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Monitoring the trade in marine ornamental fishes through the European Trade Control and Expert System TRACES: Challenges and possibilities

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ABSTRACT

The trade in marine ornamental fishes is valued at over a billion dollars annually and comprises thousands of species. Historically, scientists have pointed out the importance of accurate trade statistics to monitor this trade. Today, there remains no global systems in place to monitor it. Europe is a major importer of coral reef fishes, and uses the Trade Control and Expert System (TRACES) to monitor trade in live animals for disease prevention. This database is not intended to record strict species-specific information on marine ornamental fishes, rather numbers of traded specimens and information on species to at least family level. Therefore, it is possible to estimate the volume of trade into Europe, which amounted to approximately 4 million marine ornamental fishes per year during 2014 and 2017. Susceptible species were identified using the number of traded specimens, trends in the trade volume, IUCN Red List conservation status, as well as vulnerability according to FishBase. After normalization of this data a score was created to produce a watchlist that establishes susceptibility to over-exploitation of the species traded considering all parameters combined. Unfortunately, almost one third of all species is listed as data deficient or not evaluated by the IUCN Red List and could not be included in this calculation. Species on the watchlist should be given priority for further monitoring through the Convention on International Trade of Endangered Species (CITES). This study suggests that TRACES, subject to several modifications, could be used as a tool to monitor trade in marine ornamental fishes.

1. Introduction

The international marine ornamental fish trade is a global, multi-billion-dollar industry targeting thousands of coral reef species [25,28,36], which are widely collected throughout the Indo-Pacific and Caribbean regions, mainly for the United States and the European market [4,5,10,26,36]. The habitats of coral reef fishes are largely in decline and threatened due to several global problems, including climate change, ocean acidification and pollution [6,11,14–16,22]. To aid preservation of coral reefs and adjacent habitats, and to develop trade sustainability, it is first important to have data regarding the number of specimens traded and the diversity of species collected. Today, there is no complete understanding of all the effects trade may have on coral reef ecosystems and adjacent habitats [23]. However, it is known, that the ornamental fish industry has already impacted coral reefs and their biodiversity regionally due to unsustainable harvest [10,26,27,35–37].

Several studies have collected data on the number of specimens and species diversity traded. In the early 21st century, estimates ranged between 24 and 27 million individuals globally per year [36]. A more recent review estimated that 1.5 billion ornamental fishes (freshwater and marine) are currently traded globally per annum, and that about 73% die in transport [31]. Considering that the marine ornamental fish trade totals 10% of the entire ornamental fish industry [24,36], this would result in approximately 40 million marine ornamental fishes being handled per year. Also, the mortality rate in the supply chain is a major concern associated with this international trade [9,24,31,32,35,36]. Given that the number of fish species in the trade has also increased going from around 1,000 species in 2001 [37] to 1,471 in 2004/05 [26] to 2,300 species currently [28], it is important that this trade be monitored to scrutinize its sustainability.

With over 500 million inhabitants, the European Union (EU) is one of the largest consumer regions for marine ornamental fishes [4,19] after the United States (US) [26,28]. An economic assessment of the EU trade value accounted for € 135 million during the study period from 2000 to 2011 [19]. To date, the number of specimens traded and diversity of marine ornamental fish species entering the EU has only been estimated [4,5], but never quantified. Furthermore, the potential impact of trade on threatened species has not been analysed.

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This study used data from the EU database Trade Control and Expert System (TRACES) to analyse the number of specimens traded and the diversity of species and families of marine ornamental fishes entering the European region between 2014 and 2017. Furthermore with this data, and using parameters such as number of specimens traded, trends of trade volume, vulnerability and the IUCN Red List conservation status from FishBase [13], a watchlist was created that may help decision makers to conclude which species should be monitored through CITES. This study aims to emphasize the importance of species-specific trade data and to develop trade sustainability.

2. Material and methods

The Trade Control and Expert System (TRACES) is a management tool for tracking movements of animals, products of animal origin, and animal feed, but also plants and derivates from both outside and within the European Union [33]. TRACES aims to facilitate trade and prevent cross-border animal health issues. For TRACES, traders are required to be registered and complete customs documents titled Common Veterinary Document (CVDE), which physically accompany consignments. Traders also enter the same information into the TRACES database. The data are not publicly available. But may be accessed by government officials who can request full access via local TRACES representatives. For this study, the data were made available by the Directorate-General for Health and Food Safety of the European Commission.

TRACES is not meant to control wildlife trade or to collect species-specific information on wild animals. Nevertheless, TRACES collects data on trade in marine ornamental fish species and families for the EU. Importers are required to register their commodities at the border to a EU country [33]. TRACES was established in 2004, but collection of data on marine ornamental fishes only commenced in 2011. During the first three years until 2013, data lacked accuracy and were grouped into ‘otra pesca’ for other food fishes and were eliminated from our calculations. TRACES documents are web-based and can be completed online. TRACES records the species of fish in a predetermined pull-down list field called ‘species’, which may either contain the full scientific name or only a family name. This makes analysis of all species traded difficult. All records provided trade data at family level, but only a part thereof was discernible at species level. TRACES data from 2014 to 2017 were exported from TRACES into a local MS Access database to be analysed. This process separated the information of the TRACES species field into a real species field and a family field on the condition that, if it contains two words, it must be a species, otherwise it is recorded as a family [5]. All taxa in the MS Access database were checked manually using the World Register for Marine Species (WoRMS) [1] and FishBase [13], the most comprehensive database of the world's fishes. The records containing a species in the species field were then supplemented with the correct family name according to FishBase.

Fishes originating from land-locked countries were individually checked using the species name if available. Obvious freshwater ornamental fishes, e. g. from Malawi, were exempted from the study. Species identified originating from Turkey were retained although Turkey does not have a coral reef or tropical waters, but appears to act as a hub. Three shipments originating from Indonesia, Sri Lanka and the Philippines were identified as anonymous and eliminated from this study. Fishes that did not have a species name but were listed at genus level were manually checked using FishBase and WoRMS, and allocated a family name. Information on origin and destination, as well as number of specimens traded and diversity of species were analysed. The data were used to calculate trends in trade volume. Together with the IUCN Red List conservation status [17] and the vulnerability factors from FishBase [13], an attempt was made to ascertain the most impacted fishes. This was only possible for specimens where information was available at species level and which had a ‘threatened’ IUCN status.

A partial copy of the FishBase [13] database was replicated locally using fishbaseAPI provided by ropensci.org to filter marine species and assign an IUCN status as well as the vulnerability score. For each species a score was calculated using the following parameters: number of traded specimens, trends of trade volume, IUCN Red List conservation status, and vulnerability. The ranking of this score facilitated creation of a species watchlist: the higher the score the more susceptible the species could be to overexploitation.

2.1. Number of traded specimens

The number of specimens traded per species was normalized by allocating a value of 100 to the species with the highest four-year trade volume. To flatten the data, for each species the median were taken instead of the sum of the four years and the result was scaled from 0 to 100. Data that sheered out were not eliminated because they might be correct and spike are recorded by the trend.

2.2. Trends in trade volume

Trends for the number of specimens traded during the four years were derived by linear regression, which was named slope. The slope was normalized to values between 0 and 100. Positive numbers were divided by the maximum slope, negative numbers by the minimum slope, which again results in a positive number and was multiplied by 100.

2.3. IUCN Red List categories

The IUCN Red List categories were translated to a numerical value: least concern (LC) = 0, near threatened (NT) = 20, vulnerable (VU) = 40, endangered (EN) = 60, critically endangered (CR) = 80 and extinct in the wild (EW) = 100. Extinct (EX) did not receive a value because it is not possible to trade an extinct species. The status data deficient (DD) and not evaluated (NE) received no score due to a lack of information about the species. In the four years analysed, no species was ranked 80 or 100 because no traded species was listed as critically endangered or extinct in the wild, thus the assigned values do not change for a species if further years will be analysed in the future.

2.4. Vulnerability

For each species, FishBase calculates a value for vulnerability, which expresses the ability of a species to withstand external influences and is calculated using selected life-history parameters of a fish species such as maximum body length, age at first maturity, von Bertalanffy growth parameter K, natural mortality rate, maximum age, geographic range, annual fecundity, strength of aggregation behaviour [13]. Vulnerability is calculated according to a Fuzzy Logic System [7] and is expressed as a figure between 0 and 100. In the four years analysed, no species had a vulnerability value higher than 90. FishBase also presents a categorical resilience status, which reflects the species susceptibility to overexploitation. As resilience was highly correlated to vulnerability (0.68 correlation coefficient), it was disregarded in the analysis. Also, the analysis of the five parameters, i. e. number of specimens, trends in trade volume, vulnerability, resilience, and IUCN Red List conservation status, by primary component analysis (PCA), shows that only four primary components are necessary to describe the situation. The proportions of variance for PC1 to PC5 are 0.36, 0.21, 0.19, 0.19 and 0.06.

2.5. Score for the watchlist

After normalizing the four parameters (Table 1), a score was calculated for each species by adding up the values of the normalized parameters: number of traded specimens, trends in trade volume, IUCN Red List conservation status, and vulnerability. The higher the value of the score for a species, the higher it is ranked and the more attention it needs, i. e. monitoring through CITES. A species should either be on the

Table 1
(a) The statistical values of the not normalized parameters. Min. = minimum value, 1st Qu. = first quartile (lowest 25%), 3rd Qu. = third quartile (highest 25%), Max. = largest value. (b) The statistical values of the TRACES data using the normalized parameter scale. Total 4 years: number of traded specimens from 2014 to 2017, Trend: increase or decrease of trade volume, Vulnerability: score according to FishBase, IUCN category: IUCN Red List conservation status, NE = not evaluated, LC = least concern, VU = vulnerable, EN = endangered.

a)

	Total 4 years	Trend	Vulnerability	IUCN category
Min.	1	−28025.90	10.00	EN: 5
1st Qu.	17	−21.95	14.00	VU: 18
Median	166	−0.50	23.00	NT: 19
Mean	7,320	−93.20	25.23	LC: 846
3rd Qu.	1,530	6.70	31.00	
Max.	962,220	27,879.00	90.00	

b)

	nTotal 4 years	nTrend	nIUCN category	nVulnerability
Min.	0.00000	0.00	0.00	10.00
1st Qu.	0.0000	0.26	0.00	13.79
Median	0.0100	0.47	0.00	22.77
Mean	0.6516	8.04	1.577	25.50
3rd Qu.	0.0700	1.22	0.00	32.30
Max.	100.000	100.00	60.00	90.00

watchlist if it is ranked top in one of the parameters described above, or in a combination of multiple, medium or high parameter scores.

3. Results

3.1. Country of origin and number of specimens traded

Between 2014 and 2017 50 countries exported marine ornamental fishes to Europe. The main exporting country was Indonesia, which made up 34.4% of all shipments with on average 1,727,940 specimens annually. Indonesia was followed by Sri Lanka with 15.1% of shipments and 599,072 specimens and the Philippines with 12% of shipments and 309,350 specimens. These three countries, together with the United States, Singapore and Kenya made up 82.8% of all shipments and 84.7% of all specimens from 2014 to 2017 (Table 2). In total, 25,556 shipments with 15,599,053 specimens were imported into Europe with an average of 3,899,768 specimens a year (Fig. 1). The number of imported individuals has decreased from 100% (2014) to 68% in 2017 (Figs. 1 and 2).

Twenty-seven European countries imported marine ornamental fishes including Norway, San Marino and Switzerland, which are not members of the EU. The country importing most marine ornamental fishes was the United Kingdom followed by the Netherlands. These two countries made up 48.6% of all imports between 2014 and 2017 (Table 3.). Germany, Italy and France made up another 33.4% resulting in only five countries importing 82% of marine ornamental fishes (Fig. 2, Table 3).

Table 2
Top six countries of export of marine ornamental fishes to Europe between 2014 and 2017. Average and standard deviation of shipments and number of specimens traded per year. AVG = average, SD = standard deviation.

Country of Export	% Shipments		Specimens	
	AVG	SD	AVG	SD
Indonesia	34.4	1.7	1,727,940	223,726.8
Sri Lanka	15.1	1.1	599,072	44,163.3
Philippines	12	0.4	309,350	49,431.9
Unites States	8.6	0.5	302,255	145,034.4
Singapore	6.9	0.1	195,000	26,231.1
Kenya	5.8	1	170,934	113,045.8
others	17.2		595,212	
Total	100		3,899,763	

3.2. Diversity of imported marine ornamental fishes for 2014–2017

Between 2014 and 2017, fish species from 86 families were imported to Europe. The top 10 families made up 90% of traded marine ornamental fishes in number of specimens (Fig. 3). Labridae was the family with the highest number of imported species followed by Pomacentridae, which were also most traded in number of specimens (Fig. 3).

Because TRACES allows declaration of specimens either at the species or family level, this resulted in 29.4% off all specimens between 2014 and 2017 being known only at the family level. The number of identified increased species from 2014 with 61.1% (4,747,136 specimens) to 78% (3,225,091 specimens) in 2017.

In four years 1,334 species were recorded and imported to Europe with *Chromis viridis* being the most imported species comprising 13.1%, followed by *Amphiprion ocellaris* with 10.7% and *Centropyge bicolor* with 8.7% of the total volume (Table 4). The 20 most traded species constituted 63.8% of the overall volume for the four years (Table 4). Half of the top 20 species showed a decrease while the other half of species showed an increase in specimens traded (Table 4).

The IUCN Red List conservation status of all 1,334 species traded between 2014 and 2017 showed 33.63% to be data deficient or not evaluated (Table 5), almost two thirds as being least concern and only 0.37% of species (5 species: *Cheilinus undulatus*, *Epinephelus striatus*, *Pterapogon kauderni*, *Sphyrna lewini*, *Stegostoma fasciatum*), as endangered (Table 5). There were no species assessed as critically endangered, extinct in the wild or extinct (Table 5).

3.3. The watchlist

Using all marine ornamental fishes imported into Europe between 2014 and 2017, a list was compiled where the ranking is given by the score. Thereof, 17 species that reached an overall score of 100 were put on a watchlist (Table 6). This list should help decision makers to conclude which species should be listed in CITES because they appear susceptible to overexploitation. Of these 17 species, 47.1% were Elasmobranchii with four families comprising five species of sharks and the family of the whiptail stingrays with three species. A total of 17.6% came from the tenth most traded family, Serranidae (Table 6), but no species came from the most traded family Pomacentridae. *Centropyge bicolor* had the highest overall score and comes from the second most traded family, Pomacanthidae (Table 6). Its IUCN Red List conservation status is of least concern, but the number of specimens traded is increasing. All four coral reef fishes listed as endangered in the IUCN Red List were included on the watchlist, although only *Cheilinus undulatus* and *Sphyrna lewini* are listed in Appendix II of CITES. The shark *Stegostoma fasciatum*, giant grouper *Epinephelus lanceolatus*, and banggai cardinalfish *Pterapogon kauderni* are not listed in CITES (Table 6).

4. Discussion

The European Trade Control and Expert System (TRACES) is the primary functioning tool to monitor the trade in marine ornamental fishes in large parts of the world, in particular, Europe. Although, TRACES is not specifically designed to monitor trade in wildlife, it produced very meaningful information on number of specimens traded as well as diversity of species over the four years study period (2014–2017). TRACES could be used to propose a scoring system to identify species that require monitoring because trade in these species could have detrimental effects. Furthermore, TRACES, with a few modifications, could be used as a tool to monitor trade in marine

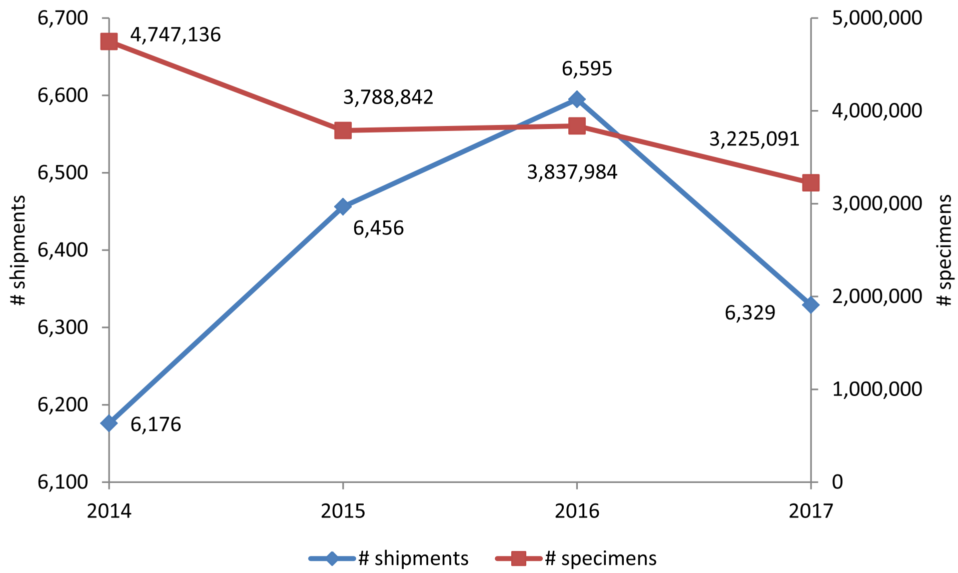

Fig. 1. Overall shipments and number of traded specimens per year of marine ornamental fishes from 2014 to 2017 entering Europe.

ornamental fishes.

4.1. Origin, destinations, number of specimens traded and trends

The marine ornamental fish trade is an international market with the most important source countries situated in Southeast Asia, and the main importing countries in the West [26,28,36]. Overall, during the period from 2014 to 2017, 50 countries exported marine ornamental fishes to Europe, which is an indication of the scale of this industry. In addition to the US, the largest importing country, 45 other nations exported marine ornamental fishes [28]. More than two thirds of all European imported specimens originated from Indonesia, Sri Lanka and the Philippines, with the main importing countries located in Western Europe where GDP is higher than for the rest of the region. These same exporting countries shipped fish to the largest importing nation, the US [26,28] and a non-EU country, Switzerland [4,5]. It is unclear how big the trade in the Asian, South American or African markets are.

Today, approximately 40 million specimens of marine ornamental fishes are traded annually worldwide [31]. For Europe the number of specimens traded decreased approximately one third over the study period 2014 and 2017 from almost 5 million to over 3 million specimens. Almost 45% came from Indonesia alone, and five importing countries imported over 80% of all specimens. With regard to potential number of consumers and comparison to the US volume and consumer capacity, the overall volume was expected to be higher.

Because the total value of coral reef fishes entering the EU was similar to the value of marine ornamental fishes entering the US [4,19,20], it was anticipated that the volume of specimens would also be similar. Furthermore, based on the fact that the EU has over 500 million inhabitants, an almost 60% larger population size than the US, it was also anticipated that even more specimens would have been imported to Europe. According to Leal et al. [19], the EU imports marine ornamental fishes worth about € 11.3 million (about US$ 12.8 million) per year. Interestingly, another study valued the EU imports of ornamental fishes at US$ 144,736 million in 2007 (Monticini, 2010), and because the marine ornamental fish trade is estimated at 10% of the marine and freshwater ornamental fish trade combined [24,36], this would result in US$ 14.5 million for 2007, thus both studies give comparable figures.

Also, some statistics are available for the UK, which has always been the biggest EU importer for marine ornamental fishes [36] followed by the Netherlands. Between 1997 and 2002 the UK imported about 875,000 specimens a year [36], which is the same as for 2017 whereas in 2014 the trade volume had reached 1.4 million specimens.

4.2. Diversity of marine ornamental fishes

Over the four years analysed, 1,334 species were recorded under TRACES at species level entering Europe, whereas internationally there were at least 2,300 species of marine ornamental fishes in trade [28]. Also, there are at least 86 families entering Europe compared to 125 families entering the US [26,28]. It is possible that there are more

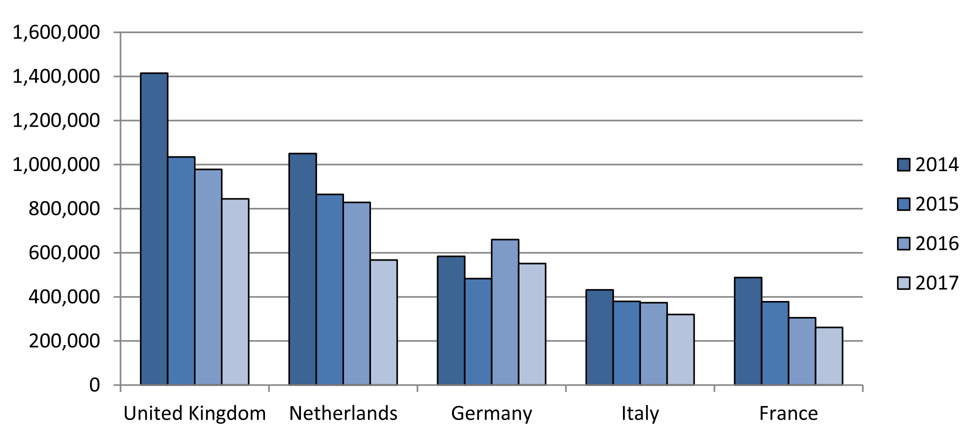

Fig. 2. Number of specimens of marine ornamental fishes imported to the five top importing European countries by year from 2014 to 2017.

Table 3
Number of imported marine ornamental fishes per European country between 2014 and 2017 with total amount of specimens over four years and the slope of trade volume as the linear regression of the four years. Slope = negative or positive average number of specimens per year.

Import country	2014	2015	2016	2017	Total	Slope
United Kingdom	1,414,494	1,034,680	978,506	844,667	4,272,347	−176,566
Netherlands	1,049,798	864,511	828,314	567,534	3,310,157	−148,299
Germany	583,889	482,637	660,114	551,266	2,277,906	7,961
Italy	431,839	379,421	373,391	320,154	1,504,805	−34,109
France	487,863	377,900	305,278	261,525	1,432,566	−75,164
Spain	237,842	117,045	131,727	81,042	567,656	−45,572
Denmark	68,144	120,674	131,517	157,571	477,906	27,912
Poland	93,191	78,044	87,300	94,473	353,008	1,310
Belgium	99,186	62,984	76,810	70,276	309,256	−7,290
Sweden	30,922	48,561	42,061	81,367	202,911	14,484
Switzerland	38,407	37,217	42,152	43,138	160,914	1,913
Austria	33,803	34,032	35,225	34,999	138,059	478
Norway	48,171	26,843	33,440	20,321	128,775	−7,695
Greece	45,573	31,876	26,898	21,880	126,227	−7,606
Czech Republic	22,187	27,462	26,633	21,817	98,099	−194
Portugal	10,067	23,633	23,900	17,178	74,778	2,160
Hungary	20,442	7,065	6,834	9,797	44,138	−3,217
Luxembourg	13,311	12,248	10,319	6,683	42,561	−2,181
Malta	4,992	10,130	5,530	5,476	26,128	−315
Cyprus	6,576	6,068	4,735	5,566	22,945	−436
Romania	1650	1,344	1,613	6,124	10,731	1,369
Bulgaria	2,517	766	909	1,681	5,873	−237
San Marino	0	1,801	2,392	0	4,193	59
Slovenia	953	770	1,041	182	2,946	−204
Croatia	481	879	519	199	2078	−121
Ireland	838	190	826	175	2029	−135
Slovakia	0	61	0	0	61	−6

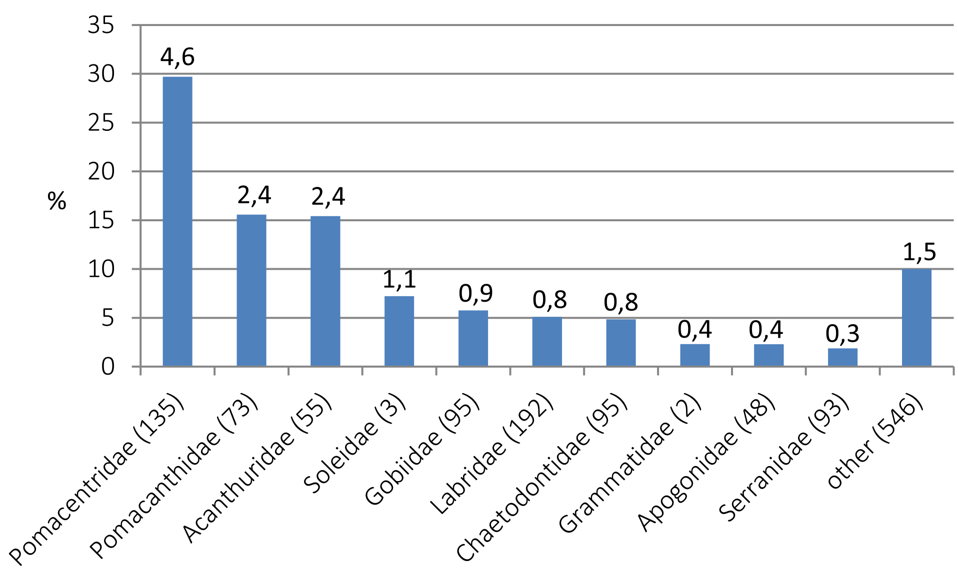

Fig. 3. The trade volume (%) of the top ten families traded into Europe between 2014 and 2017. The number of imported species in the family are in parentheses, the number on top of the bar represents specimens in millions.

species entering Europe because almost one third of specimens were not discernible at species level. Therefore, the overall accuracy of TRACES data need to improve. Rhyne et al. [28] suggests that physical import documents record species more accurately, but one Swiss study that analysed physical import documents, showed that at least one third also did not contain species lists of ornamental fishes for that country [4]. In addition, exporting countries require closer examination, as implied by the aforementioned examples of three declared ‘Antarctican’ fishes from the family Scorpaenidae - there are no Scorpaenidae in Antarctica.

Species traded are highly diverse, although the majority of specimens are confined to relatively few species. From the species identified, *Chromis viridis*, *Amphiprion ocellaris* and *Centropyge bicolor* comprised over a third of all imports and the top 20 species represented over 60% of all imports. A study for Switzerland between 2014 and 2017 showed that almost 40% of all imports were *C. viridis*. Interestingly, *A. ocellaris* was the most imported species over the same four years, although over 60% were transshipped to the EU [5]. In the US, *C. viridis* was also the most imported (> 10%) and six other fish species represented one third of all imported specimens from 2008 to 2011. A total of 20 species represented over 50% of imports.

4.3. The significance of a watchlist

Of all threats facing the oceans, the evidence so far available suggests, that overexploitation, e.g. by trade, is the most serious threat to marine fish species [2]. Therefore, all traded species were allocated a

Table 4
Top 20 species of marine ornamental fishes imported to Europe between 2014 and 2017 and their IUCN Red List conservation status (NE = not evaluated, LC = least concern, EN = endangered). AVG = average, SD = standard deviation.

Species	IUCN Red List status	2014	2015	2016	2017	Total	AVG	SD	%
Chromis viridis	NE	334,458	377,022	385,430	348,661	1,445,571	361,393	23,872.2	13.1
Amphiprion ocellaris	NE	257,520	370,199	344,363	201,973	1,174,055	293,514	77,763.6	10.7
Centropyge bicolor	LC	187,298	258,010	265,842	251,070	962,220	240,555	36,013.8	8.7
Chelmon rostratus	LC	124,892	137,841	85,396	48,954	397,083	99,271	40,284.0	3.6
Acanthurus leucosternon	LC	105,389	96,610	99,005	86,144	387,148	96,787	8,004.6	3.5
Acanthurus achilles	LC	84,317	87,950	83,788	105,511	361,566	90,392	10,248.0	3.3
Gramma loreto	LC	130,850	75,770	55,206	80,675	342,501	85,625	32,105.2	3.1
Valenciennea sexguttata	NE	8,015	34,192	81,751	85,092	209,050	52,263	37,557.7	1.9
Zebrasoma flavescens	LC	40,959	54,527	54,535	45,846	195,867	48,967	6,727.7	1.8
Pterapogon kauderni	EN	43,982	38,169	56,494	56,649	195,294	48,824	9,256.2	1.8
Chrysiptera parasema	NE	68,649	60,702	33,348	32,110	194,809	48,702	18,734.3	1.8
Pomacanthus imperator	LC	64,740	53,493	27,088	26,183	171,504	42,876	19,310.4	1.6
Labroides dimidiatus	LC	28,988	46,030	22,903	60,396	158,317	39,579	16,982.6	1.4
Centropyge bispinosa	LC	37,520	32,310	23,273	65,186	158,289	39,572	18,061.8	1.4
Valenciennea puellaris	LC	22,715	33,845	23,828	39,997	120,385	30,096	8,283.6	1.1
Centropyge acanthops	NE	48,023	31,742	32,975	6,078	118,818	29,705	17,403.3	1.1
Chrysiptera cyanea	NE	25,785	37,679	28,166	20,473	112,103	28,026	7,194.2	1.0
Paracanthurus hepatus	LC	19,735	17,409	48,129	26,761	112,034	28,009	13,990.4	1.0
Centropyge loricula	LC	22,701	38,322	13,625	30,751	105,399	26,350	10,613.5	1.0
Pseudanthias squamipinnis	LC	20,229	19,840	28,918	28,896	97,883	24,471	5,125.0	0.9

Table 5
IUCN Red List conservation status of all species imported into Europe between 2014 and 2017 and percentage (%) of all species.

IUCN Red List status	# species	%
Not listed	0	0
Not evaluated NE	393	29.37
Data deficient DD	57	4.26
Least concern LC	846	63.23
Near threatened NT	19	1.42
Vulnerable VU	18	1.35
Endangered EN	5	0.37
Critically endangered CR	0	0
Extinct in the wild EW	0	0
Extinct EX	0	0
Total	1,334	100

score reflecting trade volume, IUCN conservation status and the species vulnerability [7,8,13]. The higher the score, the more susceptible the species could be to overexploitation. Seventeen species were put on a watchlist that recommends the species that should precautionarily be listed in Appendix II of CITES. This would ensure the monitoring of these species. All species listed as endangered on the IUCN Red List were included on the watchlist, but only *Cheilinus undulates* and *Sphryna lewini* are listed on Appendix II of CITES. The banggai cardinalfish, *Pterapogon kauderni*, an endemic species that has been overfished [21,35] as well as the giant grouper, *Epinepelus striatus*, and *Stegostoma fasciatus*, are not listed in CITES.

Unfortunately, over one third of all species that were identified at species level were recorded as data deficient or not evaluated by the IUCN Red List and had therefore no conservation status. Consequently, these species did not qualify for the watchlist calculations. The fact that a species has not been assessed does not imply that it is not potentially threatened. As stated in the preamble of the IUCN Red List: ‘ … until such time as an assessment is made, taxa listed in these categories should not be treated as if they were non-threatened. It may be appropriate (especially for data deficient forms) to give those species the same degree of attention as threatened taxa, at least until their status can be assessed’ [17]. The species that were not included on the watchlist, such as *C. viridis* and *A. ocellaris,* are the most traded species in Europe and in the world [26,28,36], and could precautionarily be listed in CITES because the number of traded specimens shows an increasing trend. It is unclear how many specimens of *A. ocellaris* could

Table 6
Watchlist of the 17 species with an overall score of 100 ranked by the sum of four normalized parameters: the score of the median number of specimens traded over 4 years, the score of the trends of trade volume (slope), the score of the IUCN Red List conservation status and the score in vulnerability according to FishBase. Species that are data deficient or not evaluated by the IUCN Red List are not considered.

Rank	Species	Family	IUCN Red List status	Overall score	Median volume score	Slope score	IUCN score	Vulnerability score
1	*Centropyge bicolor*	Pomacanthidae	LC	223	100	100	0	23
2	*Chelmon rostratus*	Chaetodontidae	LC	156	41	100	0	15
3	*Sphyrna lewini*	Sphyrnidae	EN	141	0	0	60	81
4	*Stegostoma fasciatum*	Stegostomatidae	EN	137	0	0	60	77
5	*Cheilinus undulatus*	Labridae	EN	134	0	0	60	74
6	*Urogymnus asperrimus*	Dasyatidae	VU	130	0	0	40	90
7	*Pterapogon kauderni*	Apogonidae	EN	127	20	28	60	19
8	*Epinephelus lanceolatus*	Serranidae	VU	126	0	0	40	86
9	*Epinephelus striatus*	Serranidae	EN	123	0	0	60	63
10	*Taeniura meyeni*	Dasyatidae	VU	117	0	0	40	77
11	*Nebrius ferrugineus*	Ginglymostomatidae	VU	117	0	0	40	77
12	*Pomacanthus imperator*	Pomacanthidae	LC	116	16	51	0	50
13	*Taeniura lymma*	Dasyatidae	NT	112	1	1	20	90
14	*Mycteroperca interstitialis*	Serranidae	VU	108	0	0	40	68
15	*Carcharhinus amblyrhynchos*	Carcharhinidae	NT	105	0	0	20	85
16	*Triaenodon obesus*	Carcharhinidae	NT	103	0	0	20	83
17	*Gramma loreto*	Grammatidae	LC	102	31	61	0	10

derive from captive breeding facilities [28] as this information is not available.

Calculated positive trends support to the assumption that some species could be traded in even larger numbers. Negative trends may indicate that species populations are decreasing or that interest from trade is diminishing. The collection of coral reef fishes on a large scale can have ecological consequences that are both direct - resulting from the selective and non-selective removal of the organisms concerned and indirect - resulting from the disruption of habitat [26,32,36,37]. Therefore, species that are either data deficient or not evaluated but are traded in large numbers, and species that have been identified as being sensitive to trade, such as *Synchirpus splendidus,* could be monitored as a precaution and listed in CITES [4,5,32].

4.4. Importance of monitoring the aquarium trade and effectiveness of TRACES

Concern has been expressed that where species are not regulated under CITES there is *de facto* neither a global reporting system for wildlife trade in general nor for the marine ornamental fish trade in particular [3,29]. Therefore, TRACES represents a good tool that could be easily modified to function as a monitoring system. Although at present TRACES is not intended to monitor the trade in marine ornamental fishes and therefore, the volume and diversity of traded species is rarely fully reported, it allows analysis of some data. TRACES has gradually been improved, and since 2014 data for ornamental fishes are clearly divided into freshwater and marine species. Also, a consultation process among industry operators focusing on the international trade in ornamental fishes entering the EU indicated that they are also interested in a sustainable trade and that they would be willing to work in partnership with regulatory bodies towards a monitoring mechanism, with TRACES to be further investigated as a tool to control this international trade [34]. To properly monitor the marine ornamental fish trade, several additional improvements would be needed: (1) All known species of coral fishes would need to be selectable in TRACES; (2) imports would need to be declared at species level and all taxa checked regularly for their accuracy using WoRMS [1] or synonyms and alternative names would need to be allowed; (3) TRACES should require specification whether a species is captive-bred or wild caught; (4) all fishes, as for other vertebrates [33], should be traceable to their source, for example, because fishes originating from Singapore, most likely did not birth in Singapore's coral reefs; and (5) TRACES includes important policies regarding non-native species and public health. TRACES does not allow importation of species that are recorded as invasive, and requires an electronic approval by the veterinary authority of the country of import [33]. In this study, sharks of the family Charcharidae from South Africa were allowed to be imported into Europe, although South African law prohibits the commercial sale of these species [30]. As is already the case for invasive species, TRACES could require the approval of the veterinary authority to import species that are protected in the country of export.

5. Conclusion

The lack of a meaningful data collection system for the marine fish trade impedes effective management, which in turn limits the sustainability of the aquarium industry [12,26,29]. Government cooperation is urgently required to resolve monitoring and control issues [18]. The aquarium industry has clearly stated its interest in using a tool such as TRACES to monitor commerce, and to develop the sustainability of this trade. TRACES has gradually improved the information it collects on marine ornamental fishes but could supplement key parameters such as compulsory requirement for at species-level and clarification of captive-bred or wild-caught status and sourcing country of origin. Where fishes are protected in the source country, this would elicit notification to the responsible authority, as is already the case for invasive species. Also, all species of coral reef fishes need to be evaluated by the IUCN Red List, whereas currently approximately 30% are not assessed. Additionally, using parameters from TRACES, FishBase and IUCN Red List the watchlist could determine whether a species requires monitoring via CITES.

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Appendix A. Supplementary data

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