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The applicability of the U.S. Law Enforcement Management System (LEMIS) database for the protection and management of ornamental fish

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Abstract. The United States Law Enforcement Management Information System or LEMIS database has access to a wealth of data, and compiles detailed information filed on declaration forms, on all live fish and wildlife imported and exported into the country. Studies on higher vertebrates such as mammals, birds, reptiles, and amphibians have effectively used the LEMIS database to evaluate impacts of the trade on target species and their populations. In 2010, approximately 163,768,595 or 75% of the total number of live imports into the U.S. were fishes. However, in LEMIS the vast majority of ornamental fish species were identified simply as freshwater or marine tropical fish. These two groups alone accounted for 153,613,291 of the live imports compared to 4,740,404 for all other vertebrates. If criteria were developed to facilitate incorporation into LEMIS of the available detailed information in the declaration of importation forms regarding ornamental fish, LEMIS could serve as a very useful tool that can guide conservation policy and action on behalf of ornamental fish; especially since they constitute the vast majority of live animal imports into the country and may be more at risk of over-exploitation.
Key Words: aquarium fish, pet trade, conservation, wildlife use.

Introduction. Ornamental fish have long been sources of wonder, and aquariums are used as small windows into the fascinating underwater world. The practice of keeping fish for beauty and companionship began as early as the tenth century A. D. with goldfish playing a role as pets in China (Brunner 2003). Over time, the ornamental 'fish' trade has diversified to include freshwater and marine fishes, invertebrates such as corals, sea anemones, crustaceans (e.g., crabs, hermit crabs, shrimps), molluscs (e.g., snails, clams, scallops), and also 'live' rock (Livengood & Chapman 2007). Although difficult to estimate accurately, and using different sets of data, the value of the freshwater and marine aquarium livestock alone could be estimated at between US$400 and US$500 million worldwide. The retail industry worldwide has been estimated to be worth between US$7 billion and US$15 billion when aquariums, air pumps and other aquarium accessories directly associated with the hobby are included (FAO 2014; Andrews 1990). The people of the United States of America (U.S.) have become the world's largest aquarium fish enthusiasts with approximately 16 million households caring for some 158 million ornamental fish (Chapman et al 1997; APPMA 2014). To meet consumer demands, hundreds of millions of ornamental fish (including invertebrates) are imported every year into the U.S. which exerts a large influence on the worldwide supply and demand patterns on this natural resource (Chapman et al 1997; Cato & Brown 2003; FAO 2014). The imported ornamental fish are from both wild and farmed sources amount to over 1,539 species declared as ornamental 'fish' (Chapman et al 1997; Chapman 2000; Cato & Brown 2003; Livengood & Chapman 2007; Rhyne et al 2012). Propagation of freshwater fish on the farm is the source of approximately 95% of the ornamental fish in the trade (Chapman et al 1997). However, the vast majority of species are still collected from the wild (Chapman et al 1997; Cato & Brown 2003).

While farms provide significant numbers of ornamental fish into the trade, it does not meet the overall market demand. For example, popular freshwater species still collected from the wild include the clown loach (*Botia macracantha*), glass catfish (*Kryptopterus bicirrhis*), pictus catfish (*Pimelodus pictus*), arawana (*Osteoglossum bicirrhosum*), cardinal tetra (*Paracheirodon axelrodi*), and the hatchetfishes (*Gasteropelecus* spp.) (Chapman et al 1997; Chapman 2000). While nearly all marine species of ornamental fish and invertebrates (e.g., corals, sea anemones, shrimps, crabs, and 'live rock'), are collected from the wild (Holt 2000; Cato & Brown 2003; Livengood & Chapman 2007).

Poorly managed consumptive wildlife use results in their overexploitation and consequently has an effect on global biodiversity (Wilcove et al 1998). Likewise concerns have arisen regarding the adverse effects depletion of large numbers of ornamental fish may have on this biodiversity (Andrews 1990; Smith et al 2008). Studies show wild collection of ornamental fish for the trade can negatively impact species. If trade levels exceed the ability of populations to replenish, both the species and income generated from their collection will flounder and could eventually disappear (Hemley 1994). In the Peruvian Amazon, high fishing pressure reduced abundance and lowered biomass of targeted freshwater ornamental fish species, and caused reduction in the overall total number of species (Gerstner et al 2006). A threat to wild populations of the freshwater *O. bicirrhosum* which are sometimes collected by killing the mouth brooding adults to collect the juveniles has been documented (Moreau & Coomes 2006). Also, rapid decrease in local populations densities of targeted marine ornamental reef fishes were reported in Hawaii, and of both sea anemones and anemonefish in the Philippines, respectively (Tissot & Hallacher 2003; Shuman et al 2005). Certainly the high demand and collecting pressure for the ornamental fish trade have contributed to the endangered status of particular stony corals, giant clams, and syngnathid fishes (Bruckner 2001).

Determining the levels of removals of catch from the wild are essential for the management of populations in the wild (Pope 1988). The connection between free market economics and demand for wildlife products creates a trade force that directly affects wildlife with respect to population numbers and recruitment (Moulton & Sanderson 1997). Therefore monitoring of production, consumption, and trade data of ornamental species from the wild is mission critical to their successful management, conservation, and restoration. However, quantifying trade volumes in wildlife can be difficult to compile with respect to country and species (Broad et al 2003), especially given the informal nature of rural-urban marketing networks. Although many countries have their own systems of reporting that serves to monitor the trade of aquatic species imported or exported, there is no global network of reporting for the ornamental fish trade at this time.

Since wildlife trade data exists in many capacities a database of digital data can be an effective tool for the monitoring of the ornamental fish trade. The publication of digital data sets has increased the connectivity of scientists and managers, and helps them make more informed decisions (Huettmann 2005). Although not per se a science-based conservation database but that has been perceived and used as one, is the United States Law Enforcement Management Information System or LEMIS database, from the U.S. Fish and Wildlife Service (USFWS). In the U.S., all imported and exported fish and wildlife must be declared to the government by filing a Declaration of Importation or Exportation of Fish or Wildlife form (USFWS Form 3-177). Such requirement was imposed in respect to two protection and conservation laws of wildlife, fish and plants: the Lacey Act of 1900 that prohibits trade in wildlife, fish, and plants that have been illegally taken, possessed, transported, or sold. The Endangered Species Act of 1973, which purpose is to protect and recover species that are endangered or threatened of extinction. The original copy of Form 3-177 that accompanies every shipment provides the scientific name (genus, and species when known), common name, their quantity (either by number or weight) and monetary value, country of origin, exporter and importer. The information is then transcribed manually, and compiled into the LEMIS database. By reviewing and analyzing the data of all live animal imports in the LEMIS database, this paper seeks to address the utility of the data reported, and usefulness as a tool for ornamental fish management and make conservation decisions.

Material and Method. Records available in the LEMIS database of all live animals imported into U.S. during year 2010 were requested through freedom of information act provisions. Each record in the LEMIS database refers to an individual shipment, which are separated by import codes in spreadsheets for the entire year of imports. A computer program was written using open source code RUBY which separated the raw data from the records and organized shipments to groups and the taxonomic ranks of Phylum and Class. In essence creating a searchable database that collated shipments into categories of taxa or animal descriptors (like ornamental freshwater or marine fish), and populated the spreadsheet with its respective information. The program also classified shipments that had complete genus and species identifiers, and shipments without genus or species were classified as missing. Anything the program script could not specifically identify was aggregated into a separate spreadsheet and identified as 'unknown' species. From this point, we could examine how many individuals were imported for each group, Phylum, Class, and subsequent genus and species.

Results and Discussion. The electronic records retrieved from the LEMIS database disclosed 105,010 shipments of exotic live animals were imported into the U.S. during the year 2010 (Table 1a); a figure which amounted to 219,797,719 exotic live animals imported principally for the pet trade (Table 1a). Animals were primarily classified to the biological taxonomic rank of Class. Vertebrate animals were placed into the Class groups: mammalia, aves (birds), amphibia (frogs, toads, salamanders, newts), reptilia (snakes, lizards, turtles, tortoises), fishes (miscellaneous) and cartilaginous chondrichthyan fishes (Table 1a). The invertebrates were grouped into: cephalopoda (octopuses, squid, chambered nautilus), bivalvia (clams, scallops), gastropoda (snails), hydrozoa (corals and sea anemones), scyphozoa (jellyfishes), crustacea (crabs, shrimps, crayfish), arachnida (tarantulas and scorpions), and the insecta (Table 1a). Another group of animals was sorted and labeled with an entry code of "Uncategorized": Freshwater Tropical Fish (FWTF), Marine Tropical Fish (MATF), Crustacean (CRUS), Molluscs (MOLL), Insect (INSECT), and Other (Null, Non CITES listed, other live inverts) (Table 1b).

Table 1a

The composition and number of animal imports into the U.S. in 2010; principally for the pet trade

Taxon or LEMIS Labels	*Shipments, number of*	*Individuals, number of*	*Species, number of*	*Animals classified to species*
Reptilia	5,659	854,479	585	93%
Mammalia	1,246	483,984	90	98%
Aves (Birds)	1,116	171,860	327	91%
Amphibia	2,403	3,230,081	136	94%
Arachnids	568	157,332	74	62%
Anthozoa (Corals & sea anemones)	44,386	33,302,560	362	73%
Chondrichthyes	190	8,301	19	58%
Gastropoda	358	47,749	36	45%
Insecta	3,315	198,196	103	44%
Hydrozoa	132	920	3	1%
Scyphozoa	4	62	1	100%
Bivalvia	507	69,897	17	99%
Cephalopoda	876	55,858	8	92%
Fish, misc.	4,996	10,146,993	236	51%
'Uncategorized' taxa	39,254	171,069,447	unknown	unknown
Totals	**105,010**	**219,797,719**	**1,997**	**None to 100%**

Table 1b

The composition and number of animal imports into the U.S. Animals were designated only to a generic biological classification scheme

'Uncategorized' taxa labels	*Shipments, number of*	*Individuals, number of*
(Insect) code BUTT (butterflies, on CITES listed)	3,813	815,764
(Crustacean) CRUS	5,392	4,036,160
(Null, Non CITES listed & other live invertebrates) code OTHER	11,866	6,912,604
(Molluscs code) = MOLL	2,288	1,005,726
(Marine Tropical Fish) code = MATF	7,499	12,910,934
(Freshwater Tropical Fish) code = FWTF	7,712	140,702,367
(Phyla comprising less than 1%) code = MISC	684	4,685,892
Totals	**39,254**	**171,069,447**

Roughly 78% of all import shipments were of aquatic animals, of these more than half contained corals, sea anemones, crabs, shrimps, clams, and scallops. However, fishes constituted the largest volume of the imported live animals, approximately 163,768,595 or 75% of the total number. Corals and sea anemones comprised the second largest group, with 33,302,560, or 15% of the whole group. Crustaceans and other aquatic invertebrates amounted to an additional 4.8%. Aside from fishes, very few other vertebrates were imported (N = 4,740,404 or 2.1%), and of these, 68% were amphibians which amounted to 3,230,081 or 1.4% of the total.

A total of 1,997 species were tabulated from the import records. Reptiles had the highest number (N = 585) of species reported, followed by birds (N = 327), marine corals and sea anemones (N = 362), fishes (N = 255), and amphibians (N = 136) (Table 1a). The remaining species (351) belonging to miscellaneous Phyla and Classes (molluscs, crustaceans, and insects) (Table 1a). Most imports of the higher vertebrates (> 92%) as well as octopuses (> 92%) were identified to species level (Table 1a). A good number (> 73%) of corals and sea anemones were also identified at least to the genus level. However, shipments of most other invertebrates were simply entered as 'Uncategorized' crustacean or other type of live invertebrate (Table 1b). In the same way, the greatest number of imported live animals were freshwater tropical fish (FWTF; N = 140,702,367) and marine tropical fish (MATF; N = 12,910,934) (Table 1b). In fact, millions of these ornamental fish were imported annually into the U.S. for the pet trade (Figure 1). In 2010, approximately 63% of the fish imported for the aquarium trade were labeled uncategorized ornamental fish; that is without any reference to species.

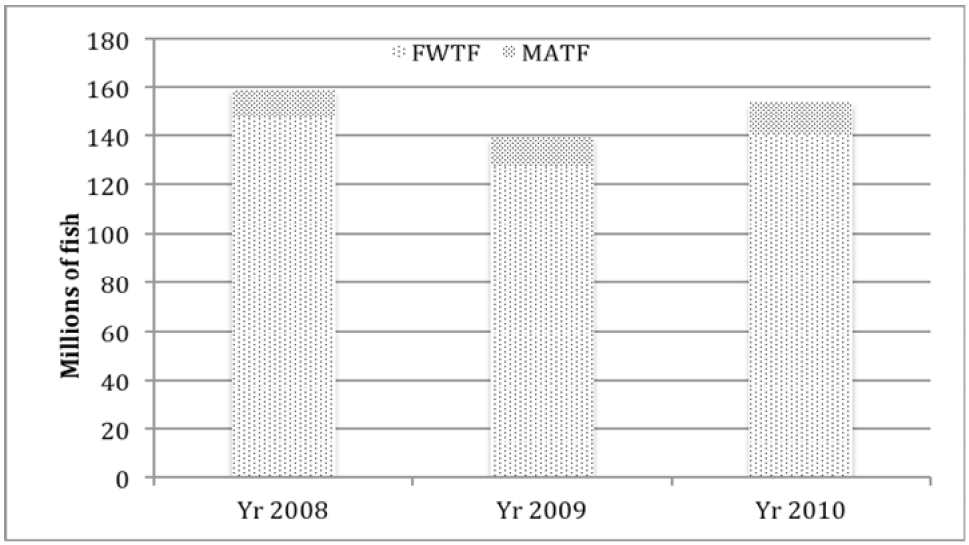

Figure 1. Number of freshwater (FWTF) and marine (MATF) ornamental fish imported into the U.S. principally for the pet trade, in years 2008, 2009, and 2010. Source: USFWS Law Enforcement Management Information System (LEMIS).

The most numerous ornamental fish, identified to species, imported into the U.S. were goldfish (*Carassius auratus*), the 'koi' carp (*Cyprinus carpio*), and guppy (*Poecilia reticulata*) (Table 2); the cardinal tetra (*Paracheirodon* sp.) was also prevalent in the records. These species with 20 others (Table 2), accounted for some 8,862,464 or 5.4% of the total number of imported fish however, 87.4% of all the fish identified to at least genus.

Table 2

Principal ornamental fishes and their numbers imported into the U.S. in 2010. Except for two species, all were of freshwater origin

Name	*Number imported*
Carassius auratus	4,554,773
Cyprinus carpio	2,427,863
Poecilia reticulata	1,372,598
Xiphophorus spp.	3551
Paracheirodon sp.	287,608
Betta splendens	46,481
Barbus spp.	2,170
Botia spp.	8,391
Ancistrus spp.	1,498
Corydoras spp.	10,229
Otocinclus spp.	7,348
Synodontis spp.	4,420
Symphysodon spp.	47,495
Pterophyllum scalare	15,989
Apistogramma sp.	2,597
Aulonocara spp.	3,504
Astronotus ocellatus	2,578
Cichlasoma spp.	16,762
Tropheus spp.	1,461
Osteoglossum bicirrhosum	6,348
Polypterus spp.	1,561
Pantodon buchholzi	3,350
Hippocampus (marine)	33,889
Aeoliscus strigatus (marine)	8,972

The information necessary for identification of ornamental fish to species level is indeed available on the Form 3-177, and has been used for a detailed analysis of the U.S. trade in ornamental fish (Chapman et al 1997). For example, approximately 201 million fish were imported into the U.S. in 1992. Ornamental freshwater fish accounted for approximately 96% of the total volume while marine aquarium fish the remaining 4% (Chapman et al 1997). Since that time, there was an apparent reduction of approximately 25% in ornamental fish imports into the country, but the percentage of imports of ornamental marine fish almost doubled to 7% by 2010 (this study). Perhaps as a result of increased hobbyist education and advances in design technology for ease of maintenance in marine aquarium keeping. Also, national production of ornamental fish has been developing considerably and increased steadily, especially for popular species that were imported entirely from abroad such as barbs and tetras. The number of imported ornamental fish species was 1,539 in 1992 (Chapman et al 1997), compared to an all total of 255 species, including non-ornamental fishes, in 2010 (this study). The names and tally of the imported species in the initial study were obtained directly from copies of the declaration of importation 3-177 forms made available through freedom of information act provisions (Chapman et al 1997). Such data differences clearly illustrate the need for accurate recording of data from the declaration of importation forms to the LEMIS database. In addition, to the other valuable data that can be obtained from the declaration of importation forms. Interestingly, the top 32 species imported in 2007

amounted to approximately 71.9% of the total number of fishes, and similarly in 2010 the top 23 species accounted for 87.4% of the number of recorded fishes. Except for four species, the majority of the 23 species in 2010 were included in the top species imported into the U.S. in 1992 and 1971 (Ramsey 1985; Chapman et al 1997). It seems reasonable to conclude that the top 19 fish presented in Table 2 are the ones preferred by hobbyists and most will remain the bulk of the trade in ornamental fishes for some time.

The LEMIS database is a tool with great potential for monitoring and management of wildlife commerce, beyond simply serving as a clearinghouse of international trade declarations. LEMIS was used to identify the most commonly traded genera and species of amphibians and reptiles, and their overall trade volumes (Schlaepfer et al 2005). It was possible to derived estimates to the number of wild caught amphibians and reptiles, and determined if harvest of particular species was sustainable. The LEMIS database was also used to examine export trends of freshwater turtles from the U.S. and derive estimates in harvest (collection) and species composition of exports (Ceballos & Fitzgerald 2004; Mali et al 2014). LEMIS was utilized to develop a risk assessment analysis to address the potential introduction and prevention of zoonotic diseases, carried primarily in mammalian wildlife (Pavlin et al 2009).

Where LEMIS fails to be as useful is with ornamental fish, and is where the emphasis should be placed now, since is the population group with the greatest number of individuals and species in the trade. Although a great number of fishes are produced in farms, the majority of the species, both freshwater and marine are still caught in the wild and not recorded. Due to their high demand, many ornamental fish species may be at risk of over-exploitation, as has happened to many populations of fish stocks destined for human consumption. Highlights of the scope and implications of trade in such a high number of fish were also addressed by Smith et al (2008). Given the ornamental fish trade is global in nature, the establishment of species in sites where they are not native is also a risk; concerns also addressed by Andrews (1990) and Smith et al (2008). Having hundreds of species, several of them traded in millions of individuals at a time, but broadly labeled simply as marine aquarium tropical fish (MATF) or freshwater tropical fish (FWTF), greatly limits the opportunity to utilized the information available to the LEMIS database. It will be of great utility if the data for ornamental fishes be recorded in the LEMIS database as detailed as for other groups of animals. As with many large collections of data, inconsistencies can abound. For example, biodiversity databases often contain incomplete distribution of data because information was collected with many different goals (Hortal et al 2007). Essentially, a database is only as good as the quality of the compiled data, and with any large database, quality control of data is critical to maintaining its utility (Pardo et al 2013).

Detailed information in the declaration of importation forms is necessary for proper evaluation of ornamental fish consumption and needs to be included in LEMIS. Most likely is not included at present simply because of the sheer volume of the shipments and forms that must be handled and transcribed. One simple method that can facilitate greatly managing such large volumes of data is to request the declaration of importation 3-177 forms to be scanned or filed electronically by the exporter. A working example: an exporter in a developing country with a mobile phone can now easily collect and submit data in the field. An open source data kit can be installed in the mobile phone; the kit enables data collection and submissions to a central server. Therefore, the declaration of importation form 3-177 can be filed electronically, or filled out, scanned, and submitted with the mobile phone. Optical character recognition (OCR) software can then be used to recognize/separate the text from the scanned document. Allowing data to be easily accessed, combined, analyzed, and placed into standardized categories. A similar system has been used for healthcare data management in remote locations (Anokwa et al 2009). The USFWS does have an electronic declarations system (eDecs), as an alternative means for filing form 3-177, for the purpose of reducing paper and time in processing. It is unclear however, how many importers and expoerters are using this system and how much of that information is directly transferrable to the LEMIS database.

The LEMIS database has access to a wealth of information. If criteria were developed that allowed for more complete datasets or better transmission of data from the form 3-177 to LEMIS, it can be a very useful tool that can guide conservation policy and action on behalf of ornamental fish.

Conclusions. The declaration of import Form 3-177 that accompanies every shipment of live animals into the U.S., provides their common name, complete scientific name (when known), their quantity (either by number or weight), monetary value, country of origin, and names of exporter and importer. Therefore, LEMIS could be a very useful database for the control of exotic species in the U.S. proper, and at the same time give insight into the management and conservation measures of the species in their native range. Especially of aquatic animals since these are the predominant species imported, and millions are traded every year. The data reported in LEMIS for species in higher Class vertebrates like mammals, birds, reptiles, and amphibians have been used effectively to evaluate impacts of the trade on target species and their populations. Unfortunately, the vast majority of aquatic animals are not identified to species in the LEMIS database, most likely due to the sheer volume of entries. Perhaps in a day and age when we are all using computers, something as simple as requesting the import forms to be scanned or digitally filled out by the exporter could greatly facilitate the access to such valuable information.

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