Understanding the United Kingdom marine aquarium trade – a mystery shopper study of species on sale

JOHN K. PINNEGAR[1,2*] | JOANNA M. MURRAY[1]

[1]Centre for Environment, Fisheries & Aquaculture Science, Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk, UK

[2]School of Environmental Sciences, University of East Anglia, Norwich, UK

Correspondence

John K. Pinnegar, Centre for Environment, Fisheries & Aquaculture Science, Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

Email, john.pinnegar@cefas.co.uk

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ABSTRACT

In this study, we conducted a unique survey of marine ornamental fishes appearing in UK retail stores, as well as a review of government trade statistics, with the aim to significantly strengthen the evidence-base in support of future management initiatives. Fifty marine aquarium retailers were visited. A total of 380 marine aquarium fish species (4926

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individuals), from 48 families were recorded with the largest proportion of individuals belonging to the families Pomacentridae, Acanthuridae, Apogonidae, Labridae, Pomacanthidae, Gobiidae and Labridae. The majority of fishes for sale (91% of species) originated from the Indo-Pacific Ocean, with only a small number (9% of species) derived from the Atlantic Ocean. However, exact sources of individual species were unclear and poorly documented. Government trade statistics revealed that the ornamental reef-fish trade in the UK grew markedly between 1996 and 2008 with a rapid acceleration in 2003–2004. However, imports have declined since 2008 and amounted to less than 305,000 kg in 2017 with an economic value of UK £3 million (*c*. US $3.8). Recent trade data (2017) identify Indonesia, USA, Philippines and the Maldives as the most important countries in terms of imports to the UK. The UK is an important exporter of wild-caught fishes *via* trans-shipment, but also production of tank-reared animals. Several species observed for sale in the UK have been designated by the IUCN and CITES as being of conservation concern, although all these animals are thought to have been captive-reared.

KEYWORDS

aquarium, biodiversity, coral reef, import, ornamental, trade

1 | INTRODUCTION

Over 20 million marine fishes are harvested each year for the ornamental aquarium trade, destined for sale in the United States and Europe in a global market worth more than US $330 million (Wabnitz *et al*. 2003; Tissot *et al*. 2010). Unlike freshwater ornamental species, 90% of which are now farmed (Evers *et al*., 2019), the vast majority of animals in tropical marine aquaria are taken from the wild and, in particular, removed from coral reefs (King,

2019). As vulnerable ecosystems, coral reefs are threatened by pollution, destructive fishing, coral bleaching, ocean acidification, tourism development and other stresses (Hughes *et al*. 2010, 2014), hence wild collection of fishes raises a number of conservation concerns, contributing an additional significant stressor and raising questions about long-term sustainability (King, 2019).

Overharvesting and extirpation of key species is a priority issue cited by those opposing the trade. The over-collection of populations of the Banggai cardinalfish *Pterapogon kauderni* Koumans 1933 for example, a species endemic to a remote archipelago in Sulawesi (Vagelli & Erdmann 2002; Tissot *et al*. 2010), resulted in dramatic declines in numbers between 2001 and 2004. In response, the species was listed as 'Endangered' on the IUCN Red List in 2007 (Allen & Donaldson, 2007). Other concerns include: coral-reef degradation associated with fishing gear and the use of cyanide and other poisons to stun and catch fish (Rubec *et al*. 2001); changes in reef ecology due to focussed collection of specific trophic groups such as herbivores and loss of biodiversity due to removal of rare species (Bruckner 2005). In addition, reef fishes often experience high post-harvesting and transport mortalities. Collected organisms that die or are rejected before a point of sale often go unreported. A study of rejections by buyers before export in the Papua New Guinea marine aquarium fishery suggested that over a six month period, 24.2% of the total fish catch was rejected (Militz *et al*. 2016). At the other end of the supply chain, a study of over 300 aquarium fish retailers in the United States indicated that mortality of fishes imported from the Philippines ranged from 30–60% within 3 days of arrival (Rubec *et al*. 2001). Although several species are now successfully cultured (Moorhead & Zeng 2010), a study analysing the culture potential of the most abundant species in hobbyist's marine aquaria found that some, including the tangs (Acanthuridae), butterflyfishes (Chaetodontidae) and lion fishes (Scorpinidae, Pteroinae), had few records of captive rearing success (Moorhead & Zeng

2014). This picture has changed significantly in recent years with some breeding of tangs and angelfish (Pomacanthidae) has been achieved. However, reliance on aquaculture as an alternative to wild collection is some way off for many marine species, increasing the need for well-managed capture fisheries and monitoring along the whole supply chain.

Limited legislation, oversight and lack of enforcement within the industry mean that monitoring the volume, value and diversity of ornamental species collected in source countries is often complex or impossible. This has driven initiatives in both the USA and Europe to explore the scattered and piecemeal data available in order to improve our understanding of the aquarium trade and to underpin effective policy and management (Rhyne *et al*. 2012; Cohen *et al*. 2013; Leal *et al*. 2016). These studies have provided detailed insights into specific areas of the aquarium trade ranging from ornamental polychaetes in the UK (Murray *et al*. 2012), to a species-level analysis of fish shipment records in the United States (Rhyne *et al*. 2012), building upon the global overview provided by Wabnitz *et al*. (2003). Using what has come to be known as the global marine aquarium database (GMAD), the authors revealed a total of 1471 species of fish are traded worldwide (Wabnitz *et al*. 2003) although a study by Rhyne *et al*. (2012) estimated this figure to be nearer to 1800 in the US alone. Leal *et al*. (2016) provided the first economic assessment of the ornamental reef-fish trade in Europe revealing a total value of > €135 million over an 11 year period. The UK was identified as the largest importing country and its dominance as a trade centre among other EU countries was found to have increased in recent years rising from 14% of total imports in 2000 to 26% in 2011. Despite advancing our understanding of the key players and value of the trade in Europe, this study did not find any species-level data; therefore, an assessment of potential consequences of the trade for natural populations and ecosystems remained impossible. Biondo (2017) investigated the trade in Switzerland by analysing import documents for live animals. In 2009, 151 import declarations with attached species

lists for marine ornamental fishes from non-EU countries were examined and totalled 28,356 specimens (11,167 from Indonesia alone). The 62% of the fishes remaining in Switzerland (28% were re-exported), comprised 440 marine species from 45 families.

Within the UK there are estimated to be *c*. 2000 retail outlets for ornamental fishes and of these, 750 are thought to sell marine species (Macfadyen *et al*. 2005). These retailers primarily source stock from a small number of major importers and wholesalers. Currently it is very difficult to obtain detailed species-level information on what reef fishes are actually being traded as there is little obligation on importers to supply this information. Suppliers must submit a species list within the AHH2 form (CEFAS, 2019) as a requirement to become an authorised importer of live fish and shellfish in England and Wales, but once submitted there is little oversight of individual consignments and quantities. In the present paper we undertook a highly novel assessment of UK retailers and in combination with government import and export records, we investigate the diversity of coral-reef fishes traded in the UK to enhance our understanding of the marine ornamental-fish trade in Europe. Similar approaches have been successfully tried elsewhere where detailed species data are lacking, for example to collect information on the diversity of cage birds for sale in 154 Taiwanese pet shops (Su *et al*. 2015).

2 | METHODS

A market survey of 50 marine aquarium shops was conducted through unannounced and covert visits to retailers in eastern England (Norfolk, Suffolk, Lincolnshire, Cambridgeshire, Northamptonshire, Leicestershire, Derbyshire, Warwickshire, Essex, Hertfordshire, Greater London) over the period April to August 2011. These 50 shops were each visited only once during the survey and represent about 7% of the total number of retailers in the UK. In each

case, notes were taken of all species offered for sale, including the number of individuals, the common name used for the species, the price (UK £) and an estimate of the size of each individual (approximate total length in cm). Length are considered only indicative due to the problem of glass refraction (*i.e.*,, where objects appear larger or closer than they would in air) and the necessity for a rapid appraisal. Validation trials to test accuracy were initially conducted using plastic strips of known length in an experimental aquarium tank. The resulting data were also compared with the maximum total length of the species, as given in Fishbase (www.fishbase.org). In addition, an assessment of the condition of each individual, ranging from A lively, B fair, C moribund to D dead or dying, was made. Notes were also taken of whether animals were listed as captive-bred [*e.g.*,, clown fishes (Pomacentridae, Amphiprioninae) and seahorses (Syngnathidae, Hippocampinae)] and some general impressions regarding the standard of tanks and the type of establishment; *e.g.*,, whether it was part of a larger chain of retailers or an independent shop. In conducting this study, we adhered to best practice codes and guidance for mystery shopping studies (ESOMAR, 2005). Researchers carrying out mystery shopping studies must take every care to ensure as far as possible that individual privacy is respected and that data subjects are not disadvantaged or harmed as a result of the work.

Following each visit, data were transcribed and species were assigned to a particular taxonomic name (where possible) using reef-fish identification guides (Lieske & Myers 2001) or Fishbase (Froese & Pauly, 2018). Summary statistics were calculated for each retailer (Supporting Information Table S1), including the number of species observed, the total number of individuals, the Shannon index of diversity and Simpson's index of dominance for each shop, as well as numbers of individuals and species per fish family (*e.g.*,, Pomacentridae, Pomacanthidae, Acanthuridae, Labridae etc.). Following completion of all shop visits, an average price (UK £) was derived for each species (based on 2011 prices; *i.e.*,,

the period when shops were visited) and this was applied where animals had been unlabelled, in order to calculate the total economic value of the stock observed. Using the information collected on individual fish sizes, the average total length (cm) per species was calculated, plus SD (Supporting Information Table S2).

Government statistics on the trade (imports and exports) of marine aquarium fishes were obtained from the HM Revenue & Customs database (Gov. UK, 2018). Statistics were downloaded specifically for the commodity 'Fish, live: Saltwater ornamental fish' (code 03011090) from 1996 to 2011 and 'Live ornamental-fish (exc. Freshwater)' (code 03011900) from 2012 to 2017. The commodity code used for aquarium fishes was altered after 2011 so code 03011090 yielded no results after this period, whereas 03011900 yielded no results prior to 2012. Available data included quantities (kg) and value (UK £) of trade between individual countries and comprised both imports and exports. It is important to note that cited quantities usually included both the mass of the fishes themselves and that of the water within which they were transported. Information was also available from HM Revenue & Customs concerning named importers of marine fishes into the UK. These included various global logistics and air-freight companies, chains of garden centres and specialist aquatic wholesalers, as well as a few independent retail outlets.

3 | RESULTS

3.1 | Market survey of aquarium shops

The 50 aquarium shops visited ranged from small independent retailers (typically in town centres) offering a few marine fishes to major marine specialists or those associated with out-of-town garden centres. The lowest number of fishes observed was 17 (shop reference 30),

while the highest number of fishes observed was 445 (shop reference 34). The average number of marine fish species observed within the shops visited was 39, although this ranged from 10 species (shop reference 30) to 99 species (shop reference 25; Supporting Information Table S1).

Three-hundred-and-eighty different species of marine fishes were observed in the shops visited (4926 individual fishes). Species available were dominated by Pomacentridae (including clown fishes; 44.2%) of individuals, but with large numbers of surgeonfishes–tangs (9.0%), cardinalfishes (5.8%), wrasses (Labridae; 5.3%), angelfishes (5.2%), gobies (Gobiidae; 4.9%) and small groupers (Serranidae; 3.7%; Figure 1). In terms of numbers of species, damselfishes (Pomacentridae) were less dominant with 47 species (12.4%), while there were 54 different species of wrasses (14.2%), 38 species of angelfishes (10%) and 28 species of gobies (7.4%). Some families were represented by relatively few individuals but many different species, for example butterflyfishes at 61 individuals from 18 species; pufferfishes (Tetraodontidae), 37 individuals from 8 species. In other cases, many individuals were observed but from a small number of species; *e.g.*, firefishes (Microdesmidae) 154 individuals from 3 species, *Nemateleotris helfrichi* Randall & Allen 1973, *Nemateleotris magnifica* Fowler 1938 and *Nemateleotris decora* Randall & Allen 1973.

Fishes ranged in price from UK £250 for a bluestripe angelfish *Chaetodontoplus septentrionalis* (Temminck & Schlegel 1844) or UK £200 for an Achilles tang *Acanthurus achilles* Shaw 1803 to as little as UK £1.95 for an individual bumblebee goby *Brachygobius nunus* (Hamilton 1822) or UK £3.89 for a green chromis *Chromis viridis* (Cuvier 1830). The total value of the stock observed in the 50 shops visited was estimated at UK £106,656, although this ranged from UK £283 (shop reference 36) to UK £8621 (shop reference 34) (Supporting Information Table S1). Most fishes on sale were juveniles. Juveniles were particularly common among the angelfish and tangs (Pomacanthidae and Acanthuridae),

whereas adults of damselfish (Pomacentridae) were often observed (Supporting Information Table S2, mean length).

The most commonly observed species were *Amphiprion ocellaris* Cuvier 1830 (436 individuals, present in 92% of the shops visited) and *C. viridis* (364 individuals, present in 44% of the shops visited). Other ubiquitous species included *Chrysiptera parasema* (Fowler 1918), *P. kauderni* and *Amphiprion percula* (Lacépède 1802) (190, 141, 107 individuals respectively; Supporting Information Table S2). Many species (126) were observed in only one shop, for example *Chiloscyllium punctatum* Müller & Henle 1838 (the only elasmobranch) and the number of novel species continued to grow as more establishments were visited. Ninety-one species were represented by a single animal, observed in a single shop.

Ninety-six per cent of the individual fishes observed (91% of species) originated from the Indo-Pacific Ocean, whereas only 4% of individuals (9% of species) were derived from the Atlantic Ocean (mostly the Caribbean Sea). However, within the Indo-Pacific Ocean, 35% of individuals (34% of species) were thought to be derived from sources only in the Pacific Ocean, 4% of individuals are only found in the Indian Ocean (8%) and 1% of individuals (3% of species) are only found in the Red Sea or Arabian (Persian) Gulf (Figure 2 and Supporting Information Table S2). Some cosmopolitan species are known to occur over a very wide geographic area and some even occur in both Atlantic and Indo-Pacific Ocean basins [*e.g.*, *Diodon holocanthus* L. 1758, *Histrio histrio* (L. 1758), *Melichthys niger* (Bloch, 1786)]. Others are endemic to a particular locality (*e.g.*, the Red Sea or Hawaiian Islands). Examples of species with particularly restricted ranges included *Meiacanthus oualanensis* (Günther 1880) from Fiji, *Neoglyphidodon crossi* Allen 1991 from Sulawesi and the Moluccas, *P. kauderni* from Banggai Islands, Indonesia and *Labroides phthirophagus* Randall 1958 from Hawaii.

Some of the species observed were explicitly labelled as captive-bred, in particular most *Amphiprion* Bloch & Schneider 1801 species, some pseudochromids and apogonids, but most other fishes observed were thought to have been caught in the wild and imported to the UK. Several species of conservation concern or interest were observed in UK shops and listed as captive-bred, most notably *P. kauderni* and seahorses *Hippocampus kuda* Bleeker 1852 and *Hippocampus reidi* Ginsburg 1933, all of which are listed under CITES.

The vast majority of the species observed were derived from tropical coral reefs. Only 7 non reef-associated species were observed for sale (81 individuals) and these were typically associated with mangrove or brackish-water systems. These species were the mono angels *Monodactylus argenteus* (L. 1758) and *Monodactylus sebae* (Cuvier 1829) (21), the green scat *Scatophagus argus* (L. 1766) (19), *B. nunus* (20), the archerfish *Toxotes jaculatrix* (Pallas 1767) (7) the green spotted puffer *Tetraodon nigroviridis* (Marion de Procé 1822) (2) and saltwater mollies *Poecilia latipinna* (LeSueur, 1821) (12), although these were often held in tanks together with reef species.

A very diverse assemblage of fish species was observed across the 50 shops. The overall Shannon diversity of the observed captive population was 4.73 and Simpson's dominance was 0.02 (evenness was 0.80). The average diversity of individual shops was 3.16 (Supporting Information Table S1) although this ranged from 2.05 (shop reference 25) to 4.31 (shop reference 25)). Average Simpson's dominance was 0.05 but ranged from 0.01 to 0.15) (Supporting Information Table S1).

3.2 | Government statistics on imports and exports

The total quantity of marine fishes imported into the UK each year more than doubled between 1996 and 2007 rising from 115,876 kg in 1996 to 468,524 kg, with a particularly

dramatic increase occurring between 2003 and 2004. Since 2007 however, imports declined, such that the total quantity imported in 2017 was 305,339 kg. Given the problems associated with mass data (*i.e.*, that statistics include both the fishes and the surrounding water), it was thought necessary to mainly focus on the available economic data. The economic value of the imported fishes has risen from UK £822,536 (*c*. US $1.23 million) in 1996 to UK £3,141,777 (*c*. US $4.08 million) in real terms over the 22 year time period, which equates to a three-fold increase. Taking into account monetary inflation (the retail prices index; RPI), the value of imports doubled (Figure 3). Throughout the 19 years, the most important supplying countries have been Indonesia, USA, Philippines, Maldives, Fiji, Kenya and Sri Lanka, respectively. Imports from other European countries have also been important, although more so in terms of value than in terms of mass. The importance of certain supplying countries has changed considerably over the period (Figure 3) with some countries such as Barbados, Singapore, Saudi Arabia and Australia peaking and then becoming less important, or halting exports to the UK altogether, while other countries have grown in importance (*e.g.*, Bahrain, Solomon Islands, Tonga, Vanuatu, Thailand). Much of the surge in imports between 2003 and 2004 can be attributed to dramatically increased trade between the UK and countries in south-east Asia (most notably Indonesia and the Philippines). However, several other countries began exporting to the UK for the first time during this period (*e.g.*, Vanuatu and Japan, but also several EU countries including Portugal, Spain and France). A decline of imports (in terms of both mass and value) over the past decade has coincided with a dramatic increase in export volumes. Reported exports in 1996 amounted to only 9591 kg but this increased to 118,640 kg by 2017, meanwhile the value of exports increased from UK £403,085 to UK £992,134 in real terms, a UK £282,854 increase accounting for RPI inflation.

In terms of value, the order of importance of countries importing into the UK was slightly different in comparison with the importance when expressed in kg. Imports from

Indonesia were still the largest at UK £675,296 in 2017 or 21%, but this compares with 31% when quantified by mass (86,932 kg). By contrast, imports from the USA represented 21% of overall value (UK £649,211) in 2017 and yet only 12% in terms of mass (34,699 kg). Generally, the value kg^{-1} in 2017 was lowest for fishes imported from the south-east Asia (*e.g.*, Indonesia UK £7.7 kg^{-1}, Fiji UK £8.3 kg^{-1}, Maldives UK £9.7 kg^{-1}) and was highest for fishes imported from highly developed nations (*e.g.*, Portugal UK £33.5 kg^{-1}, Israel UK £30.0 kg^{-1}, Netherlands UK £27.4 kg^{-1}). Values kg^{-1} will reflect a number of factors including the rarity of the species being traded, the logistical costs of collecting and transporting the species or the cost of breeding and rearing animals in captivity.

The number of countries from which the UK receives consignments of marine ornamental fishes has generally increased. In 1996 imports were derived from only 19 counties, but this rose to 28 by 2007 when imports peaked in terms of mass and value (Figure 3). The sources of ornamental fishes continued to diversify up to 2010 with fishes derived from 34 countries but have since declined to only 24 countries in 2017. The UK is highlighted as a major exporter of marine ornamental fishes, mainly to other European countries, in particular Portugal 52% (61,138 kg), Germany 16% (19,357 kg), Netherlands 11% (13,220 kg) and the Ireland 6% (7632 kg). The high value for Portugal is probably due to the presence of a branch of a major UK wholesaler in this country. These fishes also supply the Spanish market but may also be shipped to other southern EU countries. Prior to 2015 the UK was also a major exporter to the USA. Examination of official statistics concerning consignments of live marine fishes imported to the UK revealed that there were 19 named companies importing marine fishes in 2017, with 6 of these recorded as importing fishes during every month of the year. Several of these importers were wholesalers or umbrella companies for chains of outlets throughout the UK. Others were generalist shipping companies located at airports and thus, were responsible for numerous consignments. Several importers were individual retailers

with one or very few consignments, often occurring in only one month of the 17 years for which data were available. Several multinational entertainment companies were also listed as importing fishes, this included a large chain of public aquaria as well as zoological gardens.

4 | DISCUSSION

More than 380 marine aquarium fish species are available for hobbyists to buy in the UK, representing a highly diverse coral-reef assemblage comprised of animals from tropical oceans all around the world. This is an industry that trades on diversity. Ninety-five species were represented by only one individual animal observed in one shop. Rhyne *et al*. (2012) stated that, 'collectors for the aquarium trade function as a peculiar and unprecedented type of generalist predator that targets both abundant and rare species, with a premium on both biodiversity and scarcity,' and it seems that the same is true for trade in the UK.

The species and families observed in UK shops closely matched those reported for the global industry (Wabnitz *et al*. 2003), with taxonomic composition also matching those observed in other developed nations, most notably the USA (Rhyne *et al*. 2012), Switzerland (Biondo, 2017) and Hong Kong (Chan & Sadovy, 2000), where virtually the same suite of species, from the same importing countries have been observed. While patterns in aquarium diversity are comparable across global markets, these do not necessarily reflect coral-reef biodiversity in the wild. In the present study, certain diverse reef-fish families were poorly represented among the 4926 fishes observed in retailer tanks when compared with their general abundance in the wild. These species included parrotfishes (Scaridae), possibly because of difficulties in maintaining these species in captivity or successfully transporting them. Other families including Microdesmidae and Malacanthidae, were over-represented in the trade and were observed more often than would have been expected given their prevalence in the wild.

Species of conservation concern according to the IUCN and CITES require documentation from importers and exporters to verify that the species have been obtained legally and their collection does not threaten survival in the wild (Bruckner, 2005). A number of CITES listed species were observed on sale in the UK market survey: two seahorse species, *H. kuda* and *H. reidi* and *P. kauderni*. However, it is thought that all of these animals were captive bred rather than collected from the wild.

Rhyne *et al*. (2017) examined the trade in *P. kauderni* , *A. ocellaris* and *A. percula*, all recently considered under the US Endangered Species Act for protection (Gov. USA, 1973). These authors noted that *P. kauderni* was one of the original marine-aquarium captive-rearing success stories and so one would anticipate that aquaculture should dominate the source of the fishes imported into the US. In contrast, however, import records from Sri Lanka in 2009 and 2011 and Thailand in 2013 (both outside the natural geographic range of *P. kauderni*) suggested this was not the case. Following further investigation, the authors concluded that all shipments of *P. kauderni* were in fact captive-bred but had been repeatedly mislabelled as wild-caught animals (W'). This inaccuracy is compounded by the misidentification of closely-related species on export invoices, especially among species with similar morphological appearances (*e.g*., the orange clownfish, *A. percula* and the common clownfish, *A. ocellaris*) and this will greatly hamper efforts to enhance traceability and sustainable practice within the industry.

Tracing the geographical origin and source (wild caught *v.* captive-bred) of traded specimens is a challenging task that is commonly doomed to failure due to long, fragmented and highly complex supply chains (Leal *et al*. 2016). In the present study we have only been able to ascribe the fishes observed to broad geographic origins based on their known distributions in the wild. One can make some educated guesses at origins by looking at the import–export volumes; *e.g.*, it is likely that many of the Atlantic species were coming to the

UK *via* the USA (probably from Florida and US territories such as Puerto Rico) and those with a distribution centred in east Africa were probably arriving in the UK *via* Kenya. Indeed, Okemwa *et al*. (2016) recently provided a detailed overview of the marine aquarium fishery in Kenya and showed that 32 species made up 80% of the catch with the cleaner wrasse *Labroides dimidiatus* (Valenciennes 1839) and the sea goldie *Pseudanthias squamipinnis* (Peters 1855) being the most collected. In contrast, however, those species with a more cosmopolitan range could have come from any one of many different exporting countries, making it difficult to judge the sustainability of collection practices in the wild.

The estimated size of each individual animal observed during the market survey revealed that most of the individuals for sale were juveniles and this is not surprising given the large size that some coral-reef species can attain and the reduced shipping costs of transporting smaller animals. In certain damselfishes, such as the bluestreak damselfish *Neoglyphidodon oxyodon* (Bleeker 1858), the young are much more attractive and brightly coloured than the adults, hence, there might also be a preference for smaller individuals for this reason. A similar pattern of predominantly juvenile individuals was reported by Rhyne *et al*. (2012) for imports into the USA.

The total value of the stock observed at the time of the visits to UK retailers was UK £106,656. If, as we believe, the 50 shops represent around 7% of UK stockists (Macfadyen *et al*. 2005), then at any one time this would mean that > UK £1.5 million of marine fishes (70,300 individual fishes) are being held by aquarium stockists in the UK. On the whole, higher prices coincided with species that were only rarely observed in a limited number of stores (Supporting Information Table S2). This inverse relationship between export volume and price was first noted by Rhyne *et al*. (2014) who suggested that this posed a major threat to the sustainability of some marine aquarium fishes. Species with perceived rarity command extremely high prices and those prices quickly fall as supply increases. Rhyne *et al*. (2014)

illustrated this phenomenon using the firefishes *Nemateleotris* spp.; for example, the red fire goby *N. magnifica* was the most ubiquitous species among those listed and was by far the least expensive. By contrast *N. helfrichi* was encountered much more rarely and consequently was considerably more expensive. Exactly the same pattern was observed in the UK, where the average price of *N. magnifica* was UK £17.83, whereas the average price for *N. helfrichi* was observed at UK £140.00. Following the approach taken by Su *et al*. (2015), an analysis of observed average price (in 2011) for a species *v.* the frequency of occurrence in the 50 shops, revealed a significant negative relationship. Rarely observed species were on the whole more expensive (Figure 4).

Species-level information on what is being imported into the UK is not available from government records and data from importers is not forthcoming or easily obtained. Consequently, covert visits to individual retailers was viewed as the best way of establishing the diversity of species reaching the hobbyist, although it should be noted that this will always provide an underestimate as it is not possible to visit every retailer or importer on a regular and repeated basis. Added to this, in some EU countries, retail stores re-inforce their fish stocks and buy more expensive–rarer species in the months of October and November to prepare for the Christmas season. It is not clear whether this is also the case in the UK and whether this might have made any significant difference in to the main findings or trends recorded. In the US, importers are also not obliged to provide species-level data and fishes are simply ascribed to broad commodity codes. However, Rhyne *et al*. (2012) gleaned considerably more information from exhaustive examination of invoices and packing slips appended to each shipping declaration, though noting that the vast majority of shipments were mislabelled. Unlike in the present study, the authors were able to determine the number of species and individuals from each individual country. By far the greatest number of individual fishes and the greatest diversity of species were derived from Indonesia (997

species, 3.2 million individuals) and the Philippines (1050 species, 5.7 million individuals). Fewer animals were derived from countries in the Americas and those bordering the Atlantic. Interestingly the authors reported 4 species (10,507 individuals) as being imported into the US from Great Britain (*i.e*., the UK) and noted that these were probably captive-bred fishes (particularly *A. ocellaris*) rather than trans-shipment of wild-caught fishes.

UK government records revealed a dramatic expansion in the marine fishes keeping hobby in recent years, with a particularly notable increase in coral-reef fishes imports between 2003 and 2004. It has been suggested that this coincided with release of the animated Pixar film *Finding Nemo* (The Guardian, 2003), but it should be noted that Militz & Foale (2017) have now explored this phenomenon in detail and suggest that import and export figures (for the USA) show little empirical evidence for fan-based purchases of wild-caught fishes immediately (within 1.5 years of release) following the film. Relative to other popular fishes, *A. ocellaris* was not imported any more or less frequently into the US, remaining the seventh most imported fishes for both 2000 and 2004.

Efforts to provide a robust assessment of long-term sustainability in the aquarium trade has driven scientists to think creatively and to gather the scattered and disparate (albeit imperfect) strands of information available on volume, value and species composition within the industry from the point of collection through to what is actually reaching hobbyists' aquaria. The current study provides a first assessment of coral-reef fishes held in UK aquarium retail shops and hence those reaching consumer's homes, as well as drawing on official government records concerning the source countries and volumes of stock entering Europe's biggest importer. It is hoped that data resulting from this study will allow fisheries managers and consumers to at least identify those species entering the trade that are potentially at risk and to facilitate a more targeted approach to assessments of the species perceived as being most vulnerable. Fujita *et al*. (2014) suggested a framework that integrates

several data-poor assessment and management methods in order to provide guidance for fisheries that differ widely in the kinds and amounts of data available. This includes productivity susceptibility analysis to estimate vulnerability to fishing of marine aquarium species using basic information on life-history traits and the nature of the fishery. Information on the relative degree of exploitation is combined with the vulnerability ranks to prioritize species for precautionary management and further analysis. The authors illustrate the application of this framework to an ornamental fishery in Indonesia and suggest that some of the most vulnerable species are *P. kauderni, A. ocellaris*, Clark's anemonefish *Amphiprion clarkii* (Bennett 1830) and spotted dragonet *Synchiropus picturatus* (Peters 1877) all of which were commonly observed in the 50 marine aquarium shops visited in the UK (Fujita *et al.* 2014).

Certification schemes and ecolabels can help empower consumers to support sustainable production and therefore in-turn, they can be very influential in incentivizing better practices within the industry. Such schemes have become commonplace in the seafood sector (for example Marine Stewardship Council accreditation of sustainable fisheries; Agnew, 2019). At present however, there is no unified certification scheme within the marine aquarium trade, limiting the capacity for consumers to easily differentiate sustainable products from others (King, 2019). As became apparent during visits to the 50 aquarium shops in the UK, the information provided by stockists to consumers was often lamentably incomplete. Given sufficient information (and improved traceability standards), the marine aquarium industry could be positively incentivized to improve practices, rather than being forced to do so through top-down legislation (Militz *et al*. 2017). Thus, it might be possible for perceived sinners to become saints in terms of helping to maintain endangered marine aquarium species (such as *P. kauderni*) when there is a risk that they might go extinct in the

wild and offering an income to impoverished citizens who might otherwise engage in less sustainable and more destructive practices (Evers *et al*., 2019; King, 2019).

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SUPPORTING INFORMATION

Supporting information can be found in the online version of this paper

Figure Captions

FIGURE 1 Taxonomic composition of the fish family assemblage by (a) number of individuals, (*n* = 4926) and (b) number of species (*n* = 380) observed for sale in 50 UK marine aquarist shops.

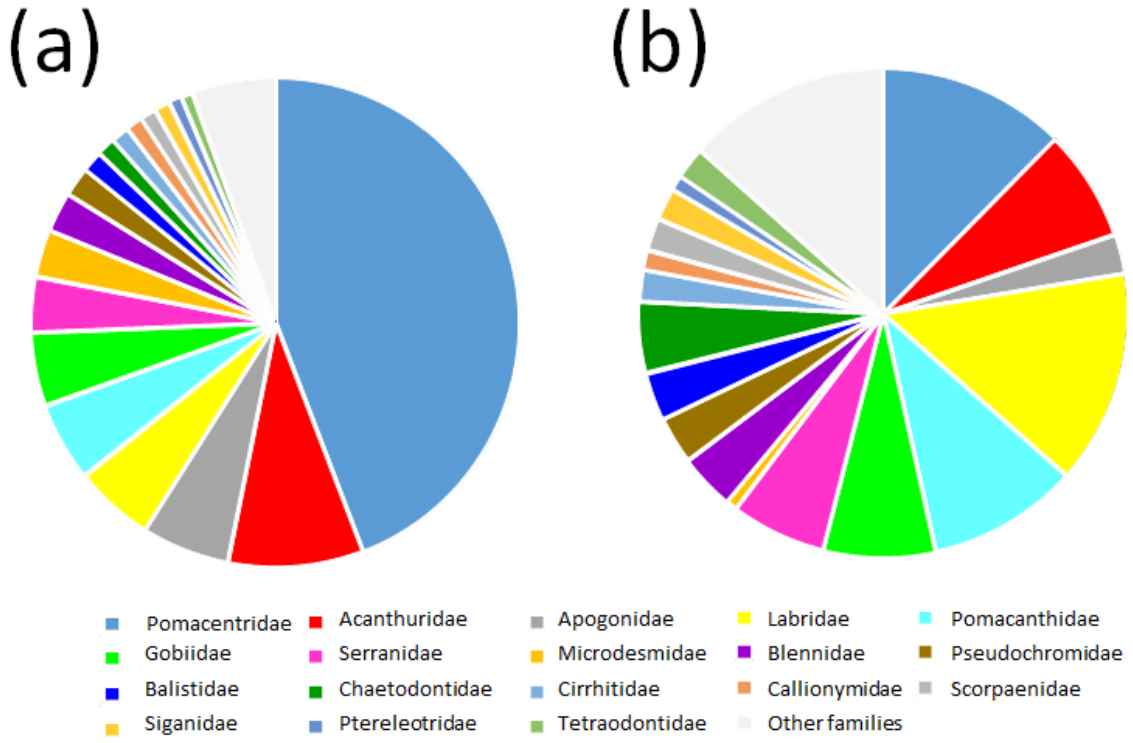

FIGURE 2 Composition of the fish assemblage by (a) number of individuals, (*n* = 4926) and (b) number of species (*n* = 380) observed for sale in 50 UK marine aquarist shops.

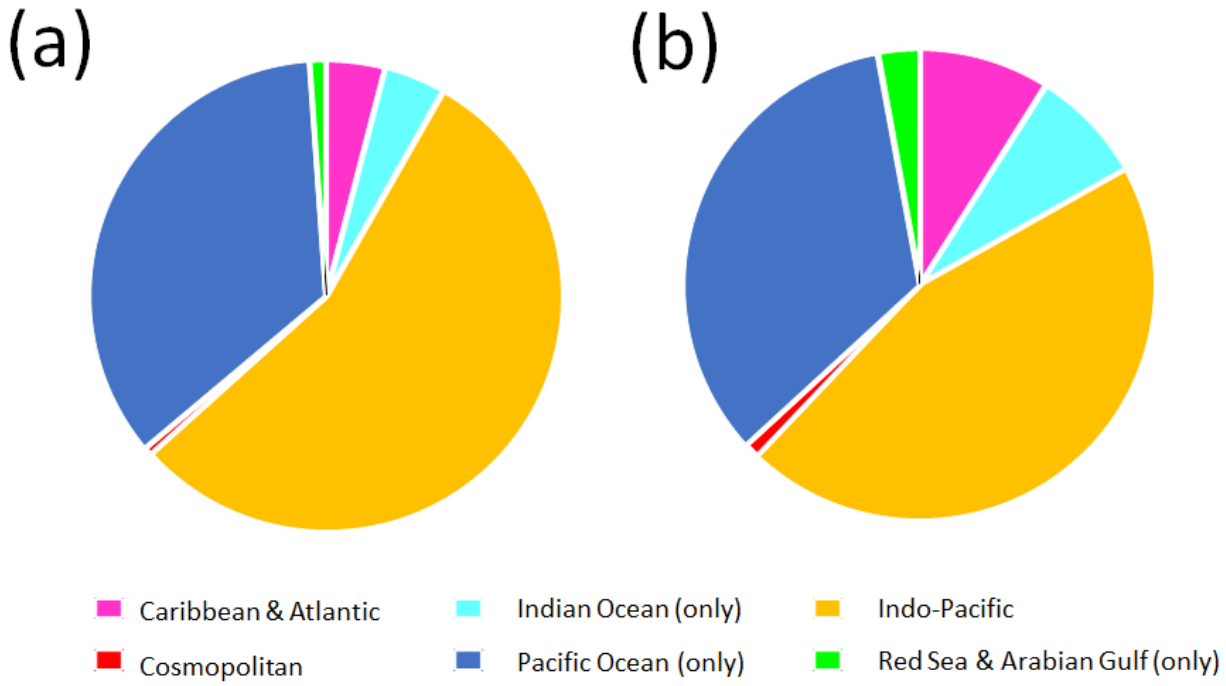

FIGURE 3. Import values of marine ornamental fish into the UK each year 1996–2017. All values adjusted to 2017 prices in accordance with the retail prices index (RPI; Gov.UK, 2018).

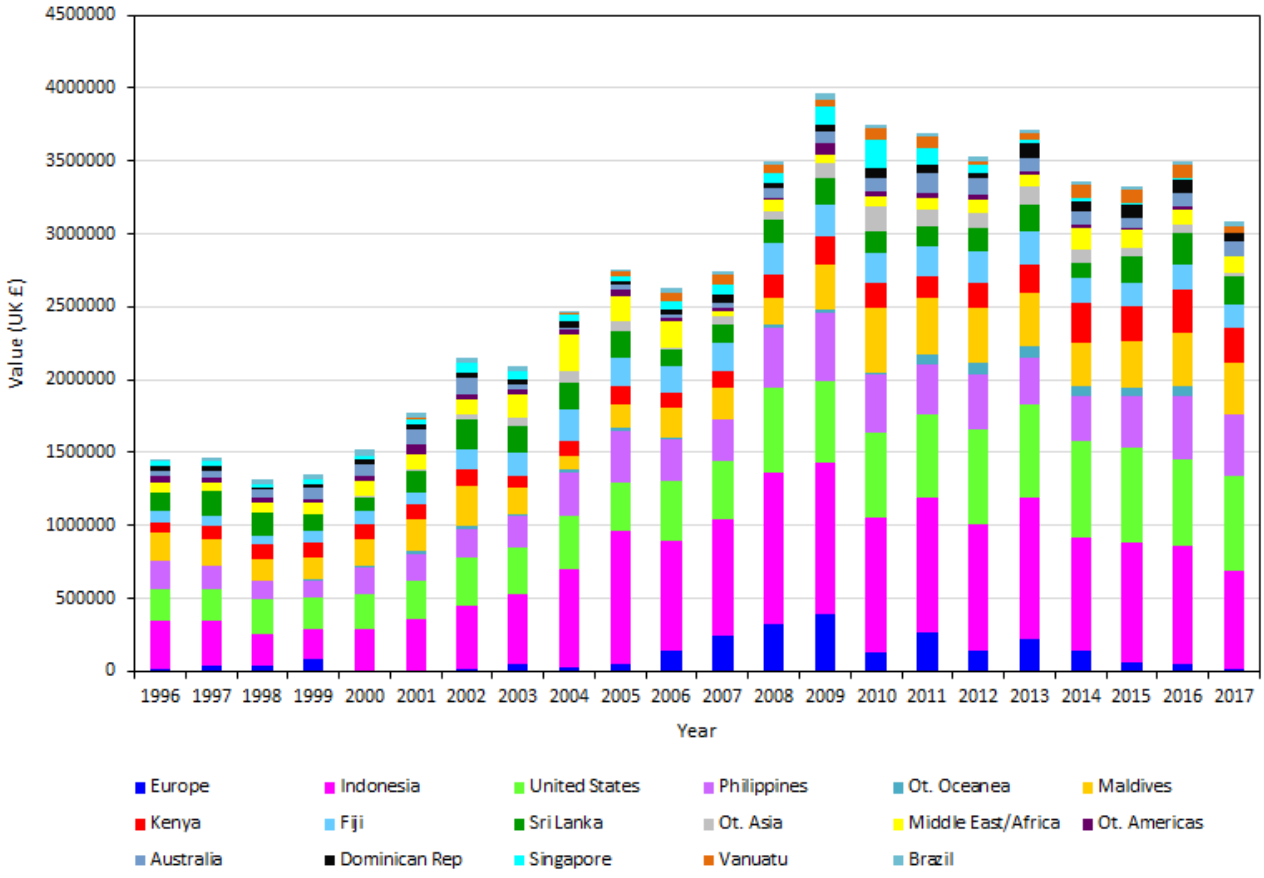

FIGURE 4 The $\log_e$–$\log_e$ relationship between price and abundance (number of individuals) of marine fish species recorded in 50 aquarist retailers in the UK (r^2 = 0.090, n = 380).