## A peer-reviewed version of this preprint was published in PeerJ on 26 January 2017.

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Rhyne AL, Tlusty MF, Szczebak JT, Holmberg RJ. 2017. Expanding our understanding of the trade in marine aquarium animals. PeerJ 5:e2949 https://doi.org/10.7717/peerj. 2949

# When one code $=\mathbf{2 , 3 0 0}$ species: Expanding our understanding of the trade in aquatic marine wildlife 

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#### Abstract

The trade of marine ornamental animals for home and public aquaria has grown into a major global industry. Since the 1990s, the aquarium hobby has shifted focus from fish-only systems to miniature reef ecosystems. Millions of marine fishes and invertebrates are removed from coral reefs and associated habitats each year, and the majority of animals are imported into the United States, with the remainder sent to Europe, Japan, and a handful of other countries. This shift in aquarium complexity demands increases in not only the volume but also the diversity of species harvested by collectors. Collectors must now supply the trade with species sought for both aesthetics as well as ecosystem services (e.g., species that contribute to the life support services of aquaria). Despite the recent growth and diversification of the aquarium trade, to date, data collection is not mandatory, and hence comprehensive information on species volume or diversity is wanting. The lack of this information makes it impossible to study trade pathways. Without species-specific volume and diversity data, it is unclear how importing and exporting governments can oversee this industry effectively and how sustainability should be encouraged To expand our knowledge and understanding of this trade, and to be able to effectively communicate this new understanding, we introduce the publically-available Marine Aquarium Biodiversity and Trade Flow online database (https://www.aquariumtradedata.org/). This tool was created as a means to assess the volume and diversity of marine fishes and/or invertebrates imported into the US over four years (2005, 2008, 2009, and 2011) and one month of additional data in 2000. To create this tool, invoices pertaining to shipments of live marine fish and invertebrates were scanned and analyzed for species name, quantity, country of origin, and city of import destination. The results for October 2000 as well as the year between June 2004 and May 2005 have been published (Rhyne et al. 2012,


http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0035808; Balboa 2003). Here we focus on the later three years of data and also produce estimated volume of species imported to create complete calendar years for 2000, 2004, and 2005. The three-year aggregate totals (2008, 2009, 2011) indicate that just under 2,300 fish and 725 invertebrate species were imported into the US, even though each year, just shy of 1,800 fish and 550 invertebrate species were traded. Overall, the total number of live marine animals decreased between 2008 and 2011. In 2008, 2009, and 2011, the total number of individual fish (8.2, 7.3, and 6.9 million) and invertebrates ( $4.2,3.7$, and 3.6 million) assessed by analyzing the invoice data are roughly $60 \%$ of the total volumes recorded through the LEMIS dataset. Using these complete years, we backcalculated the number of individuals imported in 2000, 2004, and 2005. These estimates (9.3, 10.8 , and 11.2 million individual fish per year) were consistent with the known three years of data. These data are also used to demonstrate how the trade of Banggai cardinalfish (Pterapogon kauderni) and clownfish (Amphipiron ocellaris and A. percula) can be better understood. This database can help create more effective management plans for the traded species, and if moved to a real-time format, could help in the detection of illegal trade.

## Introduction

There is no clear picture of the number of species or individuals of marine ornamental fish and invertebrates involved in the aquarium trade, primarily a result of insufficient global tracking of the import and export of these animals (Bruckner 2001; Fujita et al. 2013; Green 2003; Lunn and Moreau 2004; Tissot et al. 2010; Wabnitz et al. 2003). Increasing the sustainability of the marine ornamental animal industry should be considered a primary initiative ("low hanging fruit") for the entire aquarium industry transport chain, including aquarium retailers (Tlusty et al. 2013). Increasing the sustainability of the ornamental transport chain is achieved through a more thorough understanding of the magnitude of the trade (Fujita et al. 2013), which begins by sufficiently assessing the scale of imports into the US (the primary destination for the global trade of ornamental animals) (Rhyne et al. 2012b). Once the annual volume of US imports is realized, other relevant issues that lead to environmental and economic benefits can then be tackled, including animal quality and shipping survival (less fishing effort as fewer fish are need to maintain the trade).

The ornamental fish hobby is extremely large, although the exact magnitude of the trade is unknown. It is estimated that the US imports 190 million freshwater and marine fishes annually (AVMA 2007). The ornamental fish trade faces a multitude of potential threats, including reduced biodiversity from over extraction, habitat destruction in source countries (Francis-Floyd and Klinger 2003; Gopakumar and Ignatius 2006), and negative impacts of species invasions in the US and elsewhere (Chucholl 2013; García-Berthou 2007; Holmberg et al. 2015; Padilla and Williams 2004). Despite these threats, the aquarium trade has unique and massive potential for good (Rhyne et al. 2014), including saving threatened species from the brink of extinction through the development of captive breeding programs (Tlusty 2002) and catalyzing habitat preservation through sustainable supply-side practices, be it aquaculture or wild fisheries. These sustainable practices include stewardship, mechanisms for sustainable livelihoods via poverty alleviation, and the protection of threatened ecosystems that are otherwise unguarded and unregulated (Rhyne et al. 2014). Finally, consumer education of aquarium trade sustainability can promote widespread public appreciation for the world's aquatic ecosystems, with the ultimate goal of ensuring the natural world is left intact for future generations (Tlusty et al. 2013). While a proactive stance can transform a large consumer base into a powerful agent for biodiversity, conservation, and human well being, inaction will likely amplify the deleterious threats currently faced by the trade. Currently, the lack of oversight leading to a poor concept of the trade volume and subsequent regulatory inefficiency has greatly hampered the development of a sustainable industry.

Multiple sources of data have been used to monitor the trade of marine ornamental animals (Woods 2001, Green 2003, Balboa 2003, Wabnitz et al. 2003, Smith et al. 2008). However, not all of these data systems are sufficient for, or were even intended for, monitoring the aquarium trade. For example, compulsory data are maintained under federal mandates for species listed by the Convention on the International Trade in Endangered Species (CITES). However, previous studies found that CITES records were inaccurate, incomplete, or insufficient (Bickford et al. 2011; Blundell and Mascia 2005; Rhyne et al. 2012b). Furthermore, CITES-listed species (namely stony corals, giant clams, and seahorses) account for only a fraction of the total trade in aquatic ornamental animals. Only a handful of studies (e.g. Rhyne et al. 2012b; Smith et al. 2009; Smith et al. 2008) have attempted to quantify the movement of non-CITES-listed
aquarium species from source to market. The Global Marine Aquarium Database (GMAD) is a voluntary data reporting system, developed to provide publicly available data on the marine aquarium trade (Green 2003). Until the dataset presented here, GMAD has been the only source for aquarium trade data recorded at the species level. Unfortunately, this data source only covers a few years of data and omits important export countries (i.e., Haiti). The voluntary nature of the GMAD does not allow for complete coverage of imports or exports from countries and requires users to model trade volumes. Furthermore, in the decade and a half spanning the data and the current time period, the aquarium trade has been transformed by new technologies and husbandry breakthroughs (Rhyne and Tlusty 2014). In addition, by CITES and GMAD, the Law Enforcement Management Information System (LEMIS) database has been used to better understand the aquarium trade. In the US, the United States Fish and Wildlife Service (USFWS) inspects wildlife shipments and maintains species-specific data of shipments per CITES requirements in LEMIS. However, within LEMIS, non-CITES-listed fish and invertebrate species are listed with general codes (i.e., marine aquarium tropical fish, regardless of species, are coded MATF). Recording data in this generalized manner eliminates specific information regarding the diversity and volumes of species traded (Smith et al. 2009), which are of critical importance when assessing how the live animal trade influences ecosystem risks, such as introductions of non-native species and diseases. The need for accurate accounts of aquarium trade flow continually increases, although the current monitoring methods remain static (Bickford et al. 2011). The lack of specific data systems for recording all species exported and imported for the wildlife trade raises two main concerns: (1) because of the lack of trade data, it is unclear how importing and exporting governments can monitor this industry effectively; (2) it is also unclear how sustainability should be encouraged given the paucity of data.

To date, outside of Rhyne et al.'s analysis of 2005 US import data (2012b), the species-specific information provided on trade invoices has not been adequately catalogued or compared to associated shipment declarations. Here we report on the development of the Marine Aquarium Biodiversity and Trade Flow online database (https://www.aquariumtradedata.org/), a public portal to anonymized marine ornamental trade data collected through trade invoices. We describe an additional three years $(2008,2009,2011)$ of fish and invertebrate invoice-based data from US imports that were analyzed for country of origin, city of import, and quantity of species and
individuals associated with each port. We also relate the findings back to annual aquarium trade data from the LEMIS database. Rhyne et al. (2012) described one contiguous year of import data, based on a 12-month period from June of 2004 until May of 2005, and Balboa (2003) described data from October 2000. To address the missing months of data from these years and to increase the scope of the dataset, we modeled data for the missing months of 2000, 2004, and 2005. This work provides continued accounting of the volume, biodiversity, and trade pathways for marine ornamental fish and invertebrate species beyond the information given in voluntary reporting systems (Wabnitz et al. 2003) and LEMIS. This work provides a further demonstration that LEMIS, while well designed for import/export compliance and personnel management of USFWS staffing needs, is not designed to monitor the data-rich marine ornamental aquarium trade. Finally, using this database, we present two case studies (the Banggai cardinalfish, Pterapogon kauderni, and the orange clownfish, Amphiprion percula) that demonstrate the use of these data as tools to better understand the trade in marine species and promote industry sustainability.

## Methods

The goal of this project was to evaluate the number of aquarium species imported into the US, and to create a trade path analysis of the diversity of aquatic animals involved in the trade. The methods used to analyze trade invoices were described by Rhyne et al. (2012b) and are briefly summarized here. We reviewed all shipment declarations and the attached commercial invoices held by USFWS coded as Marine Aquarium Tropical Fish (MATF) for 2008, 2009 and 2011 as indicated in the LEMIS database. While about 22,000 invoices were marked as containing MATF in the LEMIS database, we only recovered about 20,000 shipment declarations and their attached invoices. Invoices were considered a true statement of shipping contents. We were not able to assess the veracity of the information contained on the invoice. Shipment information (date, port of origin, and destination port) was collected from the declaration page, and species and quantity information was tabulated from the associated invoices and then cataloged into a database. Both manual entry and automated optical character recognition (OCR) software (ABBYY FlexiCapture 9.0) customized for wildlife shipments (Fig 1) were utilized to retrieve the above information from these documents. The input method varied with invoice quality and length. Manual entry was utilized when invoices were of poor quality (blurry, speckled,
darkened, fonts less than six point, handwritten, or less than $1 / 2$ page), whereas all others were read using the OCR software. Once all necessary data were captured, species names were verified using World Register of Marine Species (WoRMS Editorial Board 2015), FishBase (Froese and Pauly 2015), and the primary literature (Appeltans et al. 2011; Froese and Pauly 2011). We corrected species information only when species names were misspelled, listed under a junior synonym, or listed by only a common name. A database entry (a fish species from a specific shipment-date combination) was identified as being 'unknown' only when a common name was used to which multiple species could be matched (e.g., colorful damsel or unknown damsel), when exporters marked a species as 'Assorted' (e.g., assorted damsels), or when exporters marked a species under genus only (e.g., Chrysiptera sp.).

In accordance with Rhyne et al. (2012b), this report focused on major geographic trade flows, the frequency of invoice detail to the species level, and how invoice data compared to LEMIS data. Invoice data for both fish and invertebrates were retrieved concurrently. To help organize and visualize the trade data, a publically accessible representation of the trade data was created: the Marine Aquarium Trade Biodiversity and Trade Flow data resource website (https://www.aquariumtradedata.org/). This web-based graphical user interface, powered by the open source JavaScript library D3 (http://d3js.org/), is both data-rich and visually appealing, and allows users to query over 29,000 invoices containing over 2.7 million marine ornamental animal import records.

To expand coverage of the data for months that were not recorded (11 months in 2000, five months in 2004 and seven months in 2005), we used monthly patterns to back-calculate the estimated number of fish and invertebrates for the most voluminous species (those that exceeded 100,000 individuals across the entire database) imported into the US. Fish records from invoice data for 2004 and 2005, as well as fish and invertebrates for 2000, were then used to calculate estimated import numbers of the most voluminous species. These "voluminous species" were comprised of 29 fish and 20 invertebrate species and represented $84.5 \%$ and $83.0 \%$ of the total number of individuals imported for all years in this dataset. The proportional monthly imports of voluminous species were determined from the 2008, 2009, and 2011 data. Assuming that 2000,

2004, and 2005 have a similar monthly proportion, each of these years were adjusted by an estimated total of animals determined for the unknown months

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\left.\left.\left(n_{\{k n o w n ~ 0004 \text { or } 05\}} / \overline{\operatorname{Pr}}_{(m\{080911\})}\right)-n_{\{k n o w n ~} 0004 \text { or } 05\right\}\right)
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(where n is the known number of imports for 1,5 or 7 months), $\operatorname{Pr}$ is the average proportion of known imports from corresponding months from 2008, 2009 and 2011. This estimated number of animals was then allocated across the unknown months proportionately for 2000, 2004 and 2005. We also generated estimates for the source countries and ports of import. A similar method was used to determine the estimated number of fish originating from each country and arriving at specific US ports, except values were created from all imports, not only for the most voluminous. These additional individual animals were added to the Marine Aquarium Trade and Biodiversity Flow Database as "estimated fish" and "estimated invertebrates" to provide a basis for yearly comparison of the total imports.

## Results

The Marine Aquarium Biodiversity and Trade Flow website allows users to generate database queries from dropdown menus. Initial queries can be filtered through large-scale source areas such as ocean basins or countries of origin for a defined time period (Fig. 2). Following user selections, the software compiles detailed information in the form of maps, timeline charts, and other data charts that allow users to access data at a level uncommon in user interfaces for the wildlife or seafood trades. On further analysis, it is possible, using the "species" tab, to query a single taxonomic family, genus, or species for one or more countries and/or ports of entry. The user-friendly dropdown menus are tree-based and progressive. Figure 3 demonstrates successive screens where the user has successively selected the family Pomacentridae, the genus Amphiprion, and the species complex Amphiprion percula and A. ocellaris. The dashboard displays (1) a distribution map depicting the relative geographic abundance using proportionallysized red dots, and (2) two graphs displaying export country- and port of entry-specific volumes for the selected query.

To enhance the utility of the website and promote the dissemination of the data, the user can download charts and graphs of data queries. Users can also share these charts directly to Facebook and Twitter (Fig. 4). Further, to ensure the data within the invoice-based database is an
accurate representation of the trade, users can report possible errors in data or features on the website. Using social media we can ensure that the level of data quality on the site increases over time. If users find species that are likely incorrect in distribution or taxa, we can examine the invoice record, verify its contents, and then update the database if needed. This system also logs how users interact with the database, which provides feedback on the number and types of queries users generated.

General trends - In 2008, a total of $8,299,467$ individual fishes $(97.4 \%$ identified to specieslevel) representing 1,788 species were imported into the US. The total number of fishes imported decreased to $7,102,246$ in 2009 and decreased further to $6,892,960$ in 2011. However, the number of species imported actually increased to 1,798 by 2011 . While no more than 1,800 species were imported in a single year, and 2,278 unique species were imported across the threeyear span (Table 1).

A similar decreasing trend was observed for the trade in invertebrates during this time period, although the invertebrate data were less voluminous and specious compared to the fish data. A total of 4.3 million invertebrates representing 545 species were imported into the US in 2008. The total number of invertebrates imported decreased to about 3.7 million in 2009 and 2011 (Table 2). A total of 724 species were imported over the three-year span, which is greater than in any one year ( 545 species). Compared to fishes, relatively fewer invertebrates were identified to a species-level (72.9\%).

Export Countries - 45 countries in total exported marine fishes to the US during the three years (Table 1), although 41, 37, and 36 countries were noted in 2008, 2009, and 2011, respectively. The Philippines exported $56 \%$ of the total volume ( 12.7 million fishes, Fig. 5). The overall volume of fishes traded decreased by $17 \%$ between 2008 and 2011, which is largely explained by the decreased exports of the Philippines and Indonesia across the three years. Third-ranked Sri Lanka exported consistently across the three years. Exports from fourth-ranked Haiti decreased by nearly $50 \%$ between 2008 and 2011.

The US imported marine invertebrates from a total of 38 countries during the three years (Fig. 6, Table 2), although only $27(2008,2009)$ or $28(2011)$ countries were noted per year. The volume (number of individuals) exported per year decreased 14\% between 2008 and 2011, a rate similar to that of fish. The countries exporting the greatest volume over the three years were the Philippines ( 3.6 million invertebrates) and Haiti ( 3.1 million invertebrates). The number of individual invertebrates exported from the Philippines increased by $24 \%$ between 2008 and 2011. This was likely a response to the decrease in volume from Haiti ( $52 \%$ decline from 2008 to 2011, likely due to earthquake activity in 2010). Third-ranked Indonesia ( 1.8 million invertebrates) exported a consistent volume across the three years. Even though Indonesia was third in volume, it exported the most species (413) during the three years. The Philippines and Sri Lanka were second and third respectively in terms of the number of species exported to the US.

Species - More than half (52\%) of the total fish imported into the US (identified to species, Table 3) were represented by 20 species. There was a great deal of consistency within these top 20 species between the years of this study. The species ranking was identical between 2008 and 2009, and only the $20^{\text {th }}$ ranked fish was different in 2011 (the blueband goby, Valenciennea strigata, replaced the royal gramma, Gramma loreto). The order of the top seven fish species was consistent across the years, and represented nearly $33 \%$ of the total fish imports. The green chromis, Chromis viridis, was the most popular fish species across all three years ( $>10 \%$ of total fish imports) and was exported by 13-16 different countries, depending on the year. This Chromis species was unique in being collected from a large number of countries. The only other fish that was equally sourced from a large number of countries (an average of 15 per year) was the blue tang, Paracanthurus hepatus, (Table 3a, Fig 7), although Indonesia and the Philippines exported the majority of $P$. hepatus. Invertebrates demonstrated a similar but more extreme trend. The top 20 species of invertebrates imported into the US were responsible for approximately $75 \%$ of total imports (identified to species-level, Table 3b). Yet there was more variability in the invertebrate top 20 species list compared to the fish list. Only the top two species (the scarlet hermit crab, Paguristes cadenati, and the scarlet skunk cleaner shrimp, Lysmata amboinensis) were consistently ranked across the three years. Overall, 25 invertebrate species were represented on the three yearly top 20 lists (Table 3b).

Each country tended to export one species (fish / invertebrate) more than the remaining exporting countries. Overall, the single most imported species averaged $37 \%$ (fish) or $63 \%$ (invertebrates) of total species volume exported from that country (Table 4, Table 5). In general, countries that exported greater quantities of marine animals relied less on the contribution of the single most important species to export volume (Fig. 8). Regardless, the proportion of the single most important species is greater than what would be expected at random. At random, each species from a country that exports 10 species would represent $10 \%$ of that country's total exported volume. The countries in which a single species contributes to even $10 \%$ of species volume still export hundreds and even thousands (e.g., Philippines) of total species (Table 4, Table 5).

Comparison to LEMIS data - USFWS has only compiled marine ornamental trade data for non-CITES-listed species from the LEMIS database. LEMIS data is produced by US-based importers from shipment declarations, where importers input shipment data into the required 3-177 declaration form and present the completed shipment declaration with corresponding invoice to USFWS prior to shipment clearance. We have demonstrated elsewhere (Rhyne et al. 2012b) that this method of gathering import data is fraught with errors; first, importers commonly mislabel shipments as containing marine aquarium species when they only contain freshwater fish, nonmarine species, or non-aquarium fish (all increasing the total number of fish reported in the LEMIS database); second, the data do not appear to be updated if shipments are canceled or modified (there is sometimes a significant mismatch between the number of individuals on the declaration and the corresponding values on the invoices); third, importers commonly misrepresent the country of origin and source (wild/captive bred) of species in shipments. As previously discussed (Rhyne et al. 2012), LEMIS is a tool designed for internal use by USFWS, primarily relating to volume of boxes arriving at ports and CITES compliance. Shipments of non-CITES-listed species and/or unregulated species are not held to any data integrity standards, so declaration forms and invoices need only represent the import/export companies and shipment details accurately. We propose that the invoice-based method of data collection presented here can rectify many of the data deficiency issues that currently exist within the marine ornamental trade. Through this work, it was observed that the number of fishes imported into the US was routinely $60-72 \%$ of the import volumes reported by the LEMIS database (Fig. 9). A large
proportion of the declaration form overestimate was a result of importers misclassifying shipments as containing MATF when they only contained freshwater species. Occasionally, entire freshwater shipments were erroneously listed as MATF. A second unknown portion of this error was missing invoices. Not all invoices were recovered from the system. Several hundred records were either missing the invoice or exhibited invoice/declaration mismatch, making the data impossible to verify. Similarly, invoice-based data reported a total of 45 countries exporting MATF, which was only $60 \%$ of the 76 export countries reported by the LEMIS database (Table 6). These extraneous countries represented 5,6 , and $11 \%$ of the total volume of MATF imported into the US according to the LEMIS database during 2008, 2009, and 2011 respectively (Table 6). Third is that the declaration is typically completed day/s before the order is packed, and thus there will be variation between estimated and actual order volume. Finally, there was a lack of adherence to differentiating "wild caught" and "aquacultured" animals (Rhyne et al. 2012a). The case studies presented below use the invoice-based dataset to shed light on this discrepancy.

Estimated Fish- To back-calculate estimated total number of imported fishes (2000, 2004, and 2005) or invertebrates (2000), we first determined the proportion of individuals imported during the time interval (one month for 2000, seven months for 2004, and five months for 2005) based on the three years for which we had a complete 12 -month dataset (2008, 2009, and 2011). For these three years, there was variation between months, but the inter-month variation was less than that of the between-month variation (Fig 10, upper line graph) suggesting that monthly import volumes were proportionately consistent. This proportion was then used to calculate the number of individuals that should have been imported within that calendar year. As an example, in October of 2000 , 810,705 fish and 124,308 invertebrates were imported. During the years 2008, 2009 and 2011, October represented on average $8.7 \%$ and $8.6 \%$ of the yearly fish and invertebrate imports into the US. Thus, it can be estimated that $9,327,754$ fish and $1,442,859$ invertebrates were imported into the US during calendar year 2000. Following this example, 10,766,706 and 11,229,443 fish were imported into the US in 2004 and 2005 respectively (Fig. 10 , lower bar graphs).

## Confusion between "wild" and "aquaculture" production

- The Banggai cardinalfish, Pterapogon kauderni, is a popular marine fish in the aquarium trade (ranked the $10^{\text {th }}, 11^{\text {th }}$, and $8^{\text {th }}$ most imported fish into the US during 2008, 2009, and 2011, Table 5). It was one of the original marine ornamental aquaculture success stories (Tlusty 2002), which was supposed to reduce the need for wild fish. However, all P. kauderni imported during this three-year span were reported as wild fish. Yet import data from Thailand (outside the natural geographic range of $P$. kauderni) suggest this is not the case (Fig. 11).

To determine if the volume of aquacultured $P$. kauderni imported into the US has increased in recent years, we reviewed invoice data from Los Angeles-based importer Quality Marine for two additional recent years of imports. At our request, all shipments of MATF from Thailand to Quality Marine (representing aquacultured fish over the period of March 2012 to July 2014) were supplied and reviewed. The export volume followed the typical aquarium trade pattern of lower volumes exported in the summer months (June-August) and in December (Fig. 12). Interestingly in 2013, the only year with a 12-month data set starting in January and ending in December, the volume of $P$. kauderni ( $\sim 120,000$ individuals/year) was approximately $75 \%$ of the average total import volume of this species recorded per year for 2008, 2009 or 2011. Given the life history of the species (small brood sizes), the commercial producer of these fish has made significant investments in the culture of the species. The number of broodstock and space dedicated to this species' production is likely large and highly commercialized.

Further, these fish were listed on import declarations ranging in size from 1-1.5 inches. A 1-inch fish is smaller than the average wild-caught fish (personal observation), and instead represents the typical size of an aquacultured shipment. Shipment manifests also list the number of Dead On Arrival (DOA) from previous shipments and are extremely low. A DOA rate of $<0.5 \%$ is rare for wild caught fish and, again, represents DOA values consistent with a shipment of aquacultured fish.

The shipment manifests have common errors that can be observed on the 3-177 USFWS declarations. On several occasions the importer incorrectly indicated that shipments were wild animals ("W"). After examining the invoices and associated documents, (i.e., health certificates,
and certification of aquaculture) we determined that all shipments of $P$. kauderni from Thailand to Quality Marine during the period examined were captive-bred ("C"), and the importer mistakenly selected "W" in the Source box (Box 18B, 3-177 form). Given the current proposed Endangered Species Act (ESA) listing for P. kauderni, accurate and timely trade data are essential to the management of this species.

- The orange clownfish Similar to the Banggai cardinalfish, clownfishes exported from Southeast Asia are commonly labeled as wild while many are in fact captive-bred. This inaccuracy is compounded by the misidentification of clownfishes on export invoices, especially between species with similar morphological appearances (e.g., Amphiprion ocellaris and $A$. percula). The Marine Aquarium Biodiversity and Trade Flow online database not only sheds light on source-errors (as seen in the Banggai cardinalfish case study) but also on potential species misidentifications.

Recently, the orange clownfish (Amphiprion percula) was proposed to be listed as threatened or endangered under the ESA, mainly due to its small geographic distribution and obligate relationship with giant sea anemones prone to bleaching events in the Coral Triangle. However, the proposition was also based on the assumption that out of the 400,000 individuals from the percula/ocellaris complex imported into the US in 2005 (Rhyne et al. 2012b), (a) all specimens were wild caught, and (b) A. percula and A. ocellaris were equally traded, with 200,000 individuals of each species being harvested. Utilization of The Marine Aquarium Biodiversity and Trade Flow online database removes the need for these assumptions. While in 2008, 2009 and 2011 831,398 individual clownfishes of the percula/ocellaris complex were imported into the US (Fig 13), only 163,547 individuals were A. percula ( $24.5 \%$ ). These data suggest that the original assumptions of trade volume used to petition for ESA listing were strongly overestimated.

Further, the Countries of Origin feature of the database revealed that of the ten export countries of $A$. percula, seven countries ( $41 \%$ of all individuals) fall outside the natural geographic range of this species (Fautin and Allen 1997; Froese and Pauly 2015) (Table 7). Furthermore, five of the seven non-native locations are established producers of aquacultured $A$. percula. Based on
this, $7 \%$ of the non-native individuals are likely aquacultured specimens. The remaining two non-native countries (Singapore and the Philippines) account for the residual $93 \%$ of the nonnative individuals and are likely misidentifications. Interestingly, both Singapore and the Philippines fall within the natural geographic range of $A$. ocellaris, which is commonly confused with $A$. percula. While these individuals may be misidentified, it is also important to note that Singapore is a known trans-shipping country, and could have imported their specimens from another country, making the true origin of these specimens unattainable. Furthermore, Singapore is a leader in aquaculture production of ornamental fish, and thus many clownfish could be of aquaculture origin.

In summary, $41 \%$ of $A$. percula imported into the US over the three-year span (a) were misidentified as to species or export country, (b) were misidentified as to source (wild versus aquaculture production), or (c) represent a recently expanded home range not yet noted within the scientific literature. Regardless of the reason, the contribution of $A$. percula imports to the percula/ocellaris complex is not only substantially less than assumed, it is likely even lower based on the high percent of geographic anomalies reported here. Ultimately, this case study confirms the need for more accurate and detailed trade data, such as that provided via The Marine Aquarium Biodiversity and Trade Flow Database, for any potential ESA listing activity.

## Discussion

The deficiency of meaningful data relating to the global marine aquarium trade hinders progress toward its effective management (Foster et al. 2014; Fujita et al. 2013; Rhyne et al. 2012b). Access to meaningful data will allow for immediate feedback regarding trade activity, which will increase public engagement in trade sustainability and guide responsible trade management. Currently, there is no system for tracking species-level import/export data for the marine aquarium trade. This is exacerbated by the lack of standard recordkeeping between different countries (Green 2003). Coupled to this is the fact that present data systems are either overly general, based on declaration forms (LEMIS), or specific to the trade of rare and threatened species (CITES, Foster et al. 2014). The Global Marine Aquarium Database (Green 2003) has attempted to make sense of some of these discrepancies, but can be difficult to use based on its data structures and relational databases. These complications and data limitations make
misinterpretation possible, as has occurred where trade volumes have been erroneously reported as under- or overestimates. Without changes to the current data system used to assess trade pathways, data inaccuracies and misinterpretations could have potentially costly consequences (e.g., use of such data to affect ESA listing status) of social, economic, and ecological proportions. These costs will only be exacerbated as the aquarium industry continues to grow.

For these reasons, we created a publically accessible, anonymized web portal for invoice-based trade data of ornamental marine animal imports into the US. This portal was linked to an invoice-based assessment of the import trade to the US over four years. Capturing invoice-based data can waylay many of the deficiencies of the extant databases. These data should prove useful to both conservation organizations and government agencies by overcoming the aquarium trade data deficiency that currently exists. The benefit of the more detailed invoice data we focused on here is that it allowed for a truer estimate of aquatic wildlife trade. There have been recent ESA petitions for both the Banggai cardinalfish (NOAA 2014) and the orange clownfish, with some of the assumptions in the ESA petition being based on incorrect trade data. In each of these cases, we demonstrated that increased knowledge of production areas and modalities do not support the base assumptions of the ESA petition.

The assumptions of the ESA listing were erroneous in part because of inaccurate reporting of the source (wild, captive-bred, farmed) of shipped animals. For example, exporters will often mark farmed corals as wild corals, even when, ironically, they have proper CITES permits for the export of farmed corals (Rhyne et al. 2014). Many exporters do not have the proper paperwork or government support needed to accurately mark corals as captive-bred or farmed on CITES documents, often because of the onerous process required to certify that corals are of a farmed origin. Consequently, importers must report shipments as wild, regardless of true source. While improved analysis of invoices will help limit some of this misreporting, it will not be totally unabated until a full fishery/farm to retail traceability program is initiated.

Development of the Marine Aquarium Biodiversity and Trade Flow online database (https://www.aquariumtradedata.org/) is a first step toward improving the data, which will allow for better management and oversight of the trade in marine aquatic animals. However, the
invoice analysis was necessarily developed from a post-import standpoint. The shipments were accepted at import, the paperwork processed, and the invoices stored, only to be recovered from storage and delivered for analysis within this program. However, the OCR data processing has the potential to be utilized in real time. This would allow for shipment diagnostics to be conducted, which could potentially identify misidentified or even illegal shipments. Such an import risk-based screen tool exists under the FDA's Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting program (http://www.fda.gov/ForIndustry/ ImportProgram/ucm172743.htm), and we propose that a similar model would be effective for the wildlife trade. Ultimately, such an analysis would provide support to port agents to help them more effectively monitor and police the aquatic trade.

While it was not implicitly necessary to estimate the number of individuals imported for years of incomplete data (2000, 2004 and 2005), we felt it important given the graphical nature of the presentation of the Marine Aquarium Biodiversity and Trade Flow online database. A common query without the estimated number of fish would result in a figure where the total number of indivudals in 2000 was $8 \%$ while 2004 and 2005 data would be approximately half that of 2008, 2009 and 2011. Therefore, the estimated fish numbers were created to create a more cohesive visual presentation of data, and to avoid the incorrect analysis that numbers of US imports of marine ornamental fish and invertebrates are increasing. The trade has decreased from its peak in 2005 following the economic recession and a shift to smaller tank sizes (Rhyne and Tlusty 2012; Rhyne et al. 2012a).

In summary, wildlife data tracking systems require improvement (Chan et al. 2015; Foster et al. 2014); we are beyond the age of tracking animal shipment volume solely for the purpose of assessing port agent staffing needs. The systems currently in place have proven ineffective in producing meaningful data that can move the aquarium trade toward sustainability and conservation (Vincent et al. 2014). The invoice-based dataset presented here, while set up as a post-import assessment tool, has the strong potential to be easily modified into a real-time aquarium trade data monitoring system. The ability to monitor (Wallace et al. 2014) aquarium trade pathways real-time is the crucial next step to effectively manage the trade of marine ornamental wildlife for the home aquairum industry.

## Acknowledgements.

The National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program and the National Fish and Wildlife Foundation provided funding for this work. We thank the United States Fish and Wildlife Service (USWFS) for providing access to LEMIS data and associated invoices. The authors are grateful to the dozens of Roger Williams University undergraduates that spent thousands of hours cataloging import data. Thank you to Karen Talbot (www.karentalbotart.com) for the use of her beautiful hand-drawn images.

## Literature Cited

Appeltans, W., Bouchet, P., Boxshall, G., Fauchald, K., Gordon, D., Hoeksema, B., Poore, G., van Soest, R., Stöhr, S., Walter, T., and Costello, M. 2011. World Register of Marine Species, Accessed at http://www.marinespecies.org on 2011-06-23.

AVMA. 2007. U.S. Pet Ownership \& Demographics Sourcebook (2007 edition). American Veterinary Medical Association, Schaumburg, IL.

Bickford, D., Phelps, J., Webb, E.L., Nijman, V., and Sodhi, N.S. 2011. Boosting CITES Through Research--Response. Science 331: 857-858.

Blundell, A., and Mascia, M. 2005. Discrepancies in Reported Levels of International Wildlife Trade. Conservation Biology 19: 2020-2025.

Bruckner, A.W. 2001. Tracking the Trade in Ornamental Coral Reef Organisms: The Importance of CITES and its Limitations. Aquarium Sciences and Conservation 3(1): 79-94.
Chan, H.-K., Zhang, H., Yang, F., and Fischer, G. 2015. Improve customs systems to monitor global wildlife trade. Science 348(6232): 291-292.

Chucholl, C. 2013. Invaders for sale: trade and determinants of introduction of ornamental freshwater crayfish. Biological Invasions 15(1): 125-141.

Fautin, D.G., and Allen, G.R. 1997. Anemone fishes and their host sea anemones: a guide for aquarists and divers. Sea Challengers.
Foster, S., Wiswedel, S., and Vincent, A. 2014. Opportunities and challenges for analysis of wildlife trade using CITES data - seahorses as a case study. Aquatic Conservation: Marine and Freshwater Ecosystems: n/a-n/a.

Francis-Floyd, R., and Klinger, R. 2003. Disease diagnosis in ornamental marine fish: A retrospective analysis of 129 cases. Marine Ornamental Species: Collection Culture and Conservation: 93-100.

Froese, R., and Pauly, D. 2011. FishBase. World Wide Web electronic publication, www.fishbase.org.
Froese, R., and Pauly, D. 2015. FishBase. World Wide Web electronic publication, www.fishbase.org.
Fujita, R., Thornhill, D.J., Karr, K., Cooper, C.H., and Dee, L.E. 2013. Assessing and managing data-limited ornamental fisheries in coral reefs. Fish and Fisheries: n/a-n/a.

García-Berthou, E. 2007. The characteristics of invasive fishes: what has been learned so far? Journal of Fish Biology 71(sd): 33-55.
Gopakumar, G., and Ignatius, B. 2006. A critique towards the development of a marine ornamental industry in India. Sustain Fish. Proceedings of the International Symposium on 'Improved Sustainability of Fish Production Systems and Appropriate Technologies for Utilization' held during 16-18 March, 2005, Cochi, India: 606-614.
Green, E. 2003. International Trade in Marine Aquarium Species: Using the Global Marine Aquarium Database. In Marine Ornamental Species: Collection, Culture \& Conservation. Edited by J.C. Cato and C. Brown. Blackwell Publishing Company, Ames, Iowa, USA. pp. 29-48. Holmberg, R.J., Tlusty, M.F., Futoma, E., Kaufman, L., Morris, J.A., and Rhyne, A.L. 2015. The 800-Pound Grouper in the Room: Asymptotic Body Size and Invasiveness of Marine Aquarium Fishes. Marine Policy 53: 7-12.
Lunn, K., and Moreau, M. 2004. Unmonitored trade in marine ornamental fishes: the case of Indonesia's Banggai cardinalfish (Pterapogon kauderni). Coral Reefs 23: 344-351.
NOAA. 2014. Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Eastern Taiwan Strait Indo-Pacific Humpback Dolphin, Dusky Sea Snake, Banggai Cardinalfish, Harrisson's Dogfish, and Three Corals Under the Endangered Species Act. Federal Register 79 FR 74953: 32pgs.
Padilla, D.K., and Williams, S.L. 2004. Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. Frontiers in Ecology and the Environment 2(3): 131-138.

Rhyne, A.L., and Tlusty, M.F. 2012. Trends in the marine aquarium trade: the influence of global economics and technology. AACL Bioflux 5: 99-102.

Rhyne, A.L., Tlusty, M.F., and Kaufman, L. 2012a. Long-term Trends of Coral Imports into the United States Indicate Future Opportunities for Ecosystem and Societal Benefits. Conservation Letters DOI: 10.1111/j.1755-263X.2012.00265.x.
Rhyne, A.L., Tlusty, M.F., and Kaufman, L. 2014. Is sustainable exploitation of coral reefs possible? A view from the standpoint of the marine aquarium trade. Current Opinion in Environmental Sustainability 7: 101-107.
Rhyne, A.L., Tlusty, M.F., Schofield, P.J., Kaufman, L., Morris, J.A., Jr., and Bruckner, A.W. 2012b. Revealing the Appetite of the Marine Aquarium Fish Trade: The Volume and Biodiversity of Fish Imported into the United States. PloS one 7(5).
Smith, K.F., Behrens, M., Schloegel, L.M., Marano, N., Burgiel, S., and Daszak, P. 2009. Reducing the risks of the wildlife trade. Science 324: 594-595.
Smith, K.F., Behrens, M.D., Max, L.M., and Daszak, P. 2008. U.S. drowning in unidentified fishes: scope, implications, and regulation of live fish import. Cons Let 1: 103-109.
Tissot, B.N., Best, B.A., Borneman, E.H., Bruckner, A.W., Cooper, C.H., D’Agnes, H., Fitzgerald, T.P., Leland, A., Lieberman, S., Mathews Amos, A., Sumaila, R., Telecky, T.M., McGilvray, F., Plankis, B.J., Rhyne, A.L., Roberts, G., G., Starkhouse, B., and Stevenson, T., C. 2010. How U.S. ocean policy and market power can reform the coral reef wildlife trade. Marine Policy 34: 1385-1388.

Tlusty, M. 2002. The benefits and risks of aquacultural production for the aquarium trade. Aquaculture 205(3-4): 203-219.
Tlusty, M.F., Rhyne, A.L., Kaufman, L., Hutchins, M., Reid, G.M., Andrews, C., Boyle, P., Hemdal, J., McGilvray, F., and Dowd, S. 2013. Opportunities for Public Aquariums to Increase the Sustainability of the Aquatic Animal Trade. Zoo Biology 32: 1-12.
Vincent, A.C., Sadovy de Mitcheson, Y.J., Fowler, S.L., and Lieberman, S. 2014. The role of CITES in the conservation of marine fishes subject to international trade. Fish and Fisheries 15(4): 563-592.
Wabnitz, C., Taylor, M., Green, E., and Razak, T. 2003. From Ocean to Aquarium. UNEPWCMC, Cambridge, UK.

Wallace, R.D., Bargeron, C.T., Ziska, L., and Dukes, J. 2014. Identifying invasive species in real time: early detection and distribution mapping system (EDDMapS) and other mapping tools. Invasive Species and Global Climate Change 4: 219.
Ward, T.J., and Phillips, B.F. 2008. Seafood Ecolabelling: Principles and Practice. WileyBlackwell, Oxford, UK.
WoRMS Editorial Board. 2015. World Register of Marine Species. . Accessed 2015-06-10, Available from http://www.marinespecies.org at VLIZ.

Table 1. Countries that ship fish into the United States over 3 years (2008, 2009, and 2011). Data include the number of species identified correctly, the number of individuals imported (Quantity, total \#), the \% individuals known identified to the species level, and the number of species that over 1,000 individuals are caught per time period.

|  | 2008 |  |  |  | 2009 |  |  |  | 2011 |  |  |  | 2008-2011 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Export Country | Species (\# known) | Quantity (total \#) | Quantity (\% known) | $\begin{gathered} \hline \text { Species } \\ >1,000 \end{gathered}$ | Species (\# known) | Quantity (total \#) | Quantity (\% known) | $\begin{gathered} \hline \text { Species } \\ >1,000 \end{gathered}$ | Species (\# known) | Quantity [total \#) | Quantity (\% known) | $\begin{gathered} \hline \text { Species } \\ >1,000 \end{gathered}$ | Species (\# known) | Quantity [total \#] | Quantity [\% known) | $\begin{gathered} \hline \text { Species } \\ >1,000 \end{gathered}$ |
| Australia | 115 | 12.877 | 100.0 | 3 | 162 | 8.773 | 100.0 | 2 | 199 | 9.573 | 99.6 | 1 | 298 | 31,224 | 99.9 | 6 |
| Belize | 49 | 9,472 | 99.9 | 4 | 45 | 8.846 | 99.4 | 3 | 39 | 14.976 | 99.6 | 4 | 63 | 33,351 | 99.6 | 6 |
| Brazil | 71 | 8.742 | 99.4 | 3 | 61 | 3,349 | 98.5 | 0 | 45 | 2,005 | 99.5 | 0 | 87 | 14,147 | 99.2 | 2 |
| Canada | 2 | 52 | 100.0 | 0 | 2 | 3 | 100.0 | 0 | 1 | 26 | 42.3 | 0 | 5 | 81 | 81.5 | 0 |
| Cook Islands | 23 | 4.763 | 100.0 | 2 | 27 | 3,317 | 100.0 | 2 |  |  |  |  | 34 | 8,080 | 100.0 | 2 |
| Costa Rica | 22 | 7.903 | 100.0 | 2 | 46 | 3.538 | 100.0 | 0 | 28 | 6,139 | 88.1 | 2 | 53 | 17,580 | 95.8 | 4 |
| Curaçao | 15 | 529 | 100.0 | 0 | 26 | 1,383 | 100.0 | 0 | 34 | 3,367 | 99.7 | 1 | 47 | 5.279 | 99.8 | 1 |
| Dominican Republic | 26 | 22,121 | - 86.3 | 3 | 19 | 28,944 | 77.2 | 4 | 48 | 34,272 | 96.7 | 8 | 52 | 93,872 | 86.5 | 8 |
| Egypt |  |  |  |  |  |  |  |  | 20 | 953 | 92.1 | 0 | 20 | 953 | 92.1 | 0 |
| Eritrea | 52 | 9,506 | 99.6 | 2 | 44 | 3,986 | 99.3 | 0 |  |  |  |  | 62 | 13.519 | 99.5 | 2 |
| Fed States of Micronesia |  | ค |  |  |  |  |  |  | 131 | 5,550 | 97.4 | 0 | 131 | 5,550 | 97.4 | 0 |
| Fiii | 187 | 115,520 | ) 98.9 | 28 | 228 | 88,289 | 97.8 | 19 | 311 | 156,680 | 97.6 | 25 | 363 | 362,444 | 98.1 | 44 |
| French Polynesia [Tahit | 106 | 42,846 | - 99.9 | 6 | 101 | 30,187 | 99.5 | 3 | 73 | 29,011 | 99.0 | 3 | 144 | 102,182 | 99.5 | 7 |
| Ghana | 19 | 509 | 99.8 | 0 | 19 | 686 | 96.1 | 0 | 22 | 708 | 95.5 | 0 | 33 | 1.931 | 96.8 | 0 |
| Guatemala | 3 | 1.055 | 100.0 | 0 | 3 | 343 | 100.0 | 0 |  |  |  |  | 3 | 1,398 | 100.0 | 0 |
| Haiti | 99 | 240,552 | ) 97.7 | 23 | 114 | 215,909 | 97.6 | 23 | 89 | 126,799 | 99.0 | 19 | 133 | 588,516 | 97.9 | 30 |
| Hong Kong | 9 | 262 | - 99.2 | 0 | 4 | 5 | 100.0 | 0 | 1 | 16.510 | 0.3 | 0 | 14 | 16.777 | 1.9 | 0 |
| Indonesia | 973 | 2,402,733 | ) 97.2 | 214 | 1.009 | 1,998,195 | 96.9 | 186 | 992 | 1,867,946 | 97.3 | 181 | 1.284 | 6,331,781 | 97.2 | 234 |
| Israel |  |  |  |  | 7 | 666 | 100.0 | 0 | 10 | 21.985 | 100.0 | 2 | 10. | 22,651 | 100.0 | 0 |
| Japan | 44 | 1,133 | 100.0 | 0 | 92 | 1,137 | 100.0 | 0 | 62 | 569 | 92.4 | 0 | 132 | 2.839 | 98.5 | 0 |
| Kenya | 173 | 144,211 | 97.7 | 27 | 210 | 139,129 | 97.8 | 24 | 186 | 101,910 | 99.0 | 21 | 249 | 388,376 | 98.1 | 39 |
| Kiribati | 67 | 122,971 | 99.1 | 6 | 52 | 78.812 | 98.2 | 7 | 72 | 105,679 | 97.6 | 6 | 103 | 308,889 | 98.4 | 8 |
| Malaysia | 11 | 622 | 99.8 | 0 |  |  |  |  | 1 | 13 | 100.0 | 0 | 12 | 635 | 99.8 | 0 |
| Mauritius | 63 | 823 | 93.4 | 0 |  |  |  |  | 41 | 680 | 98.2 | 0 | 81 | 1,503 | 95.6 | 0 |
| Mexico | 90 | 5.174 | 99.4 | 1 | 40 | 12,688 | 96.2 | 2 | 62 | 15,135 | 98.6 | 3 | 118 | 33,504 | 97.8 | 5 |
| Netherlands Antilles | 9 | 319 | 100.0 | 0 |  |  |  |  |  |  |  |  | 9 | 319 | 100.0 | 0 |
| New Caledonia | 2 | 84 | 100.0 | 0 | 2 | 75 | 100.0 | 0 | 17 | 387 | 99.7 | 0 | 17 | 546 | 99.8 | 0 |
| Nicaragua | 72 | 8,986 | 98.0 | 2 |  |  |  |  | 31 | 1.847 | 93.2 | 0 | 83 | 10.833 | 97.2 | 1 |
| Papua New Guinea | 132 | 6,816 | 99.8 | 2 | 111 | 8.313 | 98.6 | 2 |  |  |  |  | 176 | 15,243 | 99.1 | 2 |
| Philippines | 980 | 4,694,961 | 97.5 | 255 | 1,053 | 4,024,693 | 97.3 | 248 | 1.016 | 3,901,058 | 97.3 | 258 | 1,320 | 12.732.212 | 97.4 | 315 |
| Rep of Maldives | 141 | 24,574 | 96.4 | 5 | 109 | 22,093 | 98.9 | 4 | 67 | 34,360 | 100.0 | 11 | 174 | 81.275 | 98.6 | 19 |
| Rep of the Marshall Ist | 96 | 37,972 | 94.0 | 6 | 138 | 115,686 | 75.1 | 9 | 139 | 142,068 | 78.7 | 13 | 227 | 334,174 | 78.8 | 19 |
| Saudi Arabia | 16 | 326 | 100.0 | 0 | 4 | 19 | 100.0 | 0 |  |  |  |  | 20 | 345 | 100.0 | 0 |
| Singapore | 36 | 2,606 | 100.0 | 1 | 14 | 2,520 | 99.8 | 1 | 42 | 13.949 | 99.5 | 4 | 71 | 19,081 | 99.6 | 3 |
| Solomon Islands | 134 | 47,262 | 96.5 | 8 | 133 | 34.773 | 94.9 | 6 | 138 | 41.673 | 92.5 | 10 | 180 | 125,588 | 94.7 | 15 |
| Sri Lanka | 419 | 202,632 | 98.0 | 30 | 468 | 217,116 | 97.1 | 34 | 461 | 212,407 | 96.7 | 28 | 633 | 638,606 | 97.2 | 57 |
| Taiwan | 33 | 1,511 | 98.1 | 0 | 29 | 897 | 85.3 | 0 | 26 | 2,444 | 100.0 | 1 | 63 | 5,007 | 96.3 | 0 |
| Thailand | 10 | 39,887 | 100.0 | 3 | 3 | 8,310 | 100.0 | 1 |  |  |  |  | 10 | 48,197 | 100.0 | 0 |
| The Bahamas | 85 | 951 | 100.0 | 0 | 45 | 432 | 99.8 | 0 | 8 | 297 | 100.0 | 0 | 98 | 1,681 | 99.9 | 0 |
| Tonga | 207 | 27,857 | 89.5 | 6 | 92 | 8.047 | 92.3 | 2 | 82 | 2,676 | 91.0 | 0 | 227 | 39,253 | 90.2 | 8 |
| United Arab Emirates |  |  |  |  |  |  |  |  | 7 | 77 | 85.7 | 0 | 7 | 77 | 85.7 | 0 |
| United Kingdom | 32 | 3.710 | 98.6 | 1 |  |  |  |  |  |  |  |  | 32 | 3.710 | 98.6 | 0 |
| Vanuatu | 190 | 19,704 | 97.2 | 3 | 123 | 12,671 | 96.8 | 1 | 183 | 14.405 | 94.1 | 0 | 240 | 47,195 | 96.2 | 11 |
| Vietnam | 146 | 14,593 | 99.8 | 1 | 112 | 6,545 | 99.1 | 1 | 102 | 4,826 | 99.5 | 0 | 183 | 26,022 | 99.6 | 6 |
| Yemen | 10 | 10,340 | 100.0 | 3 | 14 | 11.871 | 100.0 | 3 |  |  |  |  | 16 | 22,211 | 100.0 | 3 |
| Total | 1.788 | 8,299,467 | 97.4 | 443 | 1.780 | 7,102,246 | 96.7 | 411 | 1.798 | 6,892,960 | 96.7 | 413 | 2,278 | 22,538,637 | 97.0 | 518 |

Table 2. Countries that ship invertebrates into the United States over 3 years (2008, 2009, and 2011). Data include the number of species identified correctly, the number of individuals imported (Quantity, total \#), the \% individuals known identified to the species level, and the number of species that over 1,000 individuals are caught per time period.

|  | 2008 |  |  |  | 2009 |  |  |  | 2011 |  |  |  | 2008-2011 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Species (\# known) | Quantity (total \#) | Quantity (\% known) | $\begin{gathered} \hline \text { Species } \\ >1,000 \end{gathered}$ | Species (\# known) | Quantity [total \#] | Quantity (\% known) | $\begin{gathered} \text { Species } \\ >1,000 \end{gathered}$ | Species (\# known) | Quantity (total \#) | Quantity (\% known) | Species $>1,000$ | Species (\# known) | Quantity (total \#) | Quantity (\% known) | $\begin{gathered} \text { Species }> \\ 1,000 \end{gathered}$ |
| Australia | 3 | 231 | 37.2 | 0 | 16 | 1,881 | 99.8 | 0 | 34 | 1,020 | 90.6 | 0 | 43 | 3,132 | 92.2 | 1 |
| Belize | 8 | 49,515 | 56.1 | 2 | 7 | 83,922 | 57.3 | 3 | 12 | 292,176 | 58.2 | 6 | 17 | 425,613 | 57.8 | 7 |
| Brazil |  |  |  |  |  | 1 | 0.0 |  |  |  |  |  |  | 1 | 0.0 |  |
| Canada | 1 | 2 | 100.0 | 0 |  |  |  |  |  | 28 | 0.0 |  | 1 | 30 | 6.7 | 0 |
| China | 3 | 1,260 | 100.0 | 0 |  |  |  |  |  |  |  |  | 3 | 1,260 | 100.0 | 0 |
| Costa Rica |  |  |  |  | 3 | 64 | 100.0 | 0 |  |  |  |  | 3 | 64 | 100.0 | 0 |
| Curaçao |  |  |  |  | 1 | 15 | 100.0 | 0 | 4 | 911 | 89.1 | 0 | 5 | 926 | 89.3 | 0 |
| Dominican Republic | 6 | 93,781 | 99.9 | 2 | 5 | 133,056 | 100.0 | 2 | 18 | 107,103 | 96.3 | 4 | 19 | 333,940 | 98.8 | 4 |
| Federated States of Micronesia |  |  |  |  |  |  |  |  |  | 1 | 0.0 |  |  | 1 | 0.0 |  |
| Fiii | 6 | -52,228 | 15.4 | 2 | 9 | 25,502 | 20.5 | 1 | 23 | 28,462 | 22.4 | 3 | 29 | 106,192 | 18.5 | 4 |
| French Polynesia (Tahiti) |  | 766 | 0.0 |  | 3 | 48 | 47.9 | 0 |  |  |  |  | 3 | 814 | 2.8 | 0 |
| Ghana | 3 | () 2,395 | 12.2 | 0 | 3 | 135 | 100.0 | 0 | 3 | 768 | 53.5 | 0 | 5 | 3,298 | 25.4 | 0 |
| Guatemala |  | - 3,000 | 0.0 |  |  |  |  |  |  |  |  |  |  | 3,000 | 0.0 |  |
| Haiti |  | 1.409841 | 92.5 | 24 | 63 | 1,011,683 | 93.3 | 24 | 47 | 676,134 | 94.4 | 26 | 79 | 3,097,658 | 93.2 | 34 |
| Hong Kong | 1 | 1,520 | 100.0 | 1 |  |  |  |  | 1 | 23.255 | 100.0 | 1 | 1 | 24,775 | 100.0 | 1 |
| Indonesia |  | 709,736 | 61.2 | 57 | 317 | 610,264 | 64.9 | 51 | 301 | 575,657 | 68.6 | 48 | 413 | 1,895,657 | 64.6 | 90 |
| Japan |  | - 425 | 76.5 | 0 | 17 | 556 | 64.0 | 0 | 12 | 168 | 91.1 | 0 | 25 | 1,149 | 72.6 | 0 |
| Kenya |  | ( 13,955 | 57.0 | 2 | 17 | 44,426 | 26.1 | 2 | 22 | 14,750 | 53.7 | 1 | 30 | 73,131 | 37.6 | 6 |
| Kiribati |  | ) 6 | 0.0 |  |  | 18 | 0.0 |  | 1 | 80 | 15.0 | 0 | 1 | 104 | 11.5 | 0 |
| Mauritius |  | 198 | 100.0 | 0 |  |  |  |  |  |  |  |  | 1 | 198 | 100.0 | 0 |
| Mexico | 24 | 1,429 | 99.4 | 1 | 8 | 4,035 | 97.6 | 2 | 17 | 17,678 | 53.3 | 2 | 38 | 23,142 | 63.9 | 5 |
| New Caledonia |  |  |  |  |  |  |  |  |  | 4 | 0.0 |  |  | 4 | 0.0 |  |
| Nicaragua | 30. | 58.918 | 83.8 | 8 |  |  |  |  | 19 | 31.052 | 74.5 | 3 | 41 | 89,970 | 80.6 | 11 |
| Papua New Guinea | 23 | 2,323 | 90.5 | 0 | 21 | 6,336 | 83.9 | 2 |  |  |  |  | 34 | 8,659 | 85.6 | 3 |
| Philippines | 259 | 1,111,002 | 71.5 | 65 | 294 | 1,154,255 | 65.6 | 67 | 284 | 1,380,014 | 68.2 | 75 | 395 | 3,645,271 | 68.4 | 118 |
| Republic of Maldives | 3 | 95 | 21.1 | 0 | 2 | 686 | 2.6 | 0 |  | 890 | 0.0 |  | 4 | 1,671 | 2.3 | 0 |
| Republic of the Marshall Islands | 3 | 47,362 | 100.0 | 2 | 7 | 200,088 | 42.1 | 5 | 24 | 39,588 | 68.8 | 3 | 29 | 287,038 | 55.4 | 6 |
| Saudi Arabia |  |  |  |  |  | 5 | 0.0 |  |  |  |  |  |  | 5 | 0.0 |  |
| Singapore | 15 | 2,654 | 45.9 | 0 | 11 | 2,063 | 64.7 | 0 | 11 | 7.017 | 56.7 | 1 | 21 | 11.734 | 55.7 | 2 |
| Solomon Islands | 17 | 12,521 | 51.4 | 2 | 10 | 4.084 | 67.4 | 1 | 8 | 16.753 | 43.7 | 2 | 21 | 33,358 | 49.5 | 3 |
| Sri Lanka | 63 | 251,373 | 90.2 | 11 | 60 | 309,053 | 91.9 | 9 | 54 | 261,004 | 88.1 | 11 | 87 | 821,430 | 90.2 | 17 |
| Thailand | 1 | 250 | 100.0 | 0 |  |  |  |  |  |  |  |  | 1 | 250 | 100.0 | 0 |
| The Bahamas | 9 | 92 | 97.8 | 0 | 6 | 28 | 78.6 | 0 |  |  |  |  | 13 | 120 | 93.3 | 0 |
| Tonga | 18 | 135,089 | 65.6 | 3 | 8 | 31.214 | 61.0 | 2 | 8 | 81.918 | 52.6 | 1 | 23 | 248,221 | 60.7 | 3 |
| United Arab Emirates |  |  |  |  |  |  |  |  |  | 2 | 0.0 |  |  | 2 | 0.0 |  |
| United Kingdom |  |  |  |  |  |  |  |  | 2 | 4 | 100.0 | 0 | 2 | 4 | 100.0 | 0 |
| Vanuatu | 8 | 672 | 99.9 | 0 | 4 | 96 | 97.9 | 0 | 5 | 132 | 79.5 | 0 | 11 | 900 | 96.7 | 0 |
| Vietnam | 25 | 293,733 | 8.1 | 6 | 23 | 108.699 | 27.2 | 5 | 24 | 106,411 | 12.2 | 4 | 38 | 508,843 | 13.1 | 8 |
| Grand Total | 545 | 4,256,372 | 73.4 | 137 | 537 | 3,732,213 | 73.1 | 126 | 535 | 3,662,980 | 72.2 | 138 | 724 | 11,651,565 | 72.9 | 220 |

Table 3. The top 20 fish (A) and Invertebrates (B) imported into the US during 2008, 2009, and 2011.

| A. Fish |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 2008 |  |  | 2009 |  |  | 2011 |  |  |
| Rank | Species | \% Total | \# Countries | Species | \% Total | \# Countries | Species | \% Total | \# Countries |
| 1 | Chromis viridis | 10.2\% | 13 | Chromis viridis | 10.5\% | 16 | Chromis viridis | 11.6\% | 13 |
| 2 | Chrysiptera cyanea | 5.6\% | 8 | Chrysiptera cyanea | 5.0\% | 8 | Chrysiptera parasema | 4.7\% | 6 |
| 3 | Dascyllus trimaculatus | 5.0\% | 11 | Dascyllus trimaculatus | 4.4\% | 12 | Chrysiptera cyanea | 4.4\% | 7 |
| 4 | Dascyllus aruanus | 3.7\% | 9 | Chrysiptera parasema | 3.6\% | 4 | Dascyllus trimaculatus | 3.7\% | 10 |
| 5 | Chrysiptera parasema | 3.5\% | 3 | Dascyllus aruanus | 3.3\% | 9 | Dascyllus aruanus | 3.6\% | 8 |
| 6 | Amphiprion ocellaris | 3.2\% | 10 | Amphiprion ocellaris | 3.0\% | 10 | Nemateleotris magnifica | 3.0\% | 8 |
| 7 | Nemateleotris magnifica | 2.7\% | 12 | Nemateleotris magnifica | 2.4\% | 12 | Amphiprion ocellaris | 3.0\% | 10 |
| 8 | Chrysiptera hemicyanea | 2.6\% | 2 | Chrysiptera hemicyanea | 2.4\% | 3 | Pterapogon kauderni | 1.9\% | 5 |
| 9 | Dascyllus melanurus | 1.8\% | 3 | Dascyllus melanurus | 2.0\% | 6 | Centropyge loricula | 1.9\% | 9 |
| 10 | Pterapogon kauderni | 1.8\% | 3 | Paracanthurus hepatus | 1.7\% | 14 | Pseudocheilinus hexataenia | 1.6\% | 9 |
| 11 | Pseudocheilinus hexataenia | 1.4\% | 13 | Pterapogon kauderni | 1.7\% | 4 | Dascyllus melanurus | 1.6\% | 3 |
| 12 | Paracanthurus hepatus | 1.3\% | 16 | Centropyge loricula | 1.6\% | 7 | Sphaeramia nematoptera | 1.5\% | 7 |
| 13 | Synchiropus splendidus | 1.3\% | 3 | Pseudocheilinus hexataenia | 1.6\% | 12 | Chrysiptera hemicyanea | 1.5\% | 3 |
| 14 | Centropyge loricula | 1.3\% | 8 | Valenciennea puellaris | 1.4\% | 10 | Synchiropus splendidus | 1.5\% | 5 |
| 15 | Labroides dimidiatus | 1.3\% | 13 | Synchiropus splendidus | 1.4\% | 5 | Valenciennea puellaris | 1.4\% | 7 |
| 16 | Salarias fasciatus | 1.3\% | 8 | Gramma loreto | 1.3\% | 6 | Paracanthurus hepatus | 1.3\% | 15 |
| 17 | Gramma loreto | 1.2\% | 6 | Salarias fasciatus | 1.3\% | 10 | Salarias fasciatus | 1.2\% | 11 |
| 18 | Valenciennea puellaris | 1.1\% | 9 | Sphaeramia nematoptera | 1.3\% | 6 | Centropyge bispinosa | 1.2\% | 14 |
| 19 | Centropyge bispinosa | 1.1\% | 12 | Labroides dimidiatus | 1.1\% | 13 | Labroides dimidiatus | 1.1\% | 11 |
| 20 | Sphaeramia nematoptera | 1.0\% | 7 | Centropyge bispinosa | 1.1\% | 12 | Valenciennea strigata | 0.9\% | 10 |

## B. Invertebrates

|  | 2008 |  |  | 2009 |  |  | 2011 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Rank | Species | \% Total | \# Countries | Species | \% Total | \# Countries | Species | \% Total | \# Countries |
| 1 | Paguristes cadenati | 22.0\% | 3 | Paguristes cadenati | 20.9\% | 2 | Paguristes cadenati | 14.0\% | 4 |
| 2 | Lysmata amboinensis | 10.2\% | 6 | Lysmata amboinensis | 13.5\% | 8 | Lysmata amboinensis | 12.3\% | 8 |
| 3 | Clibanarius tricolor | 8.0\% | 1 | Clibanarius tricolor | 5.7\% | 2 | Mithraculus sculptus | 7.3\% | 3 |
| 4 | Mithraculus sculptus | 5.1\% | 3 | Mithraculus sculptus | 4.2\% | 2 | Trochus maculatus | 4.6\% | 3 |
| 5 | Stenopus hispidus | 2.9\% | 11 | Lysmata debelius | 3.0\% | 5 | Condylactis gigantea | 3.3\% | 4 |
| 6 | Trochus maculatus | 2.7\% | 1 | Calcinus elegans | 2.8\% | 4 | Clibanarius tricolor | 2.7\% | 2 |
| 7 | Nassarius venustus | 2.6\% | 1 | Trochus maculatus | 2.8\% | 2 | Stenopus hispidus | 2.6\% | 10 |
| 8 | Tectus fenestratus | 2.5\% | 2 | Stenopus hispidus | 2.7\% | 12 | Lysmata debelius | 2.5\% | 3 |
| 9 | Dardanus megistos | 2.4\% | 5 | Tectus fenestratus | 2.5\% | 3 | Entacmaea quadricolor | 2.4\% | 12 |
| 10 | Percnon gibbesi | 2.3\% | 5 | Tectus pyramis | 2.4\% | 4 | Dardanus megistos | 2.4\% | 6 |
| 11 | Tectus pyramis | 2.1\% | 2 | Percnon gibbesi | 2.3\% | 3 | Protoreaster nodosus | 2.3\% | 5 |
| 12 | Lysmata ankeri | 2.0\% | 1 | Condylactis gigantea | 2.1\% | 5 | Nassarius dorsatus | 2.2\% | 1 |
| 13 | Lysmata debelius | 2.0\% | 5 | Sabellastarte spectabilis | 1.7\% | 5 | Percnon gibbesi | 1.8\% | 5 |
| 14 | Condylactis gigantea | 1.9\% | 5 | Heteractis malu | 1.5\% | 6 | Nassarius venustus | 1.6\% | 1 |
| 15 | Sabellastarte spectabilis | 1.8\% | 4 | Lysmata ankeri | 1.5\% | 1 | Sabellastarte spectabilis | 1.6\% | 4 |
| 16 | Heteractis malu | 1.4\% | 6 | Protoreaster nodosus | 1.3\% | 4 | Nassarius distortus | 1.6\% | 1 |
| 17 | Calcinus elegans | 1.3\% | 3 | Engina mendicaria | 1.2\% | 2 | Heteractis malu | 1.5\% | 4 |
| 18 | Archaster typicus | 1.3\% | 6 | Entacmaea quadricolor | 1.1\% | 12 | Lysmata ankeri | 1.5\% | 1 |
| 19 | Engina mendicaria | 1.2\% | 2 | Nassarius distortus | 1.1\% | 1 | Pusiostoma mendicaria | 1.4\% | 2 |
| 20 | Stenorhynchus seticornis | 1.1\% | 5 | Archaster typicus | 1.1\% | 4 | Archaster typicus | 1.4\% | 6 |

Table 4. The most commonly imported fish species for each export country, and its overall contribution to the total number of known individuals (identified to a species level) for each of three years.

|  |  | 2008 |  | 2009 |  | 2011 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Export Country | 1* Species | \% | 1* Species | \% | 1* Species | \% |
|  | Australia | Amphiprion ocellaris | 42.3\% | Choerodon fasciatus | 14.7\% | Choerodon fasciatus | 16.9\% |
|  | Belize | Gramma loreto | 22.4\% | Gramma loreto | 27.0\% | Holacanthus ciliaris | 25.8\% |
|  | Brazil | Holacanthus ciliaris | 23.0\% | Holacanthus ciliaris | 28.6\% | Holacanthus ciliaris | 44.5\% |
|  | Canada | Eumicrotremus orbis | 76.9\% | Rhinoptera jayakari | 66.7\% | Eptatretus stoutii | 42.3\% |
|  | Cook Islands | Pseudanthias ventralis | 45.0\% | Pseudanthias ventralis | 46.0\% |  |  |
|  | Costa Rica | Thalassoma lucasanum | 31.1\% | Thalassoma lucasanum | 28.0\% | Elacatinus puncticulatus | 28.1\% |
|  | Curaçao | Elacatinus genie | 28.0\% | Liopropoma carmabi | 18.6\% | Gramma loreto | 31.2\% |
|  | Dominican Republic | Gramma loreto | 59.8\% | Gramma loreto | 60.4\% | Gramma loreto | 36.0\% |
|  | Egypt |  |  |  |  | Zebrasoma xanthurum | 31.7\% |
|  | Eritrea | Zebrasoma xanthurum | 23.2\% | Zebrasoma xanthurum | 24.6\% |  |  |
|  | Federated States of Micronesia |  |  |  |  | Pseudanthias bartlettorum | 12.3\% |
|  | Fiji | Pseudanthias squamipinnis | 9.6\% | Pseudanthias squamipinnis | 12.2\% | Chromis viridis | 20.3\% |
|  | French Polynesia (Tahiti) | Neocirrhites armatus | 43.9\% | Neocirrhites armatus | 64.6\% | Neocirrhites armatus | 68.0\% |
|  | Ghana | Balistes punctatus | 20.2\% | Balistes punctatus | 36.3\% | Holacanthus africanus | 41.4\% |
|  | Guatemala | Selene brevoortii | 58.8\% | Selene brevoortii | 64.7\% |  |  |
|  | Haiti | Gramma loreto | 33.8\% | Gramma loreto | 31.2\% | Gramma loreto | 32.9\% |
| + | Hong Kong | Zebrasoma flavescens | 76.3\% | Dascyllus trimaculatus | 40.0\% | Chordata | 99.7\% |
|  | Indonesia | Chromis viridis | 10.5\% | Chromis viridis | 8.9\% | Chromis viridis | 10.8\% |
|  | Israel |  |  | Premnas biaculeatus | 34.7\% | Amphiprion ocellaris | 88.7\% |
|  | Japan | Parapriacanthus ransonneti | 66.2\% | Parapriacanthus ransonneti | 13.5\% | Paracentropogon rubripinnis | 14.2\% |
| $\bigcirc$ | Kenya | Labroides dimidiatus | 15.5\% | Labroides dimidiatus | 14.2\% | Labroides dimidiatus | 12.0\% |
|  | Kiribati | Centropyge loricula | 70.1\% | Centropyge loricula | 63.2\% | Centropyge loricula | 65.1\% |
|  | Malaysia | Amphiprion ocellaris | 35.7\% |  |  | Paracanthurus hepatus | 100.0\% |
|  | Mauritius | Amphiprion chrysogaster | 12.0\% |  |  | Macropharyngodon bipartitus | 13.2\% |
| 1 | Mexico | Holacanthus passer | 49.5\% | Holacanthus passer | 35.8\% | Holacanthus passer | 39.0\% |
|  | Netherlands Antilles | Elacatinus genie | 58.9\% |  |  |  |  |
| $\square$ | New Caledonia | Chaetodontoplus conspicillatus | 84.5\% | Chaetodontoplus conspicillatus | 85.3\% | Cirrhilabrus laboutei | 40.3\% |
| $\square$ | Nicaragua | Apogon retrosella | 22.4\% |  |  | Acanthemblemaria hancocki | 39.5\% |
|  | Papua New Guinea | Amphiprion percula | 29.7\% | Paracanthurus hepatus | 23.4\% |  |  |
| - | Philippines | Chromis viridis | 11.7\% | Chromis viridis | 13.3\% | Chromis viridis | 13.6\% |
|  | Republic of Maldives | Acanthurus leucosternon | 12.9\% | Acanthurus leucosternon | 12.7\% | Acanthurus leucosternon | 14.7\% |
| - | Republic of the Marshall Islands | Centropyge loricula | 53.7\% | Centropyge loricula | 41.9\% | Centropyge loricula | 40.1\% |
|  | Saudi Arabia | Dascyllus marginatus | 30.7\% | Anampses caeruleopunctatus | 36.8\% |  |  |
|  | Singapore | Amphiprion ocellaris | 42.3\% | Amphiprion ocellaris | 73.0\% | Amphiprion percula | 31.6\% |
|  | Solomon Islands | Paracanthurus hepatus | 19.4\% | Paracanthurus hepatus | 33.7\% | Paracanthurus hepatus | 20.4\% |
|  | Sri Lanka | Valenciennea puellaris | 22.5\% | Valenciennea puellaris | 21.1\% | Valenciennea puellaris | 26.8\% |
|  | Taiwan | Pomacanthus maculosus | 24.8\% | Pomacanthus maculosus | 19.4\% | Amphiprion ocellaris | 55.2\% |
|  | Thailand | Amphiprion ocellaris | 87.8\% | Amphiprion ocellaris | 90.5\% |  |  |
|  | The Bahamas | Haemulon sciurus | 17.5\% | Chromis cyanea | 11.5\% | Haemulon flavolineatum | 88.9\% |
|  | Tonga | Centropyge bispinosa | 14.8\% | Centropyge bispinosa | 12.7\% | Meiacanthus atrodorsalis | 9.6\% |
|  | United Arab Emirates |  |  |  |  | Zebrasoma xanthurum | 63.6\% |
|  | United Kingdom | Amphiprion ocellaris | 76.5\% |  |  |  |  |
|  | Vanuatu | Centropyge loricula | 9.4\% | Chrysiptera rollandi | 12.8\% | Chromis viridis | 6.9\% |
|  | Vietnam | Nemateleotris magnifica | 8.3\% | Nemateleotris magnifica | 16.7\% | Chaetodontoplus septentrionalis | 12.3\% |
|  | Yemen | Zebrasoma xanthurum | 48.2\% | Zebrasoma xanthurum | 47.6\% |  |  |
|  | Grand Total | Chromis viridis | 10.0\% | Chromis viridis | 10.2\% | Chromis viridis | 11.2\% |

Table 5. The most commonly imported invertebrate species for each export country, and its overall contribution to the total number of known individuals (identified to a species level) for each of three years.


Table 6. Countries reported on LEMIS database to export fish to the U.S.. Shaded countries are those represented on the invoice-based assessment of fish imports to the US.



Figure 1. The FlexiCapture 9.0 verification screen for the capture of invoice data to incorporate into the Marine Aquarium Trade Database. Left) Declaration, Center) image of invoice, Right) invoice table from OCR results. Note: brown shaded areas indicate autocorrected fields, red flags indicate errors for user to correct.


Figure 2. Country level dashboard page of the web portal, aquariumtradedata.org. Top) Trade flow map showing nodes of exporting nations and ports of entry in the U.S. Bottom) Timeline chart of US fish and invertebrate imports based on user selected dates.





Figure 3. Drop down menu for user-generated queries. Top) Countries/Ocean with Ports of Entry. Users can select any combination of Oceans, Countries, and Ports of Entry. Middle) Demonstration of the Taxa selectors with top 20 species chart. Bottom) Countries of Origin and Ports of Entry for the species selected.

Years: 2008, 2009, 2011
Exported From: All
Ports of Entry: All
Families: Pomacentridae
Genus: Amphiprion
Species: Amphiprion ocellaris, Amphiprion percula
Ports\%20of\%20Entry


Rhyne and Tlusty 2014. aquariumtradedata.org
Last updated 5/28/2015

Figure 4. Exported chart from user-generated query. Header automatically includes user generated query that generated the image. Footer automatically includes attributes of the data as well as provides user with information about when the data was lasted updated.


Figure 5. Trade flow of marine aquarium fishes from source nations to United States over 2008, 2009 and 2011. Numbers on lines indicates percent of trade. Pie chart in United States represents Ports of Entry (with the Midwest starting at 0 degrees, and clockwise, NE, SE, SW and NW).


Figure 6. Trade flow of marine aquarium invertebrates from source nations to United States for 2008, 2009 and 2011. Numbers on lines indicate percent of trade. Pie chart in United States represents Ports of Entry (with the Midwest starting at 0 degrees, and clockwise, NE, SE, SW and NW).


Figure 7. Top countries that exported Paracanthurus hepatus to the United States in 2005, 2008, 2009, and 2011. Artwork by Karen Talbot.


Figure 8. The cumulative summation the number of fish (A) or invertebrates (B) exported per country by rank order of species. The most exported species represents a significant proportion of the total individuals exported, and this importance decreases as a country exports a greater number of species.


Figure 9. The comparison of the total number of fish imports according to LEMIS and this invoice-based data across 4 years, the three years reported here along with 2005 data presented in Rhyne et al. (2012).


Figure 10. The determination of estimated numbers of ornamental fish and invertebrates imported into the US. The average number of individuals per month was determined for 2008, 2009, and 2011 (top). From here, the years for which there were incomplete data (2000, 2004, and 2005) were adjusted proportionally based on the assumptions that monthly import trends are consistent across years.


Figure 11. Top countries that exported Pterapogon kauderni to the United States in 2005, 2008 2009, and 2011, and 2013. Note: Thailand fish are aquacultured. Artwork by Karen Talbot.


Figure 12. Number of aquacultured Pterapogon kauderni exported from the Kingdom of Thailand, imported into Los Angeles California during the past three years.


Figure 13. Imports of Amphiprion ocellaris and A. percula to the US aggreagated over the years 2008, 2009, and 2011. The species were summed over countries of export depending if the country was in the species native or non-native range. All non-native fish are either a) actually native, but of an unknown distribution, b) produced in aquaculture or c) mis-identified as to origin on the shipping invoice.

