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The 800-Pound Grouper in the Room: Asymptotic Body Size and Invasiveness of Marine Aquarium Fishes

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ABSTRACT

The global trade in aquatic wildlife destined for home aquaria not only has the potential to be a positive force for conservation, but also has a number of potential risks. The greatest and most documented risk is the potential to translocate species that will become invasive in a new habitat. Although propagule pressure can influence species invasiveness, a high percentage of documented marine aquarium fish that are invasive in the US are uncommon in the trade. Here, the covariation of size with species invasiveness was assessed using a web scraper to collect size, price, life history characteristics, and behavior data from five internet retail stores for 775 species of fish. Fish that routinely exceed 100 cm in total length are traded, nevertheless are typically sold at sizes much smaller than their theoretical maximum. No economic benefit from the sale of species that will outgrow tanks and have a high risk of being released was found. Large fish, including groupers that can achieve weights of 800 pounds, will continue to enter the trade because the growth of aquaculture for commercial food markets is making it easier to acquire these species that also have appealing small life stages, making it easier and less expensive to bring these species into the aquarium trade. The entire trade should consider taking concerted action to limit the trade in fish that are likely to become invasive.

1. Introduction

The global trade in fishes that are kept in private residences as pets (the Aquarium Fish Trade, or AFT) has the potential to become a positive conservation force [1,2]. A sustainable AFT can help promote habitat preservation, environmental stewardship, poverty alleviation, sustainable livelihoods, and the safeguarding of threatened ecosystems, particularly where the ornamental trade contributes substantively to the net value of wild products [1,3]. However, there are also a multitude of potential risks in the trade [2], of which the release and subsequent introduction of nonindigenous species (NIS) is well documented [4,5].

NIS are species that are introduced to and persist in the wild outside of their natural range [6,7]. Some exist temporarily, unable to establish a reproducing population (e.g. horseshoe crabs in California), while others reproduce and become permanently established [8]. Patterns of biological invasions are influenced and shaped by trends in human activities, including the trade and transport of biota [5,9]. The potential to introduce NIS by transporting them across natural boundaries is worthy of attention.

NIS are considered invasive if they rapidly become widespread, establish self-sustaining populations, and their presence and behavior impact the host ecosystem. Examples include lionfish in the western Atlantic Ocean [10], Burmese pythons in Florida [11], and zebra mussels in the Laurentian Great Lakes [12]. The success of invasive NIS is determined in part by specific life history characteristics, susceptibility of an ecosystem to invasion, and influx of potential colonists [13,14]. The latter, also referred to as propagule pressure [15], is measured as an estimate of the frequency and magnitude of release events. Anthropogenic activity plays the most significant role in the movement and transportation of species [16], and is thus a major driver of propagule pressure. As propagule pressure increases, so too does the likelihood of invasion [17].

With an estimated 192 million individual fish (and crustaceans) imported into the United States annually [18], there is astonishing

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potential for the AFT to influence propagule pressure. Invasion success increases when fish are released directly into suitable habitat [8]. The Indo-Pacific lionfish is a *cause célèbre* for AFT invasion. Nonexistent in the region prior to the 1980s, this species has since spread to the entire tropical and subtropical western Atlantic [19]. Its success might be attributed to high potential propagule pressure (it was the 29th most imported marine AFT species in 2005 [20]) coupled with invasive characteristics (facilitating persistence post-release). However, if volume of import is the sole variable influencing propagule pressure, then one should expect to observe a correlation between rank in trade and sightings of nonindigenous AFT species. This is not always the case; indeed, several marine NIS are uncommon in the trade, so their presence cannot be explained by volume of import alone [20]. There must be a selective force influencing the release of marine AFT species that accounts for this discrepancy.

Hobbyists are the most likely vector by which marine AFT species are introduced, as there is little opportunity or incentive for release prior to consumer-level handling [21]. If surrendering unwanted fish is not an option, live release may be tempting as a more humane alternative to euthanasia. Surveys suggest that life history characteristics including size and aggression are compelling reasons for AFT hobbyists to deliberately release specimens into the wild [22]. Fish that are purchased as juveniles and outgrow their captive environment are likely to be released at a large size, enhancing their odds of survival over smaller individuals of the same species. The invasive status of the Burmese python in Florida is evidence of the ecological risk posed by mature, nonindigenous predators that are released at a large size [23].

In addition to wreaking ecological havoc, it is apparent that invasive species cost the United States billions of dollars to manage annually [24]. Augmenting prevention policies is key for managing existing threats and preventing future invasions [25]. With a substantial volume and diversity of marine species available to consumers in the United States [20], potential invasion pathways are numerous. Given the risk of intentional release by consumers, the hypothesis that desirability of “tankbusters” is greatest early in life history was tested here by examining retail size and price versus maximum potential size for marine AFT species sold by vendors in the United States. The need for a comprehensive stakeholder-based management plan in which industry, government, and NGOs develop a moving white list that guides consumers away from high-risk species was highlighted. Finally, the risk pathway model proposed by Zajicek et al. [21] as a framework for understanding the risk at each node in the supply chain was improved upon.

2. Materials and methods

In order to collect retail size and price data for marine AFT species sold in the United States, five representative internet-based vendors that published size and price data for each specimen were chosen. The chosen vendors were Doctors Foster and Smith LiveAquaria.com, BlueZoo Aquatics, Petco, Reefs2Go, and Saltwaterfish.com. Data were collected with respect to retail size (provided as a range), taxonomy, common names, life history stage (juvenile/adult), price, origin (wild/aquaculture), maximum potential size, care level, minimum required tank size, diet, temperament, and compatibility with reef tanks. Not all data were available for each species/size combination. These data were collected using web scraper software (OutWit Hub) optimized for each vendor. Optimization involved writing vendor-specific scrapers capable of locating and collecting relevant data from any number of structurally similar product pages, compiling queries of web addresses from which to collect data, and creating macros with which to automate data collection. Data was collected from each product page just once, between October 12, 2012 and May 23, 2013. Only non-sale prices were collected. No data were recorded for fish listed as hybrids and/or those for which only a genus was given. Retail size ranges and maximum potential lengths (according to vendor) were recorded in metric values. Taxonomic rank was verified with the FishBase Match Names Tool [26]. Maximum potential length (according to literature) was collected for each vendor-available species using web scraper software (OutWit Hub) optimized for FishBase. FishBase data collection took place on March 19, 2013. Fish length is represented by the literature in several ways, reflecting the appropriateness of different methodologies for measuring different taxa. Among the 775 unique vendor-available species, 612 were listed in FishBase as TL (Total Length), 146 as SL (Standard Length), six as OT (Other), five as FL (Fork Length), three as NG (Not Given), and one as WD (Width). For the remaining two species, no data were available. Given the minor discrepancies in measurement among methodologies, none of the reported sizes were adjusted, and maximum size is referred to as TL for the remainder of the analysis.

Because the retail size was typically provided as a range (e.g., small: 1–3 cm), these data were recorded as medians. The median retail size data were compared to price within each species to assess how relative price per cm changed as fish grew larger. Species characteristics (maximum potential length, origin, care level, minimum required tank size, diet, temperament, and compatibility with reef tanks) were assessed to determine if there were differences between fish sizes within the different attributes.

The relative value of small and large fish within a species was assessed by determining the ranked maximum price (RMP). For those species in which data were collected for at least four different size ranges ($n=393$), the price data were ranked according to size, and the rank order (%) of the most valuable was determined. The ranked maximum price (RMP) index varied from 1 (the smallest-size fish had the greatest associated price within a species) to 100 (the largest-sized fish had the greatest associated price).

3. Results

The search retrieved 5,296 unique species-size-price records representing 775 unique species available from the five chosen internet-based marine AFT vendors. Vendors accurately represented how large fish could become, as the maximum potential sizes listed within the species information pages were highly correlated ($r^2=0.99$, $p<0.001$) with the maximum potential sizes listed within FishBase [Fig. 1A]. Maximum potential size [26] was not correlated ($r^2=0.05$) to species rank in the AFT (data from [20]). Although vendors accurately listed the maximum potential size of fish, large species tended to be sold at relatively small retail sizes while small species tended to be sold at retail sizes equivalent to or greater than their theoretical maximum size [Fig. 1B]. No species larger than 25 cm were available at a median retail size exceeding maximum potential size as listed in Fishbase [Fig. 1B]. Only 27 (of 5,296) of the median retail sizes were >40 cm, while only 11 were >50 cm. Furthermore, no species larger than 100 cm were available at a median retail size exceeding 50% of maximum potential size [Fig. 1B]. Maximum retail price was not associated with maximum potential size [26]. The highest priced fish tended to be <30 cm TL [Fig. 1C], and large fish did not command a greater overall value than medium and small fish.

The RMP index indicated that the largest size fish within a species commanded the greatest price 53% of the time. Fish greater than 200 cm TL had a RMP index value of 100 [Fig. 2A], probably because they were sold at significantly smaller prices than their theoretical maximum [Fig. 1B]. However, even as the smaller species exceeded their theoretical maximum size, some were still sold at a high RMP [Fig. 2B]. Most fish of substantial value ($>$US $500) had an RMP close to 100 [Fig. 2C]. The one species to contradict this trend was *Chaetodontoplus conspicillatus* (conspicuous angelfish), a species for which the smallest specimens were most valuable, although they sold at sizes that often exceeded the theoretical maximum.