still not been reported in the wild in Italy, and active management measures could be adopted to halt their introduction. However, the new potential invaders are sold for just a few euros, and their trade (and possibly release) is thus favored. For example, the shrimps belonging to the Atyidae family, such as the genus *Caridina* and *Neocaridina*, are particularly loved by aquarists and over the last few years their trade has increased a lot (the so called "shrimp fever" see for example http://www.shrimpfever.com), leading to the rise of several websites and forums. *Neocaridina davidii* (Bouvier, 1904), sold as *heteropoda* (Kemp, 1918) (but the taxonomy of the species should be still clarified; Klotz et al. 2013), one of the most traded shrimps, is native to South-East China, omnivorous, highly prolific and easily maintained in an aquarium (Barbier 2010). It can colonize new habitats and can be very invasive. Today, it is present in the wild in Japan, where it was introduced as bait or food fish, and in the Hawaii Islands, where it arrived though intentional/accidental releases from aquaria. In Hawaii, the species has competed with the native *Atyoida bisulcata* Randall, 1840 for resources, causing the latter's dramatic decline (Englund and Cay 1999). Moreover, the species can transmit several diseases and parasites (Anellids and Platyhelminths), dangerous to the native shrimp species (Niwa and Ohtaka 2004; Quante 2009), and has been already reported for Germany (Klotz et al. 2013). Although its import and spread within the European Union was banned by the European Commission (Implementing Decision of 8 November 2012), *Pomacea canaliculata* (Lamarck, 1819), the apple snail, another potential invasive species, is still sold online. The species and its congeneric ones are characterised by a very large shell, which may reach the size of an apple as the name suggests. Native to South America, they have been introduced in many countries of the world, particularly in North America and Asia, both intentionally or accidentally because of both the food and aquarium trade. In Europe, the only known record of occurrence of apple snail

(*Pomacea insularum* (D'Orbigny, 1839)) is in the Ebro delta (Spain), where it has been causing damage to rice production and the natural environment. These molluscs are reported to be highly invasive: being voracious animals, they are a major crop pest and a real threat for aquatic ecosystems (http://www.issg.org).

Similarly to *Procambarus* sp., it is not clear if the sold species is *P. canaliculata* (and not *insularum*). However, both represent a potential threat for native ecosystems and their trade should be forbidden. In addition, the new emerging invasive plants for Italy are sold at low prices, in particular the South American *Egeria densa* Planch, widely used as an ornamental species due to its being very easy to grow. In Europe, it has colonized several natural habitats, forming dense mats and altering the ecological conditions of the environment (e.g. Muller 2004). Other harmful species are *Hygrophila polysperma* (Roxb.) T. Anderson and *Limnophila sessiliflora* (Vahl) Blume, included in the EPPO List of Invasive Species and in the EPPO Observation List, respectively. In addition, specimens of the genera *Azolla* and *Alternanthera* should also be banned from the international aquarium trade, since some congeneric species (i.e. *Azolla filiculoides* Lam. Encycl. (Lamarck) and *Alternanthera philoxeroides* (Mart.) Griseb., respectively), already naturalized in Italy, are considered highly invasive in Europe, and are included in the EPPO Observation List (Brunel 2009).

It is noteworthy to highlight that in Italy, similarly to Papavlasopoulou et al. (2014) who listed 25 species of fishes inserted in the IUCN red list, trade online is also uncontrolled for both alien and native protected species. Indeed, among the sold species we found the endangered native freshwater turtle *Emys orbicularis* Linnaeus, 1758, whose populations are declining in several regions mainly through habitat loss and alien competition (e.g. Gariboldi and Zuffi 1994; Panzeri et al. 2014), or *Spongia officinalis* Linnaeus, 1759 (Annex III Bern Convention).

Finally, less is known about the fauna carried "incidentally", such as parasites and pathogens (Mazzoni et al. 2003; Mrugała et al. 2014), and rotifers, micro-crustaceans, eggs and larvae of Odonata, and snails, likely to be living in the aquarium water, associated with the aquatic plants, and/or living amongst the bottom stones, sediments and detritus (e.g. Duggan 2010; Laister et al. 2014).

Conclusions

Notwithstanding that our data only describes a part of the online pet trade, and despite the fact that the market is continuously increasing and evolving, the present study clearly pinpoints the great threats posed by traded species online, both in the numbers of sold species and their associated risks. It is, however, impossible to completely block the pet trade, considering the strong economic issues behind it. Prevention is thus the best means to reduce the introduction of new invasive species. More information on the sold species should be provided by the retailers, while a better knowledge on the lesser known sold species (their biology and the potential impact they could have in other areas) and their pathways is required for management plans and development of black lists (as foreseen by the new EU regulation 1143/2014; this list, expected in 2016, will include the highly invasive species for Europe, for which management actions should be undertaken). Finally, the dissemination of information and awareness amongst the wider public on the part of researchers and managers should be increased, particularly regarding the impact of releasing species into the wild.

Acknowledgements

This research was partly granted by the project *LIFE10 NAT/IT/000239 – RARITY*. This paper is dedicated to the memory of our tireless guide Francesca Gherardi, who passed away during its elaboration. The authors warmly thank two anonymous referees for their helpful suggestions on the first draft of the manuscript, Francesca Giovannelli for the help provided during the data collection, Prof. Julian Reynolds (Ireland) and Dr. Juliet Strachan (U.S) for English revision.

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