

U.S. drowning in unidentified fishes: Scope, implications, and regulation of live fish import

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Abstract

More than half a million shipments and over one billion live animals were imported to the United States since 2000. The majority of these were aquatic organisms, including approximately 1.1 billion fishes. Imported fishes are a major source of revenue for the pet industry and aquaculture, but can be a nuisance if they escape or are released into the wild. Over 200 fish species have been introduced to the United States following importation, many of which threaten ecosystems and infrastructure. Although fishes constitute the majority of animal imports, they receive minimal attention from regulatory agencies. Moreover, poor record keeping at ports make it impossible to assess the diversity of fishes imported, making species-specific risk analysis and prevention programs difficult. As a global leader in wildlife trade, the United States is well positioned to set standards that promote safe and responsible trade practices. To date, the nation has languished, though there are mechanisms for improvement.

Introduction

The global trade in aquatic species is a multi-billion-dollar industry that supplies billions of fishes, invertebrates, and plants to enthusiasts every year (Baquero 1999; Padilla & Williams 2004). As a leading importer of wildlife, the United States supports a large fraction of this trade. Fishes constitute the vast majority of live animal imports to the United States, but receive little attention from regulatory agencies. This disparity is of immediate concern as importation for aquaculture and the aquarium trade are among the top five pathways of nonnative species introductions, and responsible for over one-third of the aquatic species on the IUCN 100 Worst Invaders list (Ciruna *et al.* 2004; GISD 2005).

The costs and benefits of importing fishes are mixed. Sales of cultured and aquarium fishes in the United States may provide a large source of income for communities, both within the country and abroad, but they have the potential to alter ecosystems, introduce novel infectious agents, and damage infrastructure if they escape or are

released into the wild (Ruiz *et al.* 1997; Ruiz *et al.* 2000; Padilla & Williams 2004; Lodge *et al.* 2006). Three primary factors make imported fishes a high-risk group for invasion and establishment in the United States: (1) the enormous volume and diversity of live imports (reported here); (2) the broad distribution of endpoint consumers; and (3) wholesaler selection for the hardest individuals (Padilla & Williams 2004). With invasive species establishment resulting from international trade predicted to increase up to 24% in the next two decades (Levine & D'Antonio 2003), the most commonly imported group deserves more attention.

Here we look “beyond ballast water” (Padilla & Williams 2004) to determine the scope and scale of live fish importation to the United States. We review the national and international policies that regulate the country's trade in fishes and other wildlife. Based on our findings, we encourage the United States to adopt a precautionary approach to minimize future negative outcomes resulting from wildlife trade and highlight several ways this may be accomplished.

Methods

To determine the composition and magnitude of live fish imports to the United States, we examined wildlife shipment records for the period 2000–2005. Wildlife trade is monitored through a system of national ports designated and managed by the U.S. Fish and Wildlife Service (USFWS) Office of Law Enforcement, U.S. Customs Service (USCS), and the U.S. Department of Agriculture (USDA) Animal and Plant Inspection Service. Through a Freedom of Information Act request we obtained USFWS Law Enforcement Management Information System (LEMIS) shipment records for live animal imports declared for the period 2000–2005. We did not request analogous records from USDA as they primarily regulate plant and domestic animals. Because USFWS LEMIS records are discarded every 6 years, we only received a portion of records from 2000. At the time of request, records for 2006 were not yet available. LEMIS provides records for wildlife shipments transported through 18 ports designated to handle such commerce. USCS also maintains records of wildlife imports that are uploaded into the LEMIS database. The ports of Anchorage, Los Angeles, Miami, New York, and San Francisco handled the greatest volume of shipments (>60% of imports) during this time period, had the most thorough records, and were thus the focus of our analysis. While cnidarians, which include corals, jellyfish, and sea anemones are imported nearly as much as fishes, we focus on the latter as we expect fishes to pose more widespread implications to aquatic resources and infrastructure.

LEMIS shipment records include information on the number of animals in the container (shipment weight may be provided in lieu of number of individuals, but this is relatively uncommon), animal taxonomy (phylum, class, order, family, genus, species), the intended purpose of contained animals (e.g., commercial, scientific, zoos, personal), their source (e.g., captive bred, wild caught), and country of origin. We compiled this information for import records with “Pisces” as the designated taxonomic class (LEMIS designates jawless, cartilaginous, and bony fishes as “Pisces”). Records missing information in these fields were excluded from categorical analyses, as were shipments in transit through the United States. Beginning in 2005, LEMIS shipment records included more thorough taxonomic data and additional information on species habitat preferences that allowed us to examine variation between freshwater and marine fish imports. Prior to 2005, the majority of shipments were identified as “all live tropical fish,” which includes no taxonomic or habitat information. Therefore, we restricted all habitat analyses to the 2005 data.

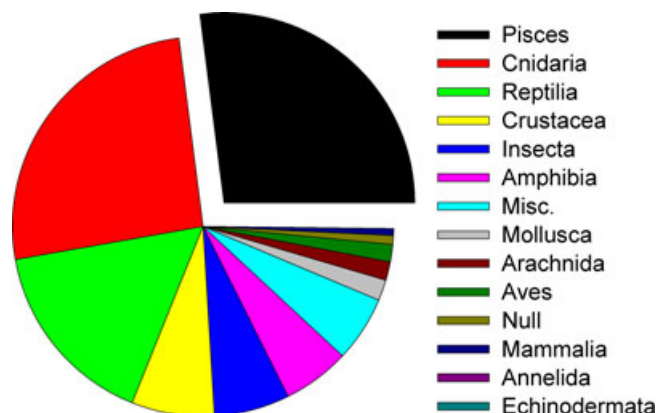
LEMIS represents only shipments that wildlife dealers have declared, excluding those overlooked or improperly recorded upon arrival, mislabeled, or smuggled into the country. When shipments contain a large quantity of animals, as is often the case for fishes, it is unlikely that an accurate count will be made on inspection. The sheer volume of animal imports, and the numerous locations where they can enter the country, makes perfecting this system of record keeping extremely difficult. For example, four-letter species codes are often the only taxonomic information recorded for a shipment. If the code is entered incorrectly or used for more than one species it can be impossible to determine the type of animals in a shipment. To fully assess our knowledge of live fish importation, we also considered the number of shipment records for which categorical information was missing, unknown, or problematic.

We used the 2000–2005 LEMIS live animal import data (K. Smith and M. Behrens, unpublished data) to determine the absolute number and percent of shipments and individual animals classified as “Pisces.” To determine if there were trends in the magnitude of fish imports from 2000 to 2005, we regressed the total number of shipments and individuals against year. For categorical comparisons (i.e., habitat, purpose, country of origin, source), we summarized data as the total percent of fish shipments or specimens in each category across all years, except habitat which included only 2005 data (see above). To assess the taxonomic uncertainty of fish data within LEMIS, we determined the percent of shipments identified to the level of family, genus or species, or to certain general taxonomic groups (e.g., “tropical marine species” and “freshwater marine species”). Additionally, we determined the reliability of species codes within the database by the number of taxa represented by each species code, and the percent of species codes represented by more than a single species.

Results

Over half a million shipments containing well over one billion live animals were imported to the United States between 2000 and 2005 (K. Smith & M. Behrens, unpublished data). More than 60% of these were aquatic organisms, with fishes exhibiting the greatest volume at approximately 1.1 billion live animals, or 27% of all imports (Figure 1). On average, approximately 18,000 fish shipments and approximately 187 million live fishes were imported to the United States through major ports of entry each year (Figure 2). The majority of 2005 fish imports were freshwater taxa: 54.1% of shipments and 92.0% of individuals. Over 99% of fish shipments contained

Figure 1 Proportion of individuals, depicted by taxonomic class, imported to Anchorage, Los Angeles, Miami, New York, and San Francisco during the period 2000–2005. Proportions ranked from greatest to least: *Pisces (0.270), Cnidaria (0.258), Reptilia (0.161), Crustacea (0.070), Insecta (0.064), Amphibia (0.057), Miscellaneous (0.056), Mollusca (0.018), Arachnida (0.016), Aves (0.015), Null (0.008), Mammalia (0.006), Annelida (0.001), Echinodermata (0.001). *LEMIS designates all jawless, cartilaginous and bony fishes as “Pisces.”



animals intended for commercial purposes (e.g., aquarium & pet sales). Countries in Southeast Asia, Oceania, northern South America, and Trinidad & Tobago represented the most common points of origin for imported fishes (Table S1).

Only 3.8% of shipments were directly identified to the level of family, genus, or species and over 35 species codes (21%) were used to represent mixed species groups. In some cases, as many as 31 unique taxa were represented by a single species code. The general taxonomic designations “tropical marine species” and “tropical freshwater

species” represented 87.5% (42.1% marine, 45.4% freshwater) of 2005 shipments. Overall, 15% of species codes were unreliable, because they included multiple species or nontaxonomic groupings, leaving only 142 uniquely identifiable species, and making it impossible to assess the full diversity of fishes imported. Respectively, 97.6% of marine and 40.2% of freshwater fishes were sourced from wild populations (Table S1). However, these numbers may be higher. Indeed, 1.7% of marine and 59% of freshwater fishes were incorrectly labeled as “animal parts and derivatives” (Table S1). All shipment records

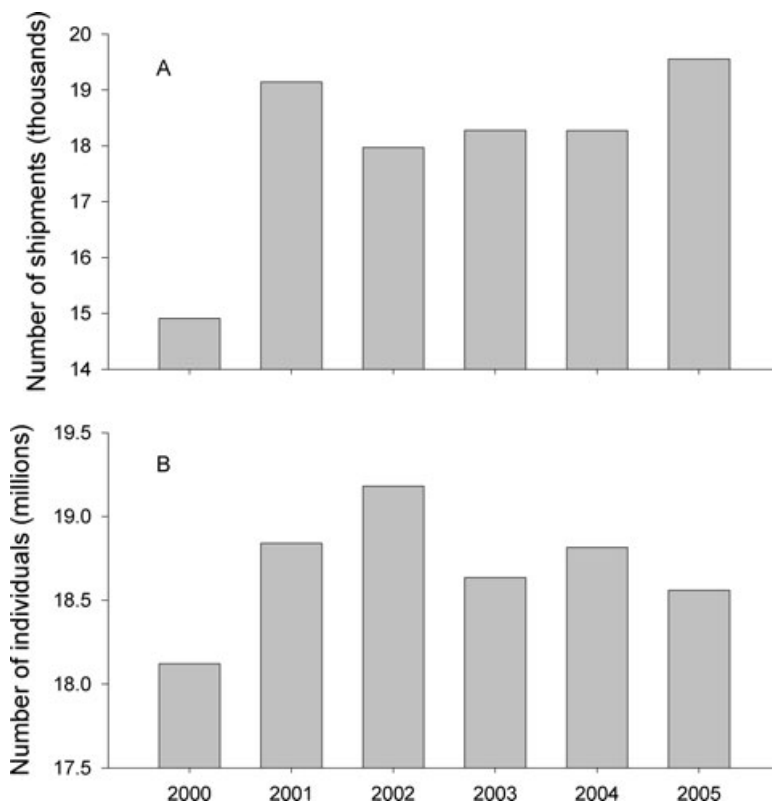


Figure 2 (A). Number of shipments containing fishes. (B). Number of individual fish collectively imported to Anchorage, Los Angeles, Miami, New York, and San Francisco from 2000 to 2005. Neither shipments nor individuals imported exhibited a significant change in quantity between 2000 and 2005 (shipments: $R^2 = 0.47$, $F_{1,4} = 3.485$, $P = 0.135$; individuals: $R^2 = 0.06$, $F_{1,4} = 0.239$, $P = 0.651$). Because shipment records are purged from the LEMIS database at regular intervals, we are missing a portion of year 2000 shipment records.

provided through our FOIA request were confirmed to be for live animals. Those labeled as “animal parts and derivatives” were therefore recorded incorrectly, and it is impossible to determine (retroactively) the correct source for these animals (Gary Townsend, USFWS, personal communication).

Discussion

Aquatic environments are species-rich ecosystems that provide some of the most valuable services on the planet (MEA 2005). The introduction of nonnative species is recognized as one of the top two drivers of change in these systems that are most difficult to reverse (MEA 2005; UNEP 2006). In the United States, over 200 nonnative fish species have been introduced to aquatic systems following importation (Table S2). Eighty-five of these, more than double the 1993 estimates, have established breeding populations that in many cases have harmed ecosystems and infrastructure (Table S2; OTA 1993). Because most of the world’s worst aquatic invaders are shared by many nations, the problem of live animal trade and nonnative species introductions calls for national and international solutions.

The Convention on Biological Diversity (CBD) identified the wildlife trade as the most glaring gap in the international legal system related to trade and invasive species (CBD 2004). As a leading importer and exporter of wildlife, the United States is well positioned to set regulatory standards that promote responsible trade practices around the world. To date, however, the nation has been ineffective as a global leader on the issue. One of only a few nations not party to the CBD, the United States is missing a critical opportunity to influence international guidelines pertaining to global wildlife trade. Indeed, a National Academy of Sciences report found the United States to be insufficiently engaged with international partners to develop strategic approaches to preventing, detecting, and diagnosing animal diseases resulting from wildlife import before they enter the country (NAS 2005). Furthermore, a recent review of international law on precautionary approaches to regulate live animal importation identified various legal actions the United States may pursue through the World Trade Organization (WTO) and World Organization for Animal Health, but has not (Jenkins 2007).

The United States’ approach to wildlife trade is equally lax at the national level. Nearly all government initiatives implemented to mitigate negative outcomes of wildlife import have been reactionary, focusing on the spread of nonnative species already established (DW 2007). Established nonnative species receive the majority of attention from researchers and regulatory agencies in the

United States’ (Puth & Post 2005), but it is during the initial dispersal stage that newly introduced species are most susceptible to eradication (Simberloff 2005). Recognizing this, the National Invasive Species Council (NISC) prioritizes prevention by identifying high-risk pathways for new species introductions, as well as early detection, rapid assessment, and response planning (NISC 2007). While these priorities are proactive, there is no coordinated national strategy, legislative authority, or funding devoted to implementation. This is in spite of the widespread agreement that prevention is the most desirable method for reducing the long-term negative effects of nonnative species. Several nations, most notably, Australia and New Zealand, have created proactive regulatory programs that have successfully reduced the introduction of nonnative animals (DW 2007). The United States is poised to accomplish this same level of protection and play a more responsible role in safeguarding international wildlife trade.

Successful prevention requires two general capabilities. Foremost is the ability to design, authorize, and efficiently implement prevention programs. The current political construct in the United States makes this difficult. In 2002, the CBD’s Conference of the Parties adopted the Guiding Principles for the Implementation of Article 8(h), on invasive species, thus supporting a precautionary screening approach to proposed species imports. United States’ membership with the CBD would enhance federal agency abilities to develop and implement more stringent import regulations and should be immediately ratified. This would help stimulate action by Congress, which has not passed legislation on aquatic invasions since the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), which expired in 2002. It is promising that two new bills are currently before Congress; the 2007 National Aquatic Invasive Species Act (NAISA) (S.725) and the 2007 Prevention of Aquatic Invasive Species Act (H.R. 889). Although the emphasis of both Acts is on ballast water regulation, NAISA directs several government agencies to formulate new national and state-level screening guidelines for imported aquatic species.

Second, we require the ability to determine which nonnative species are likely to invade and where. The introduction and establishment of imported nonnative fishes depends on numerous factors including the purpose, origin, state of individuals, consumer demand, shipment transit route, species life history traits, propagule pressure (number of individuals introduced and frequency of introductions), and habitat invasibility (environment’s susceptibility to colonization and establishment) (Davis *et al.* 2005; Dugan *et al.* 2006). At the most basic level, pathways of invasion following importation should differ

significantly by species habitat preferences. Freshwater invasions often derive from accidents (e.g., containment breaks) at distribution centers (Fuller 2003). Introduced marine fishes are much less common, but appear to be increasing and statistically linked to propagule pressure (Semmens *et al.* 2004; Dugan *et al.* 2006). Most imported marine fishes are collected from wild populations in tropical countries. Upon importation to the United States, and likely other temperate nations, these species are housed at facilities located far from invulnerable habitat (e.g., near-shore reefs). This suggests that many marine fish invasions result from intentional releases to suitable habitat, or ballast water (Padilla & Williams 2004). Habitat invulnerability for imported nonnative fishes appears to be linked to differences in both the volume of imports and import pathway, but more science is needed to tease the two apart. A recent push toward integrating invasion pathway analysis and risk analysis into wildlife law enforcement in the United States is a promising step toward wedding scientific evidence to regulation (Lodge *et al.* 2006).

Risk analysis, which includes both risk assessment (estimating risk) and risk management (controlling risk), has become the standard vehicle for identifying species invasions (Orr 2003; Anderson *et al.* 2004). As a member of the WTO, the United States must adhere to international standards when developing live animal trade policies. If the United States wants to implement tighter regulations on the import of a particular species, it must justify deviations from WTO Sanitary and Phytosanitary Agreement standards through scientific-based risk analysis (Cooper & Rosser 2002). At the national level, the Aquatic Nuisance Species Task Force's (ANSTF) Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process provides a framework for risk assessment and risk management. The risk assessment component is flexible, using quantitative and qualitative information to determine the probability and consequences of establishment of a single species, or invasion pathway for several species (Orr 2003). However, the risk management component was not comprehensively developed, and has rarely been implemented as part of a federal risk analysis (Hill & Zajicek 2007). Without properly implemented risk management, a risk assessment is rendered useless (Hill & Zajicek 2007). Executive Order 13112 charged NISC with updating the 1996 ANSTF risk analysis process by 2003 (NISC 2001), but the 2007 draft of the National Invasive Species Management Plan indicates this is at least 3 years away (NISC 2007).

The millions of fishes imported to the United States each year offer ideal candidate species for risk analysis. Unfortunately, it will be exceptionally difficult to accomplish this given the substantial fraction of imports that are not identified to the species level (> 87% of

fish imports in 2005), the relatively large number we do know of (142 uniquely identifiable fish species imported), and the sheer volume of imported organisms. Moreover, the screening process at ports is severely compromised and the responsibility of USFWS to improve. The agency is charged with record keeping, screening, and releasing live animal imports (Endangered Species Act, at 16 USC 1538(e)). Port officers have the authority to detain or refuse shipments if the required *Declaration for Importation or Exportation of Fish or Wildlife* (Form 3-177) is missing, incomplete, or inaccurate (50 Code of Federal Regulations, 14.61; see www.le.fws.gov/faqs.htm). The vast amount of information missing from imported shipments of live animals implies a major breakdown in USFWS regulation at ports, a problem also likely to apply to shipments exported from the United States. This is a sorely missed opportunity for preventing national trade in harmful species that should be addressed immediately. New coding systems, whereby port officers adopt an existing taxonomic classification system to standardize, organize, and capture wildlife trade data have been proposed and should be seriously considered (Gerson *et al.* 2008).

The lack of prevention at the border may stem from the lack of a single federal law that mandates a comprehensive assessment of wildlife import to the United States. USFWS is the primary agency responsible for regulating importation and interstate movement of nonlive-stock wildlife. The Lacey Act (1900) is the focal statute by which USFWS regulates species imports deemed injurious to humans and national resources (Code of Federal Regulation, title 50, part 16). Over 35 taxa are currently considered to be injurious. Among fishes, these include walking catfish (*Clarias batrachus*), snakeheads (> 28 species in the genera *Channa*, *Parachanna*), all species in the family Salmonidae, silver carp (*H. molitrix*), and large-scale silver carp (*Hypophthalmichthys harmandi*). The listing of a species under the Lacey Act can take years and is largely based on submitted proposals and petitioning (Fowler *et al.* 2007). USFWS simply does not have the resources to apply the Lacey Act to species not yet introduced to the country (DW 2007). Indeed, the majority of species deemed to be injurious were already present (56%) or established (44%) in the United States when listed (Fowler *et al.* 2007). Although USFWS, and other agencies, have a number of programs to deal with nonnative aquatic species that have already invaded the country (USFWS 2007a, Figure S1), there is an obvious lack of prevention at the border. This gap is unlikely to be filled anytime soon as USFWS anticipates a \$1.4 m budgetary cut to wildlife law enforcement in 2008 (USFWS 2007b). To safeguard ecosystems, human populations, and infrastructure in the United States, and abroad, wildlife law

enforcement should be moved to the top, not the bottom, of the government's priority list.

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Supplementary Material

The following supplementary material is available for this article:

Figure S1: Government outreach programs to prevent nonnative species introductions to the United States.

Table S1: Percent of freshwater and marine individuals imported to the United States in 2005, depicted by source and country of origin.

Table S2: Nonnative marine and freshwater fishes traded in the aquarium industry and documented in U.S. waters.

This material is available as part of the online article from:

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