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Research Article

Calling for more accurate information in aquarium trade: analysis of live-fish import permits in Costa Rica

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Abstract

Ornamental fish trade is a growing business around the world, but also a major pathway for the introduction of potentially invasive species. Trade patterns and policies have been evaluated in high-income countries while developing countries in tropical regions have been overlooked, even when they are especially vulnerable to invasions by aquarium fishes. We analyzed the live fish import data and regulations in Costa Rica as a study case for a tropical country that regularly trades with many countries. We evaluated the quality of the taxonomic information given in live fish import permits issued by the Costa Rican Ministry of Environment between 1998 and 2004. We used FishBase to extract information about geographical distribution, habitat, historical introduction records, and taxonomic information on all the species we cataloged. A total of 834,624 live individuals were imported into Costa Rica from six countries with the scientific name absent for many individuals (40.6%) and correctly written in only 29.6% of the cases. We estimated that 352 different species were imported into the country. Most species imported were freshwater fishes and South America natives. We found that regulations of ornamental fish imports in Costa Rica are usually not enforced. The lack of accurate information in the live fish permits does not allow the full understanding and scope of live animal imports and their potential impacts. We call for more accurate information in the global aquarium trade by aiming to have much better tools to regulate the traffic of ornamental fishes.

Key words: international trade, ornamental fishes, pets, regulation, importation, prevention policies

Introduction

Wildlife and exotic pet trade is a billion-dollar growing business around the world (Pimentel et al. 2001, 2005). Trade is incentivized by free trade policies (Jenkins 1996), globalized markets (Levine and D'Antonio 2003; Margolis et al. 2005), and an increase of online shopping (Kay and Hoyle 2001). This business environment has facilitated the easy and fast exchange of species between distant regions; therefore, increasing the risk of introduction and establishment of exotic species (Levine and D'Antonio 2003; Taylor and Irwin 2004; Dehnen-Schmutz et al. 2007). Some introductions have brought disastrous consequences for the environment (MacDougall and Turkington 2005), public health (Karesh et al. 2005;

Smith et al. 2009), agriculture (Pimentel et al. 2005), and biodiversity (Mooney and Cleland 2001; Gurevitch and Padilla 2004; Clavero and García-Berthou 2005).

Although many taxonomic groups are traded, marine and freshwater organisms comprise the majority of animals being sold as pets or ornamentals (Jenkins et al. 2007; Smith et al. 2009). Aquarium species are usually tolerant to the stressful conditions of collection and transport and possess the physiological plasticity that allows them to survive and reproduce in aquariums (Wabnitz et al. 2003; Padilla and Williams 2004). These traits probably allow these species to establish in novel environments (Padilla and Williams 2004). Indeed, releases or escapes of organisms from aquaria have also led to successful invasions in both freshwaters (Courtenay and Robins 1973; Courtenay and Stauffer 1990; Mills et al. 1993; Shafland 1996) and marine ecosystems (Randall 1987; Whitfield et al. 2002). Now, aquarium trade is considered the second most important pathway of escaped non-native species in the world (Padilla and Williams 2004; Semmens et al. 2004; Strecker et al. 2011; Secretariat of the Convention on Biological Diversity 2014).

Because of the increasing risk of introducing exotic species through human activities, recommendations have been made to all countries in order to control the import and export of species that may become invasive (COP 6 Decision VI/23, Convention on Biological Diversity [CBD]). Expectations were that the implementation of measures, such as risk assessments of species to be imported, could prevent the establishment of non-native species (Ricciardi and Rasmussen 1998). However, despite the problems caused by the trade of aquatic organisms around the world, policymakers of most countries do not place strong restrictions on the import and transport of live non-native organisms (Keller and Lodge 2007; Smith et al. 2008, 2009). Even in developed nations like the United States (US), the majority of shipment records do not contain a scientific name in the taxonomic information (Smith et al. 2008, 2009).

Although extensive research has been carried out regarding the measures needed to minimize invasions through aquarium trade, most studies have been focused on high-income economies like the US (Jenkins et al. 2007), Europe (Pyšek et al. 2010; Keller et al. 2011), Japan (Mito and Uesugi 2004), and Australia (Whittington and Chong 2007). Developing countries have received little attention as they are considered exporters instead of importers (Padilla and Williams 2004; Lenzen et al. 2012); nevertheless, the global aquarium trade also makes them vulnerable to invasive species (Wabnitz et al. 2003). As most developing nations are located in the tropics, the exchange between distant inter-tropical regions makes them especially susceptible to be invaded as most of the aquatic species are adapted to warm waters (Kimball et al. 2004; Albins and Hixon 2008).

Here we analyzed the live fishes import data and regulations in Costa Rica as a case study for developing countries in a tropical region. Costa Rica has a growing and stable economy that depends on tourism and agricultural exports (Bustos Alvarado 2010). Ornamental fishes have been both exported for profits of about US$ 3,995,000 between 1997 and 2012 (Estado de la Nación 2014), and imported for a value of about US$ 641,636 between 2008 and February 2013 (INCOPESCA 2016). However, policies to regulate international trade of live organisms in Costa Rica are ambiguous, allowing traders to use different pathways to import or export live animals or plants. We evaluated the import permits (each corresponding to a shipment) issued by the Ministerio de Ambiente y Energía (MINAE: Ministry of Environment and Energy) between 1998 and 2004 to determine the scope, scale, and implications of live fishes imports to Costa Rica. Based on our findings, we made recommendations to minimize future negative outcomes resulting from live fish trade.

Methods

Study site

Costa Rica is a Central American country with 51,100 km^2 of land and 589,000 km^2 of sea surface in both the Caribbean Sea and the Pacific Ocean. Native ichthyofauna includes about 934 marine species, 250 freshwater species, and 38 species living in both environments. At least nine non-natives (eight freshwater and one marine) have established populations in the country (Bussing 1998; Bussing and López 2009; Angulo et al. 2013; Froese and Pauly 2016). Permits to import live organisms in Costa Rica are issued by the MINAE (Law No 7317, Law of Wildlife Conservation of Costa Rica), Instituto Costarricense de Pesca y Acuicultura (INCOPESCA), and Servicio Nacional de Salud Animal (SENASA). There are at least 92 species that require an official certificate for importation declaring that no disease was found in the premises of origin (Departamento Regulatorio Dirección de Cuarentena Animal 2016). These species have been reported to be vectors of diseases such as the infectious hematopoietic necrosis virus and the epizootic ulcerative syndrome. Permits to import ornamental live fishes are issued jointly by MINAE and SENASA, but permits to import fishes for farming are issued jointly by INCOPESCA and SENASA. We focused on ornamental fishes because they represent most of the new species entering the country and most of the fishes for farming are already established (Angulo et al. 2013). In order to be granted an import permit, importers must provide scientific and common names of the species being imported, the number of live individuals, countries of origin, and final destination of all individuals.

Data collection

We reviewed all permits (henceforth referred to as shipments) for import of ornamental fishes approved by MINAE between 1998 and 2004, which totaled 371 shipments. We recorded the shipment number (code), year, source country, importer, genus, epithet, common name, and the number of individuals imported.

Data analysis

We used the FishBase database (FB) (Froese and Pauly 2016) and the R package "rfishbase" (Boettiger et al. 2015) to classify our data. Complete scientific names were sometimes in the wrong field (e.g. common name) instead of the proper fields ("Genus", "Epithet"). Therefore, we separately evaluated the scientific names of each entry and classified the entry as "correct" if it included a current accepted scientific name or a synonym in one of its fields. The correct use of a current valid scientific name or a synonym did not assure that the imported specimen corresponded to the taxonomic denomination registered in the permit (Monteiro-Neto et al. 2003).

For the rest of data, we used FB to individually search for the scientific names provided by the genus, epithet, or common names fields of the shipment. When the entry was both a single species and spelled roughly in the same manner as the original name searched, we assumed the entry as "correct" and "misspelled", and registered the returned name.

We classified the entry as "absent" when there was no information on the genus or epithet fields, the written name was not found on FB, or the search returned an ambiguous result. For an entry classified as "absent", we searched the common name in FB and accepted the scientific name for a search return that resulted in a single species that was included in the Aquatic Sciences and Fisheries Information System (ASFIS) (FAO 2016). We used this system because ASFIS list compiles a unique common name for a single species.

Once we had our species list, we used FB to extract additional taxonomic information (Family and Order), natural habitat (marine, freshwater, or both), and geographic distribution of each species. The distribution was classified as part of the major continents (the Americas were considered as North, Central, and South) for freshwater species and major oceans (Atlantic, Indian, and Pacific) for marine species. We separated each species as native or non-native to Costa Rica. We also classified species as established elsewhere when information in FB indicated that the species have reproducing populations in countries outside their natural range. We used an analysis of variance to compare the number of individuals imported between these two groups. To describe general patterns, we summarized the data according to source country, year of importation, nomenclatural errors, taxonomic group, natural habitat, and native geographic distribution. Additionally, we extracted information from FB about potential human health risks by the species imported. Finally, we compared the imported species list against the current CITES species list (UNEP-WCMC 2015) and the current fishes species list that require a health certificate to be imported into Costa Rica (Departamento Regulatorio Dirección de Cuarentena Animal 2016).

Results

Number of individuals

From 1998 to 2004 a total of 834,624 live individuals were imported into Costa Rica from six countries: USA (57.3% of all fish shipments), Colombia (28.6%), Cuba (7.4%), Peru (6.4%), Panama (0.1%) and Italy (0.1%). The number of imported individuals varied through the years with a substantial increase in 2004 (Figure 1). Shipments varied regarding the amount of individuals and taxa (entries with different names). The average number of individuals was 3582 individuals/shipment (minimum = 57, maximum = 21931), while the mean number of taxa was 18 taxa/shipment (minimum = 1, maximum = 50). All permits were variable regarding the information that they provided. The number of individuals was not reported in seven shipments.

Nomenclature errors

If considered together, both the genus and the epithet were correctly written for 29.6% of the individuals. Genus was correctly written but with the epithet absent or misspelled for an additional 10.9% of the individuals. Scientific names of the genus or the epithet were misspelled for 18.8% of the individuals, and absent for 40.6% of individuals (Figure 2). Some shipments classified as "ornamental fishes" included scientific names corresponding to other taxa, like frogs and salamanders. Even with these miscues, all requested permits were approved.

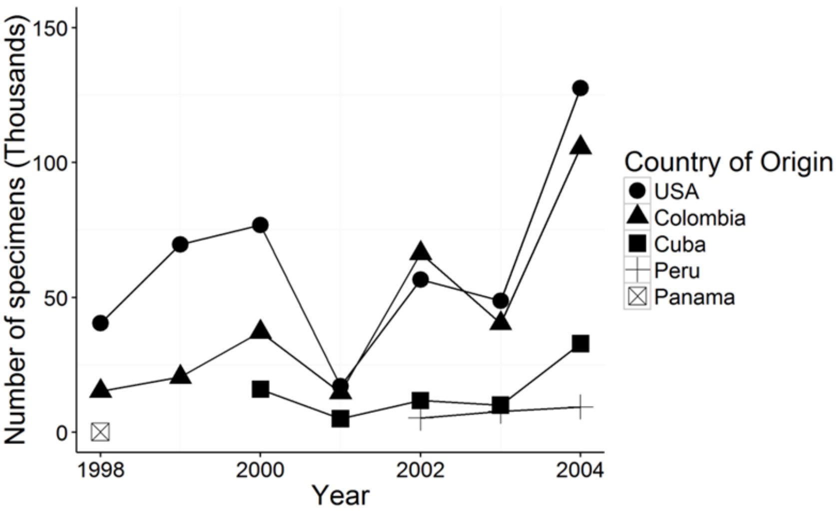

Figure 1. Number of live individuals of ornamental fishes imported by Costa Rica between 1998 and 2004 according to year of importation and the countries of origin.

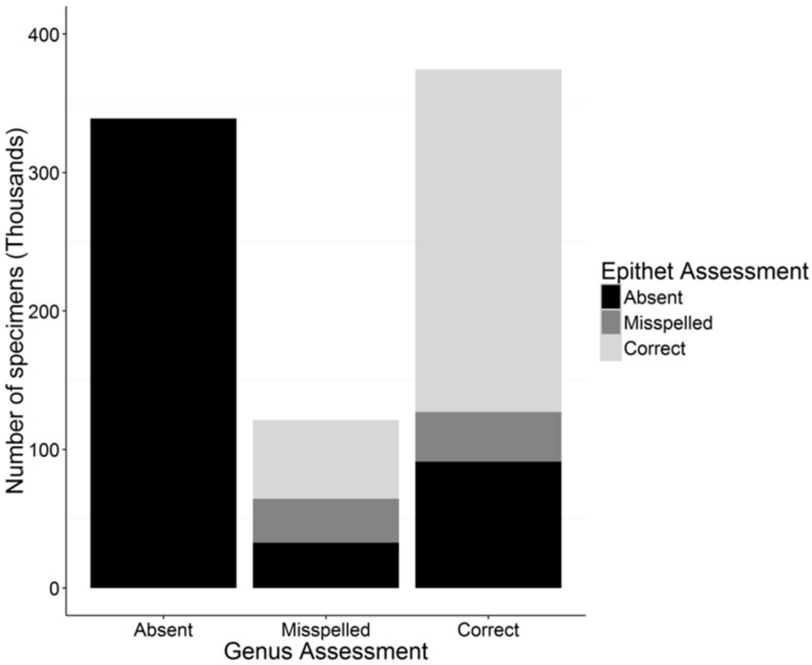

Figure 2. Number of live individuals of ornamental fishes imported by Costa Rica between 1998 and 2004 according to the result of genus and epithet assessment (See methods).

Number of species

Based on the scientific name and common name we were able to identify 47% of the individuals to species level, 13.8% of the individuals to genus level, and the remaining 39.2% could not be identified. This information allowed us to extract a total of 231 genera and 318 species names (Appendix 1). For 34 genera, no epithets were identified but were considered as additional species because no other species in the same genus was identified in the permits. However, they could still represent several species, as they were present in several permits. Therefore, at least 352 species of fishes belonging to 84 families and 18 orders were reported as imported into Costa Rica between 1998 and 2004 (Appendix 1).

Species of importance

Three genera (*Pangasius*, *Oreochromis*, and *Corydoras*) and seven species (*Paracheirodon axelrodi*, *Carassius auratus*, *Xiphophorus helleri*, *Paracheirodon innesi*, *Betta splendens*, *Xiphophorus maculatus*, and *Ictalurus* punctatus) accounted for 31% of all imported live

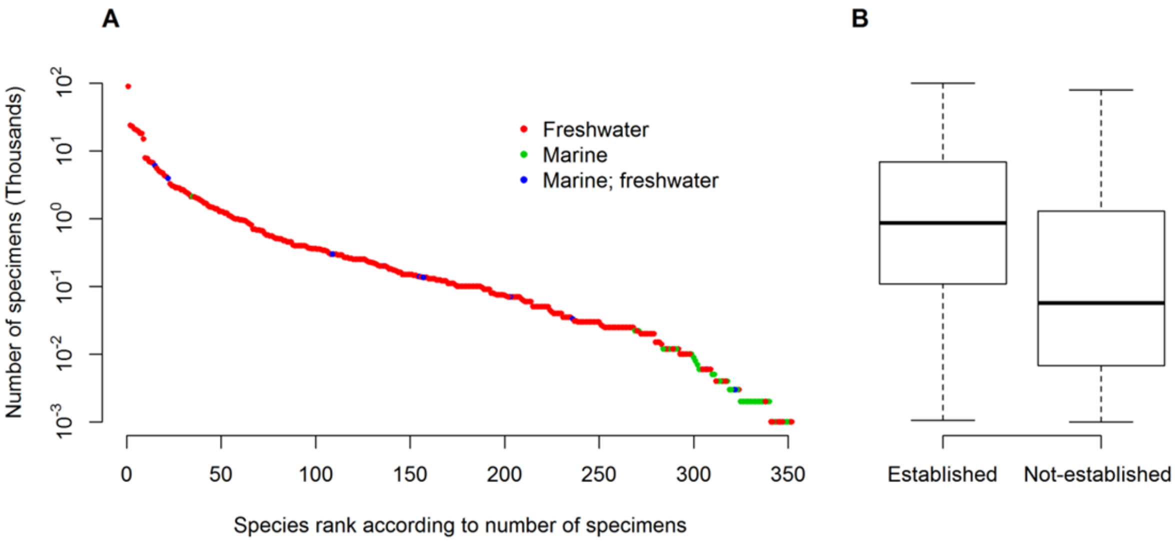

Figure 3. (A) Species and unique genus in rank order according to the number of individuals of ornamental fishes imported into Costa Rica between 1998 and 2004 that were reported to the Ministry of Environment and Energy. (B) Boxplot with the distribution of the number of individuals imported that previously have been reported as established or not-established elsewhere.

fish (Appendix 1). For each one of those taxonomic groups, more than 10,000 individuals were imported (Figure 3). Furthermore, between 1000 and 10,000 individuals were imported for an additional 46 species (Figure 3a). Species reported as established elsewhere had more individuals imported than those not being established in other countries ($F_{1,317}$=9.194, p=0.002; Figure 3b).

Twelve of the imported species are also native to Costa Rica. In addition, we identified 301 species (85.5%) as freshwater, 42 (11.9%) as marine, and eight (2.6%) can survive in both environments (Appendix 1). Most of the freshwater, non-native species are native to South America (54.8%), Asia (15.29%), and Africa (7.9%; Figure 4a). Marine, non-native species are found throughout the three major oceans, mostly concentrated in the Indo-Pacific region (Figure 4b). A hundred and thirty-one species in our list have established populations in countries out of their natural range, nine of which have been considered as a potential pest by FB (Appendix 1). Although 19 can affect human health because they are toxic, venomous or traumatogenic, most species are harmless (Appendix 1). The species *Hippocampus hippocampus*, *Hypancistrus zebra* and *Scaphirhynchus platorynchus* are currently in the appendices of CITES, while *Carassius auratus*, *C. carassius*, *Cyprinus carpio*, *Platycephalus fuscus*, *Scatophagus argus* and *Trichogaster trichopterus* currently have special requirements to be imported in Costa Rica because they have been reported as disease vectors.

Discussion

According to Wabnitz et al. (2003), over 1450 species and 20–24 million individuals of marine fishes were traded worldwide between 1988 and 2003 (see also estimates from Townsend 2011 and Rhyne et al. 2012). Although most live animal imports occur in developed countries, imports are also occurring in developing countries. Here, we found that in Costa Rica over 800,000 live individuals representing more than 352 species of ornamental fishes were imported over seven years (1998–2004). This number is very high if we compare our results with data from the US during the same period (Rhyne et al. 2012). In 2004, Costa Rica imported 1.75 times more individuals per capita and 4.48 times more individuals per unit area than the US (Rhyne et al. 2012; The World Bank 2016). Although, the number of species is lower than values reported for the US with 1802 species (Rhyne et al. 2012; Wabnitz et al. 2003), the number is relatively similar to other countries like Greece (326 species, Papavlasopoulou et al. 2013) or Hong Kong (342 species, Chan and Sadovy 2000). However, the species number is considerable high if we take into account the number of ports of origin. Only six countries were involved in import permits during a six-year period for Costa Rica, while 39 countries were included as countries of origin over a one-year period for the US (Rhyne et al. 2012).

The number of individuals imported increased during the last year of this study, but the importation

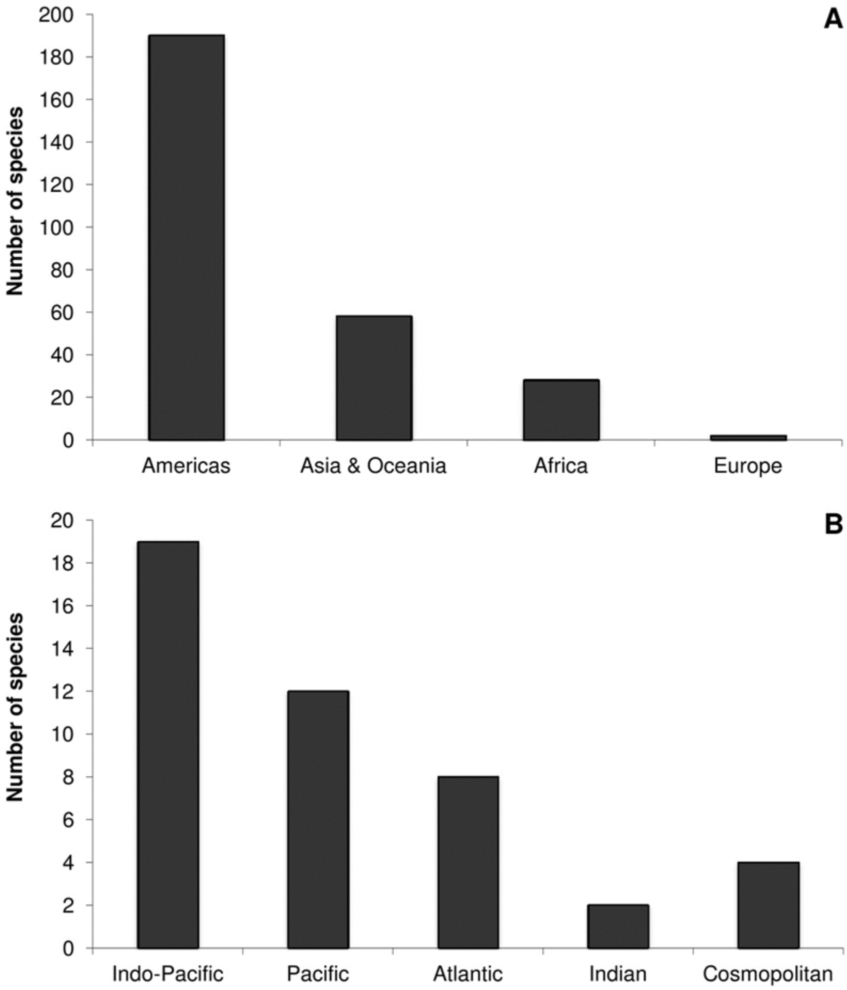

Figure 4. Number of freshwater (A) and marine (B) species of fish imported into Costa Rica according to their native range.

of individuals was rather variable throughout the study period (Figure 1). Data regarding the expenses on live fish importations between 2008 and 2013 suggests that the pattern during this later period has also been fluctuating (Estado de la Nación 2014; INCOPESCA 2016). For other countries, Leal et al. (2016) reported a steady increase of 3.1% per year in marine ornamental fish imports to the European Union between 2000 and 2011, with high variation among countries. A decrease in the number of shipments of live fishes occurred in the US between 1996 and 1998 (Balboa 2003), and then increased between 2000 and 2005 (Smith et al. 2008). These patterns reveal fluctuations of the fish trade market, possibly caused by changes in the economies and policies influencing exporters and importers. The role of some countries as exporter or importer can change through the years, depending on the ease of trade between countries (Leal et al. 2016).

The US plays a major role in Costa Rica's exotic fish trade by providing the greatest amount of live fishes for the Costa Rican market. The US may also serve as a commercial intermediary because many species imported from the US have native ranges in other countries (e.g. Indo-Pacific Ocean or Asia). This trade pathway previously explained by Zajicek et al. (2009) suggests that the trade regulation of exotic organisms must start in the exporter country (usually a developing country), be intensified in the intermediary (especially if it is a developed country), and re-checked at the final destination. However, poor trade regulations, as well as insufficient information of imported live animals, have been detected at the US ports of entry (Smith et al. 2008, 2009; Rhyne et al. 2012). Poor trade regulations in a key country like the US could have implications for downstream trader countries due to their economic dependence on maintaining open markets to its exportations.

We are aware that our dataset is dated. However, this study remains relevant because the regulations and procedures in Costa Rica have not changed, and similar results regarding the lack of accurate taxonomic information are still obtained from the US markets (Smith et al. 2008, 2009; Rhyne et al. 2012). We found that regulations of ornamental fish imports in Costa Rica are also weak, which is reflected in the taxonomic information declared by importers in the shipment records analyzed. The scientific name of the species entering the country is essential information to assess the potential risks involved accurately; however, it was entirely or partially absent in almost 53% of the cases or incorrectly written when present in 19% of the cases. Importers frequently used only the common name of the organisms, which is insufficient to identify species with complete certainty. We used the common name as a species identifier; however, we were unable to obtain a partial or complete scientific name for more than a half of the individuals imported. Many of these mistakes could involve endangered species included in international agreements such as CITES or even species banned because they are vectors of diseases or pests (Raghavan et al. 2013). The lack of reliable information prevents us to fully understand the scope of live animal imports and the potential impacts of introduced species.

The absence of accurate information is especially concerning when the origin and type of species being imported into Costa Rica are considered. We found that most species originally range from South America and tropical areas of Asia and Africa, including the surrounding oceans. In addition, a high proportion of species (37%) were classified as established elsewhere and some are considered as potential pests, including three of the most imported species in Costa Rica. The environment similarities between Costa Rica and the native range of the imported species increases the probability of biological invasions in Costa Rican freshwater and marine ecosystems. For example, the lionfish (*Pterois volitans*) was released in subtropical environments, but its tremendous success was only achieved when it reached tropical environments in the Caribbean Sea, including Costa Rica's coast (Whitfield et al. 2002; Kimball et al. 2004; Albins and Hixon 2008). Introduced species with established populations in Costa Rica (e.g. *Pterygoplichthys pardalis*, *P. disjunctivus*, *Hypostomus panamensis*, *Micropterus salmoides*) probably entered Costa Rica via pet trade before this study (A. Angulo, com. pers.). Possibly they are absent in the permits because they are easy to breed in captivity, and therefore produced by aquaculturists for the local market.

Developed countries have invested significant efforts and resources to control the trade of live animals in order to reduce the risks of introducing potential pests or organisms (European Union 2010). Most of these efforts have been carried out to comply with international regulations, such as the World Trade Organization agreement on the application of sanitary and phytosanitary measures (SPS Agreement). Different policies could be applied to control the international trade of fishes or pets in general. However, some of the implemented policies turned out to be inefficient, self-defeating, and expensive and complex for government implementation (Perry and Farmer 2011). Instead, we advocate for the implementation of risk assessments using resources already available on the internet (e.g. FishBase). Risk assessments based on life traits have proved to be effective predictors of invasions (Kolar and Lodge 2002). Because taxonomic information and accurate information are imperative for risk assessments, they also could enhance the prevention and control programs of invasive species. Accurate information also provides added value for the consumer, as the real taxonomic identity of a pet most likely specifies better guidelines for its care. Additionally, many pet consumers are conscious of the problems associated with pet trade; therefore, a seal or certification that guarantees the reliability of the information provided with the product could encourage consumers to buy species even at higher prices (Leal et al. 2016). Traders could benefit from more opportunities when they follow high standards of commercialization or label their products as "ecological" as seen in commercial fisheries (Kaiser and Edwards-Jones 2006; Whitmarsh and Palmieri 2011). Certification for the pet trade has been already proposed by others (Tissot et al. 2010; Murray and Watson 2014) as a means to address many environmental problems associated with aquarium pet trade.

Commonly, exporting live animals only requires a health certification issued by an accredited veterinarian. However, because of the increase in animals traded as pets and the expertise needed to identify some fish species accurately, we recommend that an accredited biologist should certify the identification of the exported animals. Governments should include policies specifying a pre-border certification of identity for animals traded as pets. The export certification should assure that the identification and the origin of the individuals are accurate. Certifiers of exporters should be validated by entities of accreditation following international quality systems and procedures. The import permit should be filled through a web application provided by the government with information available about the fishes. Tax incentive may be designed for those traders that provide information about fishes traded. The information available on the web should include the scientific name of the fishes for sale, the current taxonomy, the source of the individuals (caught at sea or in freshwater, or produced in aquaculture), the conservation status, the original distribution, and the historical information about adverse introductions, global introductions, and invasiveness. Currently, there are valuable tools such as FishBase, which provide much information about the natural history of fishes and could be useful to regulate live fish trade. We suggest that high taxes should be imposed to trade fishes captured from natural ecosystems, with aims to preserve natural populations and encourage research for the production of fishes in aquaculture systems.

In this study, we analyzed the scale of exotic fish trade in the developing country, Costa Rica. We showed the pathways followed by live individuals imported into Costa Rica, and shed light on the lack of appropriate regulations to avoid the introduction of potential pests. Although we used Costa Rica as a case study, these deficiencies may be prevalent for many developing countries. Our findings can be used 1) as a call for governmental authorities to apply stricter regulations during the process of exotic species trade, and 2) to encourage similar analysis in other developing countries. We advocate for accurate and precise information throughout the supply chain as it provides a tool to evaluate risks and implement more objective and successful policies.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Species list and number of live individuals of each species imported into Costa Rica between 1998 and 2004.

This material is available as part of online article from:
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