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Original Research Article

Quantifying the trade in marine ornamental fishes into Switzerland and an estimation of imports from the European Union

Monica V. Biondo

Institute of Ecology and Evolution, University of Bern, Baltzerstrasse 6, 3012 Bern, Switzerland

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ABSTRACT

Millions of marine ornamental fishes are traded every year. Today, over half of the known nearly 4000 coral reef fish species are in trade with poor or no monitoring and demand is increasing. This study investigates their trade into and through Switzerland by analyzing import documents for live animals. In 2009, 151 import declarations with attached species lists for marine ornamental fishes from non-EU countries totaled 28 356 specimens. The 62% of the fishes remaining in Switzerland, comprised 440 marine species from 45 families, the rest transited to EU and non-EU countries. Despite the recognized large trade volume for the European region, due to bilateral agreements, no data is collected for imports from the EU. However, inferred data shows that more than 200 000 marine ornamental fishes could be imported into Switzerland every year and an unknown quantity re-exported. As biggest import region, it is therefore safe to assume, that the European region is importing at least as many marine ornamental fishes as the US. There is no adequate data-collecting system known to be in place in any country for monitoring this trade. The EU Trade Control and Expert System (TRACES) to monitor animal diseases could be adjusted to gather compulsory information for the EU and Switzerland. More than half of the species imported into Switzerland are not assessed by the IUCN and therefore marked as 'not evaluated' on the Red List. Overall, 70% of all known coral reef fish species have not been evaluated. If coral reef fishes are threatened or endangered due to large, possibly unsustainable numbers traded, it may be rational to monitor the trade in these species through the Convention on International Trade of Endangered Species (CITES).

1. Introduction

Coral reefs occupy less than 0.1% of the total expanse of the world's ocean areas (Spalding et al., 2001). However, coral reefs are considered to be amongst the most biologically rich and productive ecosystems on Earth, often referred to as the 'rainforest of the seas'. Coral reefs support approximately 4000 species of fish (Froese and Pauly, 2014) (or a third of the world's known marine fishes), about 800 species of reef-building corals (stony corals) (Veron, 2000), and a great number of other invertebrates (Spalding et al., 2001). Roughly 7.5% of the human population depends on coral reefs, for example, for food (Madin and Madin, 2015). However, over one third of the scleractinian corals are at elevated risk of extinction

E-mail address: monica.biondo@students.unibe.ch.

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(Carpenter et al., 2008). The world has effectively lost 19% of the original area of coral reefs, 15% are seriously threatened with loss within the next 10–20 years, and 20% are under threat of loss in 20–40 years (Wilkinson, 2008). Furthermore, overexploitation, coastal development (Wear, 2016) as well as land-based pollution (Lough, 2016) are identified as major threats.

Ornamental coral reef fishes and invertebrates are the most valuable product (Fotedar and Phillips, 2011; Wabnitz et al., 2003) that can be harvested from a coral reef, hence making it a profitable target for trade. In 2000, 1 kg of coral reef fish for the aquarium trade sold for US$500 whereas food fish sold for US$6 (Cato, 2003). Overcollection of coral organisms for the aquarium trade can have a significant impact on both population viability and the wider ecological system (Thornhill, 2012; Vagelli, 2011; Tissot et al., 2010; Bshary, 2003; Sadovy et al., 2001). According to a comprehensive study by the United Nations Environment Program (UNEP) and the World Conservation Management Centre (WCMC), the vast majority of fishes for marine aquariums come from the wild and only about 1% (approximately 15 species in 2003) are commercially produced and readily available (Wabnitz et al., 2003). The Food and Agriculture Organization of the United Nations (FAO) and the World Association of Zoos and Aquariums (WAZA) state that only 25 marine ornamental fish species are being captive bred in commercial numbers (Penning et al., 2009, Bartley, 2005). A list of captive bred marine ornamental fishes published by the Marine Breeders Association (MBA) lists 15 species in 2013 and 29 species of captive bred marine ornamental fishes in 2015 and 27 in 2016, which are readily availability in the US (Sweet, 2016a, b, 2014). There are reports of between 100 and 330 species of marine ornamental fish having been bred in captivity, largely on a hobbyist or research scale. Of these, approximately 30–35 species are currently in commercial production, albeit still on a relatively small scale (Sweet, 2016b; Fotedar and Phillips, 2011).

The United States (US) constitutes the largest importing country whereas all the countries of the European Union (EU) correspond to the largest market of marine ornamental fishes (Leal et al., 2015; Wabnitz et al., 2003). The diversity of species in trade has increased from 1000 marine ornamental fish species in 2001 and 1471 in 2005 (Rhyne et al., 2012; Wabnitz et al., 2003; Wood, 2001) to around 2300 species in international trade today (Rhyne et al., 2017) the volume being between 20 and 30 million a year (Wabnitz et al., 2003; Wood, 2001), 11 million alone to the US (Rhyne et al., 2017; 2012). Despite the volume and diversity of fishes traded few laws or regulations are in place to control this animal trade (Rhyne et al., 2017; 2012 and Wabnitz et al., 2003). Most exporting countries are reported to have either no specific management plans, or they have produced management plans that are rarely enforced and implemented based on weak scientific baseline studies or monitoring activities (Dee et al., 2014; Thornhill, 2012; Wabnitz et al., 2003).

Many fishes die during capture due to trauma, poor handling, stress and in transportation or as a result of poisoning from sodium cyanide, which, although illegal, is still widely used for the capture of reef fish throughout Southeast Asia and causes extensive fish mortality as well as damage to many more coral habitat animals (Dee et al., 2014; Cervino et al., 2003; Wabnitz et al., 2003). Therefore, the number of fishes extracted from the reefs must be higher than the estimated numbers (Militz et al., 2016). There are about two million private (Wabnitz et al., 2003) and about 1000 public (ConsultEcon, 2008) marine aquariums worldwide. Globally, many cities are planning to build new public aquariums (ConsultEcon, 2008) and also private demand is increasing (Santhanam et al., 2015; Fotedar and Phillips, 2011). Animation films such as Disney/Pixar's 'Finding Nemo', which first aired in 2003, seem to promote incentives to own marine aquariums in domestic environments, which may have a significant impact on trade and keeping (Frisch et al., 2016; Madduppa et al., 2014; Jones et al., 2008). Conservationists worry that the follow-up film 'Finding Dory'could spike trade volumes as, in contrast to the main character in 'Finding Nemo', a clown fish, Dory, a surgeon fish, cannot be bred in captivity. So far, no increase in trade could be observed (Militz and Foale, 2017).

Data regarding numbers of marine ornamental fishes entering Switzerland is very limited. In 1995, the Swiss Animal Protection Organization (Schweizer Tierschutz STS) estimated that the most commonly kept pets in Switzerland constituted seven million ornamental fishes (Stumpf, 1995). The US is estimated to keep 160 million ornamental fishes (ASSALCO, 2015), around 10 millions of which are of marine origin (Rhyne et al., 2012). Very few marine ornamental fish are protected or monitored by the Convention on International Trade of Endangered Species (CITES), the exceptions are sea horses (*Hippocampus* spp.), the humphead wrasse (*Cheilinus undulates*) and since 2017 the clarion angelfish (*Holacanthus clarionesis*). Trade information on marine ornamental fishes in Europe is collected through the trans-European veterinary health agreement (Trade Control and Expert System TRACES).

Declarations pertaining to shipments from outside the EU are recorded on the Common Veterinary Entry Document (CVED) and it is optional to list species. The CVED is used in Switzerland as well as in the EU. A registered importer or private person has to declare imports to the appropriate border veterinary control body prior to importation. Border customs execute random checks by inspecting two boxes per shipment. Due to bilateral agreements, no import declarations are required to accompany a shipment when entering Switzerland through an EU country (European Trade Commission, 2016). In order to be able to monitor or restrict trade for a marine ornamental fish not only biological and ecological criteria are necessary (which are lacking for 70% of all known coral reef fishes) but also trade volumes are required. Both are necessary to convince the world community of the necessary of CITES-listing of species to monitor trade.

Except for very few studies on the marine ornamental fish trade (Rhyne et al., 2017, 2012; Smith et al., 2009, 2008), to date, no other study has tried to quantify the imports of marine ornamental fishes. The present study focuses on the import of marine ornamental fishes into Switzerland and their transit to EU and non-EU countries through Switzerland in 2009. This study is the first to analyze CVED information for the European region.

2. Materials and methods

The Swiss Federal Food Safety and Veterinary Office (FSVO) is responsible for the inspection of live wildlife shipments, but is not instructed to keep any species-specific data. Data on all imports of live animals, dead specimens, hunting trophies, medical animal materials, etc., which are not under the jurisdiction of the Convention on International Trade of Endangered Species (CITES) are collected through the Common Veterinary Entry Document (CVED) and transferred voluntarily to the electronic database Trade Control and Expert System (TRACES). This data is not intended for the supervision of wildlife trade, rather it serves to monitor animal diseases. Usually, these CVED documents are stored for three years, after which they are destroyed, and a retrospective analysis is no longer possible. All third countries (i. e. non-EU-countries) have to declare all exports of live animals at the border to an EU country or to Switzerland. However, due to bilateral agreements for fishes no border control is implemented between the EU and Switzerland and, therefore, no detailed information exists regarding coral reef fish species entering Switzerland through the EU.

Records of marine ornamental fishes are kept under the general data grouping of 'ornamental fishes', which comprises saltwater and freshwater fishes as well as invertebrates. To assess the volume of marine ornamental fishes imported into Switzerland, all declarations containing marine ornamental fishes were first identified from 2009 import declarations, which were made available to this study in 2013. To estimate the number of marine ornamental fishes entering Switzerland from imports without species lists, numbers of other pet animals in the US and European region were compared and two calculations were performed. Variant 1 assumes that the average specimens/shipment/destination (Switzerland or transit) is the same for the shipments without a species list as for the one with a species list. In variant 2, the number of specimens is calculated by expecting that the ratio of shipments of marine ornamental fishes to freshwater to invertebrates is the same for the shipments without a species list as for the one with species list. Both variants assume that 90% of ornamental fishes are freshwater species (Monticini, 2010; Bartley, 2005; Wabnitz et al., 2003).

All shipment declarations from the CVED documents and attached commercial invoices came through the airport of Zurich. Basel and Geneva airports had no discernible imports of marine ornamental fishes, and imports from online buyers and private persons importing by car could not be accounted for. Where a species list was included, the information was entered manually into a database at species level, citing the number of individuals, and, if available, body size and value were also recorded. The export country was listed as origin of the fishes. Not all importation documents included invoices and species lists, and documents that did not contain the required information were not considered for the calculation. In all cases, species names were verified using the World Register of Marine Species (WoRMS) (Appeltans et al., 2011) and FishBase (Froese and Pauly, 2014) and corrected when species names were misspelled, listed under a former synonym, or listed with common names (4% of cases). Forty-seven specimens (0.2%) were not identified to the species level and were removed from analyses where the species level was required. The information on the IUCN Red List status was gathered from FishBase (Froese and Pauly, 2014).

3. Results

3.1. Origin and destination

For 2009, 1478 import declarations labelled ornamental fishes for the aquarium industry from non-EU countries were counted. Of those imports, 55.9% contained only freshwater ornamental fishes, 28.6% did not have a species list, 5.3% contained only marine invertebrates, and 10.2% contained both marine and freshwater ornamental fishes. Of these, 45% stayed in Switzerland and 55% were transshipped to EU and non-EU countries. The marine fishes destined for Switzerland came from eight countries; Indonesia being the main exporter, followed by Sri Lanka, Singapore and the Philippines (Table 1). The size of shipment ($n = 68$) averaged 260 marine ornamental fishes with the smallest shipment containing 3, the largest 1070 fishes ($SD = 247$). Of the 422 import declarations without species lists 12% were destined for Switzerland. Of the 373 import (transshipped) declarations without a species list 55% were exported to Canada, followed by Israel with 13% and the US with 6%.

3.2. Number of imported ornamental fishes

Of the 1478 import declarations 1056 contained species lists. 68 declarations included marine fishes (17 673 specimens) whose final destination was Switzerland, 83 declarations (10 683 specimens) were transshipments of marine ornamental fishes, 826 declarations contained only freshwater fishes and 79 declarations were invertebrates. Import declarations with marine ornamental fishes consistently included freshwater fishes. In total, the import declarations contained 28 356 marine ornamental fishes (Table 2). 422 declarations did not enclose a species list, but 91% contained numbers of specimens of marine and freshwater fishes as well as invertebrates and totaled in 4 440 427 specimens. Of these, 96 268 remained in Switzerland and 4 344 159 were transshipped to EU and non-EU countries (Table 2).

Besides the counted 28 356 marine ornamental fishes that entered Switzerland in 2009, data for shipments without species lists inferred from known average marine ornamental fish specimens per shipment ($CH = 260$, $transit = 129$) resulted in a further 8627 specimens (variant 1). Inferring the ratio of shipments of marine to freshwater to invertebrates with species lists to the ones without species lists (average $CH + transit = 188$) resulted in 11 332 marine ornamental fishes (variant 2) that

Table 1
Origin and destination of shipments as well as number of shipments (= import declarations) containing species lists of marine ornamental fishes.

Origin	Final destination	Number of shipments	Number of fish specimens with final destination Switzerland
Singapore	Switzerland	21	1892
	Spain	32	
	Serbia	1	
	Russia	1	
	Romania	1	
	Portugal	11	
	Israel	1	
	Ireland	1	
	Germany	1	
	Czech Republic	3	
Sri Lanka	Switzerland	11	2179
	Russia	1	
	Romania	5	
	Portugal	5	
	Poland	2	
	Canada	1	
Indonesia	Switzerland	25	11 167
Thailand	France	11	
United States	Switzerland	5	522
	Russia	2	
Philippines	Switzerland	2	671
Vietnam	Switzerland	1	219
Kenya	Switzerland	2	659
Israel	Portugal	1	
Japan	Portugal	1	
Netherlands Antilles	Switzerland	1	364
Tanzania	Poland	1	
Total		151	17 673

were possibly additionally imported into Switzerland. Therefore, between 36 983 (variant 1) and 39 688 (variant 2) marine ornamental fishes could have entered the country in one year (Table 2). Due to bilateral agreements between Switzerland and the EU, no data is gathered for shipments entering Switzerland via the EU.

For 12 385 fishes (70% of 17 673), a value was specified on the import declarations, and the import prices ranged from US$0.20 to US$260 per fish. The average price for a fish was US$3.

3.3. Species

The 68 imports remaining in Switzerland and containing marine fishes totaled 17 673 specimens. These imports comprised 440 species from 45 families. The family with the most species was Labridae (70 species, 11.3% of specimens) followed by Pomacanthidae (47 species, 6.7% of specimens). The family with the most specimens was Pomacentridae at 27%. The six families with the most specimens represented 62% of species and 70.3% of individuals imported (Table 3). Four species from two families (Pomacentridae and Labridae) including the clown anemonefish (*Amphiprion ocellaris*) and the bluestreak cleaner wrasse (*Labroides dimidiatus*) represented 20.9% of the traded fishes. For 81% of the 17,673 fishes, there was no information on body size. From the 3343 fishes with body size information, 28% were labelled juvenile, 34% were medium sized (most probably sub-adults), and 38% were adults. Of the 940 juvenile fishes (from 84 genera), 902 fishes (from 55 genera) exhibited an ontogenetic dichromatism compared to the adult stage; specifically, angelfishes (Pomacenthidae). Of the 1273 adult fishes (from 110 genera), 425 were clown anemone fishes (*A. ocellaris*) followed by the longhorn cowfish (*Lactoria cornuta*) with 57 fishes and the bluestreak cleaner wrasse (*L. dimidiatus*) with 48 fishes.

3.4. Conservation status

Of all species entering Switzerland 51.8% were listed as ‘not evaluated’, 2.5% were ‘data deficient’, 43% ‘least concern’, 0.7% were ‘near threatened’, 0.5% were ‘vulnerable’, and 0.2% (one species, *Pterapogon kauderni*) was ‘endangered’. Six species were not listed by FishBase. An analysis of the conservation status of all known coral reef fish species that are listed in FishBase (Froese and Pauly, 2014) showed that of all recorded 3711 coral reef fish species, 70% are not evaluated (Table 4).

Of the ten most imported fish species, seven are included on the IUCN Red List as ‘not evaluated’. At import rank 1 is *Chromis viridis*, with 1600 specimens, followed by *Amphiprion occellaris* with 1008 specimens. Also, *Chrysiptera parasema* at rank 4, the *Pseudanthias squamipinnies* at rank 5 and *Valenciennea puellaris* at rank 7 as well as *Zoramia leptacanta* at rank 8 and *Synchiropus splendidus* at rank 10 are not evaluated by the IUCN Red List. *L. dimidiatus* (rank 3) with 597 specimens and *Paracanthurus hepathus* (rank 9) with 346 specimens are listed as warranting ‘least concern’. *P. kauderni* (rank 6) with 413 specimens is listed as ‘endangered’ (Fig. 1).

Table 2
Number of import declarations with and without species lists of ornamental fishes staying in Switzerland (CH) or transshipped to EU and non-EU countries. Origin are non-EU countries. Variant 1: inferring data using the average specimens/shipment and assuming that 90% of ornamental fishes are freshwater. Variant 2: inferring amounts from the number of shipments with species lists and number of specimens. No information is available for shipments entering Switzerland via the EU. Inferred values in bold.

	Origin	Species list	Destination	Type	Counted shipments	Inferred shipments	Counted specimens	Inferred specimens	Counted specimens/ shipments	Total of counted and inferred specimens
Variant 1	**Non-EU**	With species list	CH	Marine	68		17 673		260	
				Freshwater		**364**		**159 057**	**437**	
				Invertebrates	34		60 805		1788	
			Transit	Marine	83		10 683		129	
				Freshwater	**462**			**96 147**	**208**	
				Invertebrates	45		467 212		10 382	
			Total CH + transit	Marine	151		28 356		**188**	
				Freshwater	826			**255 204**		
				Invertebrates	79		528 017		6684	
				Total	1056			**811 577**	**769**	
		Without species list	CH	Marine		**7**		**1860**	**260**	**19 533**
				Freshwater				**7774**	0.9	
				Invertebrates				**87 631**	**1788**	
			Total CH	MarFreInv	49		96 268			
			Transit	Marine		**52**		**6768**	**129**	
				Freshwater				**424 342**	0.9	
				Invertebrates				**3 872 668**	**10 382**	
			Total transit	MarFreInv	373		4 344 159			
			Total CH + transit	Marine				**8627**		**36 983**
				Total	422		4 440 427		10 522	
Variant 2		With species list	CH	Marine	151		28 356		**188**	
				Freshwater	826		255 204		**309**	
				Invertebrates	79		528 017		**6684**	
				Total	1056		811 577			
		Without species list	CH + transit	Marine		**60**		**11 332**	**188**	**39 688**
				Freshwater		**330**		**101 985**	**309**	
				Invertebrates		**32**		**211 007**	**6684**	
				Total	422			**324 323**		
			Total		1478					

Table 3
Family and number of species as well as specimens imported into and remaining in Switzerland in 2009. Top 20 families, ranked according to number of specimens; the first six families represent 70% of the total number of individuals imported.

Family	Species	Specimens
Pomacentridae	43	4763
Labridae	70	1991
Gobiidae	46	1958
Acanthuridae	38	1369
Pomacanthidae	47	1186
Serranidae	29	1157
Apogonidae	8	942
Chaetodontidae	42	738
Callionymidae	7	666
Blenniidae	18	617
Ptereleotridae	7	428
Pseudochromidae	10	263
Syngnathidae	8	194
Ostraciidae	3	184
Monacanthidae	11	144
Scorpaenidae	9	128
Grammatidae	1	124
Siganidae	4	123
Zanclidae	1	114
Tetraodontidae	9	94
Other	29	490

Table 4
IUCN Red List evaluation (%) of marine ornamental fish species imported into Switzerland. Switzerland, n = 440 (left) compared to worldwide known species, n = 3711 (right).

IUCN Red List Definition	Switzerland	Worldwide
Not evaluated NE	51.8	70.0
Data deficient DD	2.5	3.3
Least concern LC	43.0	23.2
Near threatened NT	0.7	1.1
Vulnerable VU	0.5	2.1
Endangered EN	0.2	0.2
Critically endangered CR	0.0	0.1
Not listed	1.4	0.0

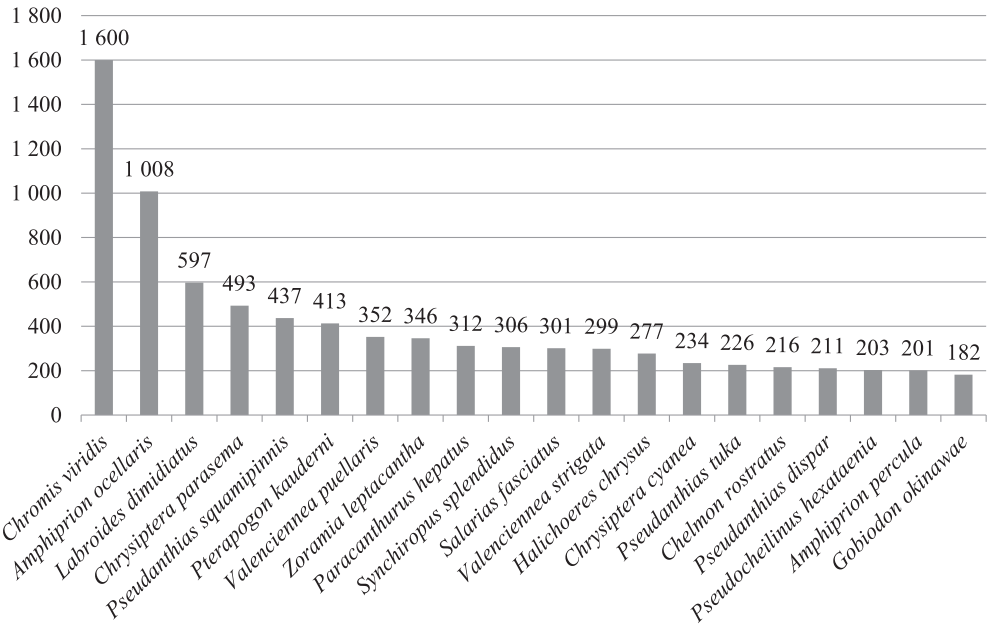

Fig. 1. Number of specimens of the top 20 marine ornamental fish species imported and remaining in Switzerland in 2009.

4. Discussion

4.1. Origin, destination and trade volume

In 2005, FAO estimated the entire freshwater and marine ornamental fish industry (non-exported products, wages, retail sales and associated materials) to be worth around US$15 billion. Considering that the marine ornamental fish trade amounts to 10% of the entire marine/freshwater ornamental fish industry (Monticini, 2010; Bartley, 2005; Wabnitz et al., 2003), this would translate to approximately US$1.5 billion a year. Collectively, European Union countries constitute the largest market (500 million consumers) for ornamental fishes (Leal et al., 2015), and Indonesia is the largest exporter, followed by the Philippines (Leal et al., 2015; Rhyne et al., 2012; Wabnitz et al., 2003).

Previously, no study has attempted to quantify the import volume of marine ornamental fishes into Switzerland through the available import documents. The only previous research on trade relied on oral or written information provided by Swiss importers and retailers (Weber, 2001).

The present analysis relies on the quantitative information contained on the shipping declarations (Common Veterinary Entry Document CVED) and the associated species lists. This study found that in one year, Switzerland imported 28 356 marine ornamental fishes, of which 17 673 specimens belonging to 45 families remained in Switzerland and came from eight countries. Switzerland imported most fishes from Indonesia followed by Sri Lanka (rather than the Philippines as is the case for the US, probably because Sri Lanka is geographically closer and Switzerland has a strong Sri Lankan community).

Almost a third of all imports lacked a species list, although 91% declared a total amount of ornamental fishes, which totaled 4 440 027 (marine, freshwater fishes and invertebrates). To overcome the uncertainties regarding the number of marine ornamental fishes entering Switzerland, two variants were used to calculate possible volume. Adding the inferred number of marine ornamental fishes to those formally counted, it is possible that almost 40 000 (between 36 983 and 39 688) marine

ornamental fishes entered Switzerland in one year with one part being re-exported. However, it is very important to take into consideration that, due to bilateral agreements, no information at all is available for shipments entering Switzerland through the EU and therefore probably a substantial portion of this trade is not accounted for.

Comparing population, wealth and pets of the US, EU and Switzerland it seems peculiar that Swiss households should keep 10 times less marine ornamental fishes per capita than the US or the EU/UK (Table 5). Assuming that Switzerland imports (without re-exporting) the same volume of marine ornamental fishes per capita as the US, this would result in 240 000 marine ornamental fishes entering and staying in Switzerland every year (8 million citizen x 0.03 fishes). This would result in an estimated number of unreported cases of about 220 000 marine ornamental fishes (240 000 calculated - 17 673 counted - 1860 inferred fishes). As there are no declarations of this trade between the EU and Switzerland due to bilateral agreements, these specimens are likely to be coming from the EU.

Wabnitz et al. (2003) and Rhyne et al. (2017, 2012) state that the main destination countries are the US and the EU, which is reflected by the almost identical value of imported marine ornamental fishes in US$ for the two regions (Table 5). Although, the EU has about 60% more people than the US, but a 30% lower GDP, it is therefore possible that the EU imports a similar amount of marine ornamental fishes as the US. This supports an assumption that wealth is loosely coupled with fishes per capita.

4.2. Species

The diversity of species in trade has been increasing. Studies show that during approximately the last 20 years the species in trade worldwide rose from 1000 to about 2300 coral reef fish species (Rhyne et al., 2017, 2012; Wabnitz et al., 2003; Wood, 2001). Moreover, in one year (2004-5) the US, the main importing country, imported almost 10.5 million marine ornamental fishes, representing 125 families (Rhyne et al., 2012) re-exporting about 1 million marine ornamental fishes. The number of marine ornamental fish species in the aquarium trade will probably continue to increase, as demand for new species has been growing (Rhyne et al., 2017). Globally, the number of home aquariums (Rhyne et al., 2017; Santhanam et al., 2015; Fotedar and Phillips, 2011) is growing and new public and private aquariums are being built or planned (Google search, 2014). There is growth potential for the aquarium industry, as only half of the 100 major cities (more than three million habitants) have a public aquarium, in particular in China, the Middle East, North America, Southeast Asia, South America and Eastern Europe (ConsultEcon, 2008). As commercial fishing and storage equipment become more sophisticated, it will also be easier to acquire stock. This is underlined by the fact that within approximately 20 years, the marine aquarium hobby developed from 'fishes-only' aquariums to entire coral reef set-ups, with people spending up to US$20 000 for uncommon organisms (Ho, 2013; Courchamp et al., 2006). FAO calculated that between 1985 and 2005 the marine ornamental fish industry increased by 14% annually (Bartley, 2005). Most capital does not remain in the source country and is passed to importers and other traders, as well as to retailers in the importing nation. For example, fishermen receive approximately US$0.05 per Banggai cardinal (*P. kauderni*) caught (personal communication Vagelli, 2015) whereas the same fish is sold for up to US$65 in Switzerland (a 1300-fold increase) (Aqula, 2016). Furthermore, tank-bred marine ornamental fishes command at least 25% higher prices than wild-caught fishes (Fotedar and Phillips, 2011).

Table 5
Comparison of marine ornamental fishes (specimens), number of public aquariums and fishes per capita, as well as households with pets and per capita dog, cat and bird pets between the USA, the EU, the UK and Switzerland, N. d. = no data. Where available, data from 2009 was used.

	USA	EU-27[a]	UK	CH
Human population in millions (2009)[b]	307	503	62	8
GDP per capita in US$ (2009)[c]	47 000	34 000	37 000	70 000
Imported marine ornamental fish specimens in millions staying in country	10.5 (2005) (Rhyne et al., 2012)	n. d.	1.4 millions (2014)[d]	0.02 (this study)
Value of imported marine ornamental fishes (US$) in millions	11.2 (LEMIS, 2011)	11.3 (mean 2000–2011) (Leal et al., 2015)	4.6[d]	n. d
Number of public aquariums	118[e]	135[f]	28[f]	0
Imported marine fishes per capita	0.034	n. d.	0.02	0.003
Homes with pets in millions	80[g]	75 (2014)[h]	n. d	0.88[j]
Dogs per capita	0.3 (2015)[g]	0.2 (2014)[h]	n. d.	0.07[j]
Cats per capita	0.3 (2015)[g]	0.2 (2014)[h]	n. d.	0.2[j]
Birds per capita	0.05[g]	0.08[h]	0.02[i]	0.07[j]

[a] includes the UK.
[b] http://data.worldbank.org/indicator/SP.POP.TOTL?end=2009&start=1981.
[c] http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2009&page=1&start=1960.
[d] http://www.ornamentalfish.org/wp-content/uploads/Wild-caught-ornamental-fish-the-trade-the-benefits-the-facts.pdf.
[e] https://en.wikipedia.org/wiki/List_of_aquaria_in_the_United_States.
[f] https://en.wikipedia.org/wiki/List_of_aquaria#Europe.
[g] http://www.americanpetproducts.org/press_industrytrends.asp.
[h] http://www.fediaf.org/facts-figures/.
[i] http://www.pfma.org.uk/pet-population-2008-2012.
[j] https://www.hausinfo.ch/de/home/wohnen/haustiere/haustiere.html.

For over 80% of the imported fishes, information regarding size class was not included. However, over 60% (2070 specimens) of those fishes carrying size data were labelled as juveniles and sub-adults. Almost all juvenile fishes in the present study manifested ontogenetic dichromatism, i.e. juveniles and sub-adults showed different coloration compared with adults, and this is also the case for Pomacanthidae, which represents the second most traded family. These species seem to attract particular interest from the aquarium industry in Switzerland, as well as in the US and worldwide (Rhyne et al., 2012; Wabnitz et al., 2003). In addition, some coral reef fishes are sequential hermaphrodites (changing sex during their life cycle), and fishing may result in a sex drift, and ultimately in a reduction of size in natural populations (Coleman et al., 2000).

4.3. Conservation status

The natural habitat of coral reef fishes, the coral reefs, faces great threats such as climate change (Frieler et al., 2012; Hughes et al., 2007), ocean acidification and over collection for food and of key species (Hoegh-Guldberg, 2007). Moreover, there are no controlling entities in place for establishing sustainable trade. The Marine Aquarium Council (MAC) was established in 1998 in order to ensure responsible fishing, including the use of nets instead of illegal use of poison, and good husbandry, as well as managing fair prices - allowing consumers to choose more responsible operators and traders. Conforming companies were certified (MAC label) (UNEP, 2009). However, this certification has not been active since 2008 (GuideStar, 2014). Albeit this failing, Murray and Watson (2014) argue that a certification scheme which would be founded with governmental support could be a very efficient way to move towards a self-regulated commerce.

With few exceptions, for example *P. kauderni*, which has been thoroughly studied (CITES, 2016; Conant, 2015; Vagelli, 2011, 2008, 2002; Lunn and Moreau, 2004), very little information is available on the ecology, life cycle, and population dynamics for many known coral reef fish species. This dearth of information is arguably a major concern regarding the evaluation of potential threats to coral reef fishes.

4.4. Case studies

The Banggai cardinalfish (*P. kauderni*) endemic to Eastern Sulawesi, Indonesia, is a very popular marine ornamental fish in Switzerland (import rank 6) and the US (import rank 10) as well as worldwide (Rhyne et al., 2012; Wabnitz et al., 2003) and only caught for the aquarium trade. As of 2016 the US included *P. kauderni* in its Endangered Species Act ESA enabling protection through US laws (Conant, 2016). The species plays an important role in its environment by preying on larval stages of coral reef fish parasites, and as a prey item for several fishes and a sea snakes (CITES, 2016; Conant, 2015; Vagelli, 2011, 2008, 2002; Lunn and Moreau, 2004). Physical injury during capture, confinement in holding pens, and transportation stresses result in high mortality (Lilley, 2008). In addition, mortality can be approximately 80%–100% between post-import and consumer stages (Vagelli, 2011). It has been estimated that the abundance of *P. kauderni* within its natural range (~23 km^2) (CITES, 2016) has suffered an approximate 90% decline compared with its pre-harvest level (Vagelli, 2011; Allen and Donaldson, 2007). Some *P. kauderni* populations have already been overexploited and others extirpated (CITES, 2016; Conant, 2015; Vagelli, 2011, 2008, 2002; Lunn and Moreau, 2004). Although captive breeding *P. kauderni* is possible, wild caught fish are considerably cheaper and, therefore, widely traded (Vagelli, 2011). Attempts to restrict trade through CITES in 2007 and 2016 failed, although in 2016 the CITES member states decided that Indonesia will have to implement protection and management schemes by the mid 2018 (CITES, 2016). In 2007 the species was listed as 'endangered' by the IUCN. In light of the information available today, a listing of this species in CITES would be warranted and developing conservation approaches with the local communities could be beneficial to the species (Ferse et al., 2010).

The bluestreak cleaner wrasse (*L. dimidiatus*) was the third most imported marine ornamental fish in Switzerland and also one of the most imported species into the US and the EU (Rhyne et al., 2012; Wabnitz et al., 2003). *L. dimidiatus* fairs poorly in aquariums (Michael, 1999), but is essential to the health of coral reefs and drives diversity. The species removes ectoparasites from other animals and thus reduces parasite abundance (Grutter, 1999). Studies have shown that the species' absence is followed by a rapid decline of fish diversity (Waldie et al., 2011; Bshary, 2003).

The palette surgeonfish (*Paracanthurus hepatus*), at import rank 9 in Switzerland, is also one of the most traded and valuable marine ornamental fish traded in the US and worldwide (Rhyne et al., 2012; Wabnitz et al., 2003). The species requires a continuous intake of zooplankton (Thaler, 2015), reacts aggressively toward other surgeonfishes or coral reef fishes, is notably susceptible to disease (Corrales et al., 2009), and became well known as a result of the Disney/Pixar film 'Finding Nemo'. However, contrary to anemone fishes, it cannot be bred in captivity partly because very little is known of its very long larval cycle (Thaler, 2015, 2008). In 2016, the new Disney/Pixar film 'Finding Dory', which portrays a female *P. hepatus* as the primary character, and has led to concern that a surge in trade in this species may result, as occurred with anemone fishes when 'Finding Nemo' was screened (Frisch et al., 2016; Madduppa et al., 2014; Jones et al., 2008), but an increase does not seem to be happening (Militz and Foale, 2017) as *P. hepatus* grows to 30 cm, too big for home aquariums, and is much more difficult to keep (Thaler, 2015).

The mandarinfish (*S. splendidus*), at import rank 10 in Switzerland, manifests intricate fins and bright colors, and accordingly it is a highly prized fish in the marine aquarium trade in the US and worldwide (Rhyne et al., 2012; Wabnitz et al., 2003). Up to 70% of fish caught are male (Wabnitz et al., 2003). Female mandarin fishes may refuse to mate with smaller males (Sadovy et al., 2001). The species' leads a relatively secluded lifestyle, and this has led collectors to develop a spear fishing method for their capture, which can result in injury, paralysis, or even death (Thornhill, 2012). Furthermore, most individuals

of these species do not acclimatize to the home aquarium, often refusing to feed, and consequently succumb to disease and death in captivity (Wabnitz et al., 2003; Michael, 1999). Captivity-related mortality increases demand, driving additional collection and results in further harm to mandarinfish populations (Sadovy et al., 2001).

5. Conclusion

This and other publications (Rhyne et al., 2017, 2012; Leal et al., 2015) show that collecting data via customs documents may lack precision due to data deficiency, although the method does provide a general overview of this trade. Regardless, more detailed information is warranted and important. The lack of trade controls and of an adequate information system for recording all imported and (re-) exported (transitory) marine ornamental fishes renders the monitoring of trade in marine ornamental fishes very difficult, if not impossible. Catch data at the species level is important when attempting to assess the effects of collection, development of management strategies, and assessment of their efficacy (Wabnitz et al., 2003). In addition, more detailed information should be collected in order to be able to quantify what effects trade is having on ecology, species conservation, and animal welfare. In Switzerland up to the year 2013 marine and freshwater ornamental fish as well as invertebrates where recorded as ornamental fish only. Since 2013, the electronic database TRACES (Trade control and Expert System) used by customs in Switzerland and the EU includes a list of approximately 2000 marine ornamental fishes, although TRACES is not suited to accurately monitor trade data. At present a trader can voluntarily state the number of specimens imported. Additional compulsory information such as volume, origin and size of specimens, and whether animals are wild-caught or captive-bred, should also be collected. Accordingly, and although not fully accurate (Rhyne et al., 2012; Smith et al., 2009, 2008; Jennings and Polunini, 1999), it has been suggested that the similar US database LEMIS (Law Enforcement Management Information System) could be adapted to incorporate more information on ornamental fishes, and hence be a useful tool to collect data concerning the coral reef fish trade (Rhyne et al., 2012; Tissot et al., 2010) but overall trade control have to improve (Foster et al., 2016; Chan et al., 2015). Also, these two databases could be made compatible to exchange information and support the data analysis.

To conserve and manage reef fishes properly, it is important to first identify those species that are susceptible to over-collection (Jennings and Polunini, 1999). However, in order to reliably assess the conservation status of relevant species, data regarding the ecology, population dynamics, and recruitment patterns are required, yet often poorly known. Because more than half of the specimens entering Switzerland, and 70% of all known marine ornamental fishes, are not evaluated using the IUCN Red List, it is recommended that all the known coral reef fish species listed in FishBase are urgently assessed by the IUCN. Potential impacts associated with the overall international trade remain unclear because data is only collected accurately for organisms listed in the CITES appendices (Bruckner, 2001), which therefore excludes very many species commonly in trade. Species, which are threatened by international trade should to be monitored by CITES (Murray et al., 2012). CITES listing requires that non-detriment findings will be conducted, and therefore, trade will not negatively impact species. Such a step was taken only three times. In 2002 all seahorses (*Hippocampus* spp.) as well as the humphead wrasse (*Cheilinus undulatus*) and in 2017 the clarion angelfish (*Holacanthus clarionensis*) were listed in CITES Appendix II to monitor their international trade (Foster et al., 2016; IUCN Red List, 2016). This situation indicates that it is important to have monitoring measures in place.

Conflict of interest

Author have been commissioned by the Swiss Federal Food Safety and Veterinary Office (FSVO) for data analysis and I am currently employed by the University of Basel and the Fondation Franz Weber.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.gecco.2017.05.006.

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