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CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Technical workshop on marine ornamental fishes
Brisbane (Australia), 7 to 10 May 2024

Developing an evidence-led species prioritisation framework

1. This document has been submitted by the Ornamental Aquatic Trade Association (OATA) and Ornamental Fish International (OFI).

2. To support the considerations of the workshop, the Annex to this document presents a framework for identifying species that may warrant further investigation into their populations or management in order to determine whether trade in them is sustainable.

3. The framework utilises species level data on global trade volumes, sourcing methods, conservation status, distribution, vulnerability to harvest, life history traits and shows the diversity and volume of species traded globally. This level of detail allows the framework to prioritise relevant species that may benefit from more detailed assessments of their populations and/or further management measures. The framework allows for adjustments to be made to the prioritisation criteria according to parameters that are considered appropriate. The document also provides details of existing controls and measures in source countries that govern the collection of marine ornamental fishes to provide some context when considering the benefits of additional management measures.

4. Summary of the document's key contents:

   a. The trade in marine ornamental fishes supports sustainable livelihoods around the world in some of the world's poorest regions, but is poorly understood in terms of it's scale, sustainability and impact.

   b. Marine aquarium fish in trade are highly diverse, yet commonly are small bodied species, with fast growth rates, relatively high fecundity and long dispersal distances. However, some species in trade exhibit life history traits that may make them vulnerable to exploitation, such as slow growth rates or low fecundity. Any process that aims to examine the sustainability these species much take into account the inherent ability of species populations to respond to harvest.

   c. Conservation and population statuses of many species in trade are poorly understood, and therefore further examination is required to ensure that the most vulnerable species get the appropriate amount of attention.

   d. Data sources often used to examine the trade are often flawed in terms of their level of detail and accuracy. Technological tools do exist to collect data at the species level but are currently under resourced and limited in their scope.

   e. This paper utilises industry data from several sources to provide key information on the species in trade, sourcing method, biological vulnerability and existing management measures in place in source countries.

f. Example frameworks for species prioritisation are presented that draw on the best available information, in order to best direct resources to the species that may benefit from further research into their populations or management measures.

g. This paper also discusses the limitations of the data sources that are available and provides a brief overview of alternative methodologies which more accurately assesses species inherent biological vulnerability to harvest in the absence of data on their populations or catch.

h. This paper and its frameworks represent a way forward for an ongoing process to assess marine ornamental fisheries and target future effort to where it is most needed. Where management measures are appropriate for certain species, these should be implemented in collaboration with fisher communities, to ensure best compliance and foster sustainable practices while considering the livelihoods of those reliant on the trade.

i. Where data is lacking, resources should be directed toward tools and research which improve our understanding of the trade in certain species so that management is focussed and proportionate to the threat posed to those species.

5. The document has widespread support from industry globally, including from Asociación Española de la Industria y el Comercio del Sector Animal de la Compañía (AEDPAC, Spain), Dibevo (The Netherlands), European Pet Organization (EPO, Europe), Norges Zoohandlers Bransjeforening (NZB, Norway), Pet Advocacy Network (PAN, USA), Pets Canada (Canada), Pet Industry Association of Australia (PIAA, Australia), Sustainable Users' Network (SUN, UK), Wirtschaftskammer Österreich (WKO, Austria) and Zoobranschens Riksförbund (ZOORF, Sweden).

6. The authors gratefully acknowledge the input received from UNEP-WCMC, IUCN, the UK Department for Environment, Food and Rural Affairs (Defra, UKMA) and its agencies the Joint Nature Conservation Committee (JNCC, UKSA) and the Centre for Environment, Fisheries and Aquaculture Science (Cefas) whose thoughts for improvement were invaluable in developing this framework.

Annex

Developing an evidence-led species prioritisation framework

Background

1. The 18th meeting of the Conference of the Parties to CITES agreed Decisions 18.296 – 18.298 [1] stating that the CITES Secretariat would, subject to external funding:

    a) convene a technical workshop to consider the conservation priorities and management needs related to the trade in non-CITES listed marine ornamental fishes worldwide with a particular focus on data from importing and exporting countries;

    b) invite the Animals Committee, representatives from range States, exporting, and importing countries, fishery stakeholder, industry representatives and relevant intergovernmental and non-governmental organizations to participate in this workshop;

    c) contract appropriate technical experts to prepare workshop documents on marine ornamental fishes' biology; conservation status; trade and management; applicable trade regulations; and enforcement, and invite workshop participants to [submit the] contribute relevant information and expertise to the workshop; and

    d) submit findings and recommendations of this workshop to the Animals Committee.

2. During the 19th Conference of the Parties to CITES, decision 19.238 [2]was agreed and directed the Animals Committee to:

    a) agree a terms of reference for the technical workshop; and

    b) consider the results of the workshop referred to in Decision 19.237 and make recommendations to the 20th meeting of the Conference of the Parties.

3. The 32nd meeting of the CITES Animals Committee prepared a draft terms of reference and modus operandi for the technical workshop on marine ornamental fishes as set out in Animals Committee Document 40 [3] but with an agreed amendment to paragraph 2 which states "The workshop will contribute to the following outcomes:…":

    a) identification of non-CITES listed marine ornamental fish species in international trade;

    b) an understanding of the scale and dynamics of this trade, including the degree to which data are available at a national or population scale; and evidence of captive breeding;

    c) identification of potential options for monitoring of species trade volumes;

    d) a better understanding of the biology, conservation status and intrinsic vulnerability to extinction for all non-CITES marine ornamental fish species identified as being in international trade;

    e) prioritisation for further research into the potential impact of international trade on species considered to be at higher risk of extinction as a result of international trade;

    f) improved management measures and best practices to ensure the conservation of the marine ornamental fish species identified; and

    g) improved regulations for international trade in non-CITES listed live coral reef fishes and their enforcement.

Summary

4. Industry data collected for this document indicates there are 1040 species of marine ornamental fish regularly in trade for private aquaria. To support the considerations of the workshop, this document presents a framework for identifying species that may warrant further investigation into their populations or management in order to determine whether trade in them is sustainable.

5. The framework utilises industry data from several sources to show the diversity and volume of species traded globally. Unlike other data sources currently used to assess the trade, the data used has species-level information on trade volumes, sourcing method, conservation status and distribution (where known). In addition, the database presented here also includes species level measures of vulnerability to harvest based on peer reviewed metrics and species life history traits. This level of detail allows the proposed frameworks to prioritise relevant species (e.g. not those temperate species that may rarely feature in public aquaria or get erroneously recorded as ornamental instead of as food fish), that may benefit from more detailed assessments of their populations and/or further management measures. The framework also allows adjustments to be made to the prioritisation criteria according to parameters that are considered appropriate. In addition, the document uses existing literature (both published and grey) to provide details of existing controls and measures in source countries that govern the collection of marine ornamental fishes in order to provide some context when discussing the benefits of additional management measures.

Introduction

6. Fish destined for private and public aquariums are sourced from over 60 countries around the world, with many categorised by the United Nations as Least Developed Countries (LDCs) [4] and Small Island Developing States (SIDs) [5]. The trade in these species supports some of the most remote and poorest communities around the world that are often solely reliant on coral reefs and their associated fisheries for their income.

7. The trade in marine ornamental fishes contributes to numerous UN Sustainable Development Goals [6], including:

- Goal 1 – No Poverty.
- Goal 8 – Decent Work and Economic Growth.
- Goal 14 – Life Below Water.

8. As such, understanding the sustainability of marine ornamental fisheries is paramount not only for the preservation of coral reef ecosystems and the services they provide but also for the communities of people that rely upon them [7]–[9].

How are marine ornamental fish sourced?

9. Marine ornamental fishes are mostly sourced from the wild from coral reefs around the world, with a smaller but growing proportion of individuals from the most commonly traded species being sourced through captive breeding enterprises [10]. Unlike food fisheries, the value of marine ornamental fishes to the trade and to keepers is in live healthy unstressed individuals that have best survivability [11]. This fact drives the capture methods used which are typically low impact to minimise stress and often highly targeted, with orders requesting certain species of a given size [12]–[14]. These techniques, such as the use of small hand nets, barrier nets, traps etc, also have the benefit of being relatively low impact on coral reef structures [11], [12], [14], [15] compared with techniques associated with food fisheries e.g. benthic trawls and blast fishing [16], [17]. Fishers are commonly artisanal, using small boats with minimal, if any, modern technology, limiting the range of areas that can be fished [12]. In combination with supply chain limitations (e.g. airport access, quarantine facilities), and other management factors (marine protected areas, no take zones, etc) [18] it is reasonable to assume that large areas of coral reefs in source countries are un-exploited by the trade. In addition, the target body size and life history strategies of many species in trade lend themselves to being resilient to exploitation. Typically, individuals are caught as juveniles as these are most desired by the end consumer, meaning that breeding adults are typically left untargeted [18]–[20]. The majority of the species targeted are highly fecund, often have long dispersal distances as part of their life cycle, and therefore very large natural ranges [21]–[25]. Together this supports the idea that ornamental fisheries can maintain high levels of recruitment and resilience to fishing, though further studies are needed to understand these patterns across targeted species.

Quantifying the diversity and volume of trade

10. The trade in marine ornamental fishes has historically been difficult to quantify. The trade is global, with sometimes complex supply chains, and highly diverse in terms of the number of species it trades in [11]. Currently, no official recording system exists that captures data globally and records down to the level of species. If sustainability of the trade is to be assessed, levels removed on a per species basis would be needed alongside good resolution population data. Of the official data sources available that monitor trade, these typically provide data that lacks the granularity needed (species level recording) or are prone to inaccuracies [11], [26].

11. Marine ornamental fishes are captured by a single harmonised commodity code (03011900), the codes used globally to describe goods for customs purposes. This commodity code encompasses all species of marine fishes traded for ornamental purposes. There are known recording inaccuracies associated with the use of this commodity code, such as the mis-reporting of food-fish as ornamental [11], alongside the limitations of trade data recorded as weights and value as opposed to number of individuals. This then becomes problematic when trying to assess global trade. The majority of marine ornamental fishes are packed singly or in pairs with water making up the majority of the recorded weight. In contrast, food fisheries are a much larger industry, and the associated consignments are predominantly a lot heavier. This essentially means that a single mis-recorded consignment of food fish can result in a drastic overestimation of trade volumes in ornamental fish if data is not properly checked and accounted for. Such examples of this in recent years include Spain, France and Greece featuring as major exporters of marine ornamental fishes which has been subsequently shown to be erroneous.

12. Of those data sources that can record trade volumes down to the species level (e.g. TRACES, LEMIS) these are often limited to certain (albeit large) markets which mean there are caveats to consider if extrapolating to a global scale [27]. Trade patterns for certain species will undoubtedly differ between end-user countries, both in terms of consumer trends and also the availability of captive-bred individuals within markets. There are also known inaccuracies with some of these systems, such as whole consignments being listed, at the permission of regulators, as only containing a single or limited number of species. The rationale behind this is to simplify the import process and expedite delays at airports that could lead to welfare issues for fish within consignments. In such cases, regulators will also require full species lists (usually in the form of packing or shipping lists) to be included with export documentation e.g. export health certificates. These discrepancies in how species are recorded can lead to some official data sources under and over-representing the numbers of some species in trade [27].

13. Adequate tools do however exist to assess the trade in marine ornamental fishes at the resolution and accuracies required to determine the scope, diversity and potential sustainability of trade. Systems that leverage invoice / packaging data scanned from consignment boxes offer an accurate picture of what species are traded, their source location and volumes in which they are traded. However, these tools are still limited in size and scope, with data only covering limited time periods and certain markets [28]–[31]. The development and adoption of these tools, in particular by importing countries at point of entry, would greatly aid in assessing the volumes and diversity of marine ornamental fishes in trade and may well have far wider beneficial applications to monitoring of trade in a wide variety of goods globally. However, in the absence of these tools, there is a need for data that accurately estimates the species currently in trade and the volumes that they are traded in before any decisions can be made about the appropriate management of marine ornamental fish species.

Assessing conservation and sustainability of species in trade

14. Given the potentially high diversity and volume of species in trade of marine ornamental fishes, understanding take and vulnerability to harvest is paramount for the future sustainability of trade.

Several assessments have already been undertaken of the trade utilising various existing metrics to prioritise species that might warrant further examination.

15. Commonly used are IUCN Red List categorisations, where species have been assessed by conservation experts on the status of their populations [32]. Whilst a valuable tool for signposting species that may be in decline and in need of further research attention, the Red List can be variable in the population data that underpins assessments and the subsequent categorisations that are applied (e.g. Vulnerable or Endangered). In contrast to requirements to amend the CITES Appendices [33], species can be listed based on "suspected" decline in population size attributed to a wide variety of causes. Although the use of proxies for population size and declines may be needed in the absence of good data, some proxies may be better suited than others. For example, trends in long term catch data may be highly relevant given the length of time many of these species have been utilised. Other proxies may be less appropriate depending on the species being examined. For example, recent research indicates that population abundance and habitat availability may not be tightly correlated for all reef fish species [34] and that some species groups persist despite sustained loss of coral genera [35], [36].

16. As such, when assessing the likely sustainability or vulnerability of a species to collection, IUCN status would ideally be weighted against the factors that drive productivity in a species (e.g. fecundity, growth rate) [37] and factors that effect susceptibility to harvest (habitat usage, trade vulnerability). In addition, due to resource limitations, many species remain unassessed by IUCN or have assessments undertaken too long ago to be certain they remain relevant to the current conservation status of the species [26].

17. FishBase is a global species database of fish species, including information on taxonomy, geographical distribution, biometrics and morphology, behaviour and habitats, ecology and population dynamics as well as reproductive, metabolic and genetic data [38]. Built into FishBase are several metrics associated with species resilience to harvesting, which are calculated using papers that parameterise from life history characteristics and population growth curves. These metrics are a valuable tool to assess the sustainability of given species of fish, but the methodology used to parameterise these metrics should be carefully considered before usage. For example, metrics that incorporate a wide range of life history characteristics (e.g. fecundity, spawning method, natural range, growth rate) such as the vulnerability score set out in FishBase [38], [39], are useful when considering sustainability of stocks but consideration must be given to the fact that scores are generalist in their usage and may be skewed by large bodied species harvested for food.

18. Alternative methodologies exist to calculate vulnerability to fishing in the absence of comprehensive catch or population data such as Productivity-Susceptibility Analysis (PSA). PSA analysis can utilise a variety of biological parameters weighted against another to determine the vulnerability of species to exploitation, and crucially focus down on parameters relevant to the species groupings being considered. This has been recently developed for some ornamental species [37] and would be beneficial when determining appropriate management at the species level.

19. Where trade volumes are recorded down to species level, care should be taken when utilising these values to assess whether a species may be vulnerable to harvest or not. Blanket thresholds across species; i.e. greater than X many individuals traded over a given timescale; does not reliably indicate the vulnerability to harvest of a given species without the appropriate context also being available on that species. Many species of marine ornamental fishes traded will differ in their natural range, levels of recruitment, population size, spawning method etc, meaning that setting a one-size-fits-all volume threshold as a proxy for exploitation level is inappropriate and could lead to species receiving inadequate levels of scrutiny. These population dynamics are also likely to vary across a species natural range due to various site-specific factors such as presence or absence of predators [40], competitors [22], [41], and prey species, as well as differing usage of key habitats throughout a species range [40], [41]. Species that may have small population sizes and may naturally be vulnerable (e.g. low fecundity, limited range), may avoid the necessary degree of investigation on account of being relatively rare in trade as opposed to some that may be biologically very resilient to harvest (highly fecund, widely distributed) receiving unnecessarily high levels of attention. What is clear from initial assessments of the trade is that it is highly

diverse in terms species traded but, in many cases, data poor in terms of population dynamics and resilience.

20. **Any process to assess the vulnerability of marine ornamental fishes to levels of international trade should clearly be related to the inherent ability of a species and its populations to respond to harvest [37], [42] . Sole or predominant reliance on a flawed measure of vulnerability/sustainability and/or use of flawed data to begin with, will lead to inappropriate levels of attention on certain species. Therefore, any system that aims to focus further research or management efforts should consider an approach that uses multiple metrics, including those that account for a species' resilience to harvest, as well as utilising data that represents current trends at the granularity needed to assess sustainability at a species level.**

Methods

Creation of industry database

21. The creation of a database of marine ornamental fishes in trade began in 2016 [43]. The initial aim was to create a comprehensive list of all species potentially traded utilising data from literature and industry sources to produce a list of species. This initial list was inflated by the presence various species less relevant to this workstream, e.g. cold water species occasionally sourced for public aquaria [43].

22. This list was further refined in recent years (2020-2022) using industry sources to gain an understanding of species that are currently in trade and the volumes they are traded in. Industry data can inflate the number of species counted as it often contains multiple entries for the same species divided by individual size (e.g. small, medium, large), colour morph, location of export or captive bred/wild caught status. Additionally, scientific names can be outdated or misspelt. In some cases, outdated scientific name might be used by one exporter, a correct name used by another whilst a third uses a misspelt correct name. This gives the appearance of three species when only one is traded. To account for these errors and to ensure results were accurate, the data used in this framework was cleaned extensively before analysis began. Sizes, colour morphs and location of export were removed and the results amalgamated into a single species. Scientific names were updated using FishBase and any misspellings were corrected. This process ensured no multiple counts of the same species occurred. Captive bred and wild caught status was initially removed from raw data to create a species list but was added back in later once verified.

23. Once this data cleaning was completed, species level data on popularity in trade and captive bred availability (from industry sources, the Coral magazine list and commercial producers) was added [44]. The 2019 edition of the Coral Magazine captive bred list was utilised as, although a more recent list has been published, it does not provide data on commercial availability on a per species basis. This, along with industry sources allowed for more accurate estimation of how much of the trade is sourced through captive breeding.

24. The database was then further populated with taxonomic information (family of each species), distribution data (from IUCN and FishBase), IUCN classification and threat data (from IUCN) and vulnerability scores and breeding method (from FishBase). As previously discussed, vulnerability scores within FishBase are skewed by food fish species, meaning that some vulnerable species can be underscored on vulnerability. Box 1 provides a description of a PSA for ornamental species that generates a more accurate score of vulnerability. Whilst the data is not currently available for all species within our database, the framework outlined below would benefit from utilising vulnerability scores derived from the ornamental PSA [37] instead of FishBase as it is currently.

25. The species listed, their relative proportions in trade, and total volumes traded were then extrapolated globally although may underestimate eastern markets (e.g. China, Japan, South East Asia) which may be subject to different market trends for species kept in aquaria. This should be considered when interpreting results arising from the framework presented below.

26. The database can be found at https://ornamentalfish.org/cites-database/.

Box 1: Summary of factors and scoring used in PSA paper on marine aquarium fisheries by Baillargeon et al (2020).

Productivity-Susceptibility Analysis (PSA) method in Baillargeon et al (2020) was developed to assess the vulnerability of marine aquarium fish (MAF) species to harvest. It incorporates various factors to generate vulnerability scores that can be used to inform management and research of coral reef aquarium fisheries.

Productivity Factors:

1. Maximum age
2. Maximum size
3. Trophic level
4. Length at maturity
5. Fecundity
6. Breeding strategy (e.g. dermersal egg laying, broadcast spawning, mouth brooder, etc)
7. Larval duration (length of time as planktonic larvae before settlement)

Susceptibility Factors:

1. Trade vulnerability (A combination of volume in trade, geographic distribution, and number of exporting countries for a species).
2. Cyanide fishing
3. Encounterability depth
4. Ecological niche
5. Aquarium suitability

Vulnerability Scores:

- The vulnerability score is calculated by combining the weighted productivity and susceptibility factors.
- Higher scores indicate greater vulnerability to fishing.
- Other factors can also be included as needed, e.g. global threat level, habitat specificity.

Sustainability Categories:

1. The vulnerability scores are clustered using a Gaussian mixture model (GMM). These clusters are then labelled into different sustainability categories.
2. Categories include:
   - **Highly Sustainable**: Low vulnerability scores.
   - **Sustainable**: Moderate vulnerability.
   - **Moderately Sustainable**: Intermediate vulnerability.
   - **Unsustainable**: High vulnerability.

Framework for species prioritisation

27. As the diversity of species in trade is high, it would be extremely time-consuming and costly to properly assess the sustainability of all species in trade. As such, prioritisation is required to ensure effort is directed to the species most likely to be negatively impacted by trade. The flowcharts (figure 1-3) and text below indicate how species may be prioritised for further examination based on the best information available. Built into the proposed framework is optionality on the criteria used – these prioritisation criteria (shown in red bold text in figures 1-3) can be changed or removed which consequently alters the number of species that are recommended under each final category (green, yellow and red coloured boxes). This allows decision makers to adjust criteria according to policy objectives. In addition, Parties may also utilise information presented in the database (such as vulnerability score or numbers in trade) to rank and prioritise species within categories in order to effectively target resources.

28. The first step was to only select species for which there was evidence of trade from commercial operators (as opposed to those only listed in literature sources). The process then initially utilised IUCN categories as a basis for prioritisation. Most of the species recorded in trade are classified as “Least Concern” but the date of the IUCN assessment can vary widely. Given that population dynamics and pressures on species can change over time, date of assessment represents a criteria that can be used to shortlist species. Here we present examples of the framework that either do not include species classified as Least Concern at all (these are classified into the green LOW PRIORITY box) or include Least Concern species for further examination if they are over 10 years old.

29. The second stage box contains criteria designed to assess the inherent vulnerability of species to harvest based on life history traits and other ecological parameters. In the frameworks, we provide two options, A and B. Option A draws on the vulnerability score recorded in FishBase which ranges from 1-100 and is parameterised using a range of fish life history traits [38], [39]. This score is then used as a criteria for the selection of species that might warrant further management measures or investigation of their population sizes (yellow MEDIUM PRIORITY or red HIGH PRIORITY boxes). In these examples, the threshold score was set relatively low as many food fish species skew the scoring system that is recorded in FishBase. This means that many small-bodied reef fish that are caught for the aquarium trade score at the lower end of the scale (1-100). Alternative tools, such as PSA mentioned above (see Box 1), are available that weight species biological factors against other relevant criteria (e.g. trade vulnerability, ecological niche) to produce a more “ornamental species” focussed vulnerability scores. Option B in each framework draws on this based on the findings of Baillargeon et al (2020), but unfortunately, at

time of writing, these scores are not yet publicly available at the resolution of our study. However, they could be developed utilising existing methodology and relevant information from this industry database.

30. In lieu of these scores, the threshold scores for vulnerability (Option A in frameworks below) currently used can be altered according to the needs of those who wish to assess the trade and prioritise species – the lower the threshold, the more species will be identified as needing further examination. UNEP-WCMC's report for the CITES 19th COP [26] set the vulnerability score thresholds at >60 for high likelihood to be threatened by international trade, 30-60 for moderate likelihood, and <30 for low likelihood. In the results section we present the outcome of setting the vulnerability threshold at 20 and above as well as results for each final category at a threshold of 40 or above. This allows us to adapt existing methodologies for shortlisting with industry knowledge and data to improve the accuracy of species that are examined.

31. Two other prioritisation criteria were included to ensure the inherent flaws in the vulnerability score did not preclude any species at threat from overharvest. Species which occur in only one location (country of incidence was used a proxy for this) were selected, as was any species which was a "brooder" (i.e. species which hold young in a pouch/mouth). This was because the vulnerability score in FishBase appeared to underrepresent endemic species or those with life histories which might exhibit relatively low fecundity and limit dispersal but potentially high levels of larval survival (e.g. Bangaii cardinalfish = 19/100, *Hippocampus reidi* =12/100). Fecundity and larval survival could also be additional metrics that could be included in the framework, but this would require further collating of existing published and grey literature to fill the significant gaps that exist in FishBase.

32. Species that meet the criteria outlined above are then either recommended for assessment on whether or not they would benefit from further management and/or assessments of their populations to understand the impact of collection on their populations.

33. Species are then divided between High and Medium priority for further assessment based on the current measures that are in place that help moderate the sustainability of those species. For those species that are already under management measures that are proving effective at managing take OR species that are commonly available as captive bred are classified as **Medium** priority (thresholds for commonly traded as captive bred are described in the legend of figure 1). Those **Medium** priority species should be assessed in light of how effective current management measures are OR if captive breeding is effectively reducing the number of species taken from wild populations. **High** priority species are those that either are lacking in management of their populations or the management methods currently in place are not proving effective at reducing exploitation of the species. In both Medium or High priority categories, where a species is lacking data on its population trends, it should be prioritized for high resolution assessments of its population and/or catch data.

34. Application of the above criteria will generate a list of species for each category, which can then ordered by various metrics in the database (such as popularity in trade) to further prioritise which species are to be examined. It is important to note that this framework is a way to help effectively decide how to best focus resources on the species that require further attention and possible management actions. Deciding what species fall within medium or high priority categories is beyond the scope of this paper, as this requires a detailed assessment of the management and data currently in place at the species level. What is presented here are list of species that are identified as biologically vulnerable that need sorting into medium or high priority.

35. Below are three example frameworks that will generate different numbers of species to be sorted into medium or high priority depending on the variables used in each framework.

Example 1

36. This framework sorts species recorded as in trade in recent years (included in the associated database), and sorts those unassessed by IUCN and those assessed by IUCN to be Endangered, Vulnerable, Near Threatened or Data Deficient into the central box that assesses biological vulnerability to harvest. All species listed as Least Concern by the IUCN Red List are categorised as Low Priority (green box). The threshold to assess whether a species is biologically vulnerable is either:

- A vulnerability score of 1.2 or lower from PSA analysis (as detailed in Box 1) OR
- A vulnerability score of 20 and above (based on the score in FishBase), or other indicators of vulnerability (e.g. high endemism or low fecundity).

Figure 1: Schematic to illustrate the framework presented as Example 1 which shortlists species for further research or assessment based on various criteria (described in text). † Here "Commonly available as captive bred" refers to both featuring as Common on Coral magazine's captive bred list and in industry data where over 25% of stock is sourced from captive bred sources. It is worth noting that availability of captive bred stock will vary with proximity to captive breeding operations.

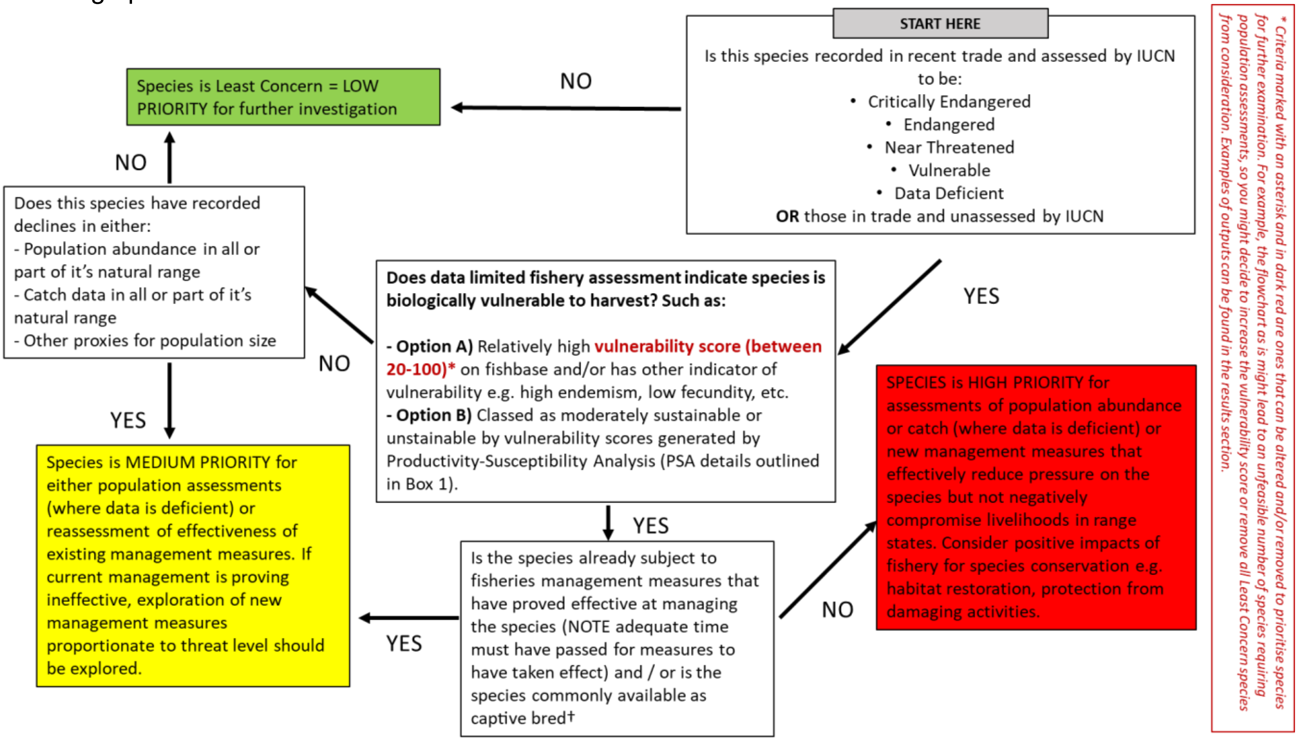

Table 1: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 1, utilising Option A as selection criteria

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kauderni	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Pholidichthyidae	Pholidichthys leucotaenia	Y	0.004464665	No culture record	NA	NA	NA	24	8	
Acanthuridae	Zebrasoma velifer	Y	0.004294876	No culture record	NA	NA	NA	36.94	44	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Ostraciidae	Ostracion cubicum	Y	0.002315386	No culture record	NA	NA	NA	35	61	open water/substratum egg scatterers
Ostraciidae	Lactoria cornuta	Y	0.001888844	No culture record	NA	NA	NA	36	41	
Serranidae	Pseudanthias cheirospilos	Y	0.001817523	No culture record	NA	NA	NA	NA	NA	NA
Syngnathidae	Dunckerocampus dactyliophorus	Y	0.001677183	Moderate	2016	2016	Data Deficient	10	24	external brooders
Haemulidae	Plectorhinchus chaetodonoides	Y	0.001302405	No culture record	NA	NA	NA	48.8	27	open water/substratum egg scatterers
Gobiidae	Elacatinus figaro	Y	0.00121682	Common	2022	2022	Vulnerable	10	1	
Labridae	Cirrhilabrus aquamarinus	Y	0.001101097	No culture record	NA	NA	NA	NA	NA	NA
Labridae	Cirrhilabrus naokoae	Y	0.000829159	No culture record	NA	NA	NA	10	1	
Syngnathidae	Hippocampus reidi	Y	0.000636823	Common	2017	2016	Near Threatened	11.63	21	external brooders
Siganidae	Siganus uspi	Y	0.000535134	No culture record	2016	2015	Near Threatened	14	2	open water/substratum egg scatterers
Plotosidae	Plotosus lineatus	Y	0.000436666	No culture record	NA	NA	NA	28.28	58	nesters
Apogonidae	Ostorhinchus compressus	Y	0.000350391	No culture record	NA	NA	NA	10	15	external brooders
Labridae	Cirrhilabrus filamentosus	Y	0.000323013	No culture record	2010	2009	Data Deficient	10	2	
Serranidae	Chromileptes altivelis	Y	0.000290804	No culture record	2018	2016	Data Deficient	34	24	
Hemiscylliidae	Chiloscyllium punctatum	Y	0.000269408	Common	2016	2015	Near Threatened	79.2	17	open water/substratum egg scatterers
Opistognathidae	Opistognathus rufilineatus	Y	0.000266417	No culture record	NA	NA	NA	10	1	

The full list can be found at https://ornamentalfish.org/cites-database/.

Example 2

37. This framework sorts species recorded as in trade in recent years (included in the associated database), and sorts those unassessed by IUCN and those assessed by IUCN to be Endangered, Vulnerable, Near Threatened, Data Deficient OR Least Concern over 10 years ago into the central box that assesses biological vulnerability to harvest. All species listed as Least Concern within the last 10 years by the IUCN Red List are categorised as Low Priority (green box). The threshold to assess whether a species is biologically vulnerable is either:

- A vulnerability score of 1.2 or lower from PSA analysis (as detailed in Box 1) OR
- A vulnerability score of 40 and above (based on the score in FishBase), or other indicators of vulnerability (e.g. high endemism or low fecundity).

Figure 2 – Schematic to illustrate the framework presented as Example 2 which shortlists species for further research or assessment based on various criteria (described in text). † Here “Commonly available as captive bred” refers to both featuring as Common on Coral magazine’s captive bred list and in industry data where over 25% of stock is sourced from captive bred sources. It is worth noting that availability of captive bred stock will vary with proximity to captive breeding operations.

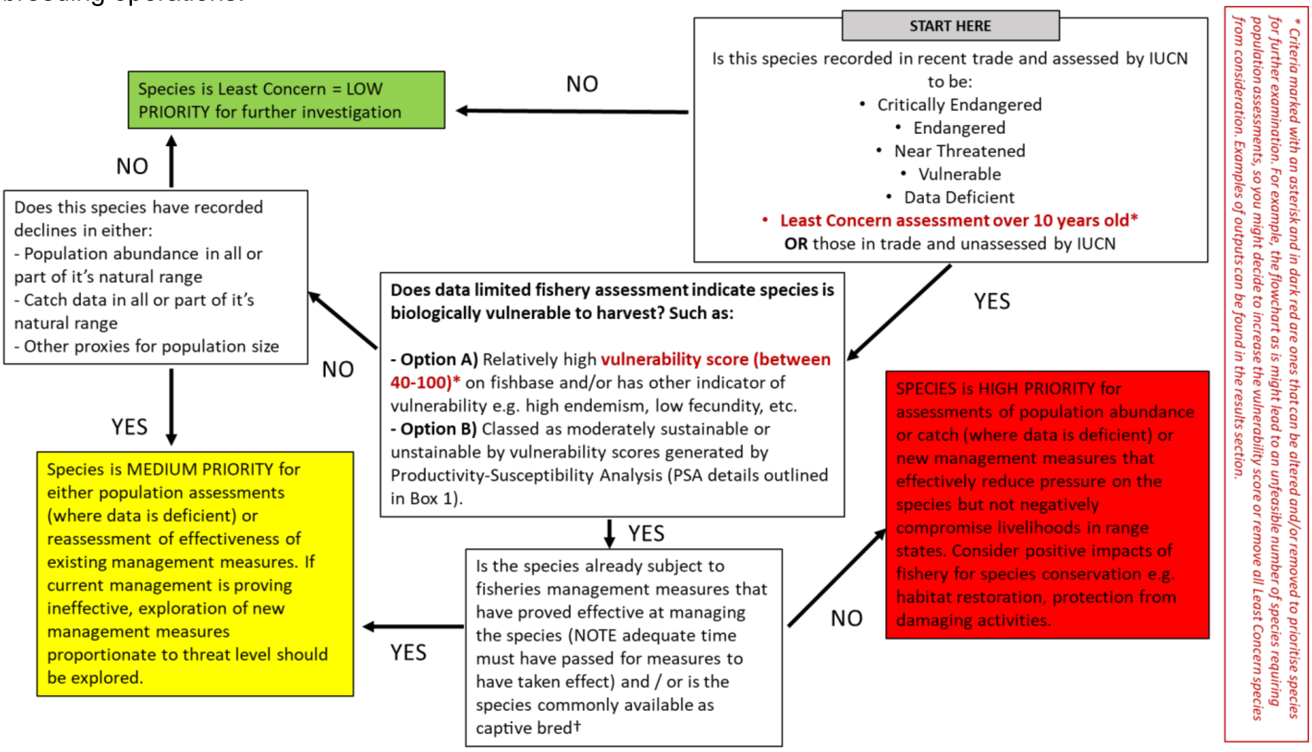

Table 2: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 2, utilising Option A as selection criteria.

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kauderni	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Acanthuridae	Zebrasoma flavescens	Y	0.01403933	Common	2012	2010	Least Concern	57.42	23	open water/substratum egg scatterers
Acanthuridae	Acanthurus leucosternon	Y	0.00771389	No culture record	2012	2010	Least Concern	41.6	25	open water/substratum egg scatterers
Acanthuridae	Naso elegans	Y	0.004920426	No culture record	2012	2010	Least Concern	41.96	24	open water/substratum egg scatterers
Acanthuridae	Zebrasoma scopas	Y	0.004144413	No culture record	2012	2010	Least Concern	66.27	50	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Pomacanthidae	Pomacanthus imperator	Y	0.003344242	No culture record	2010	2009	Least Concern	67.79	58	open water/substratum egg scatterers
Opistognathidae	Opistognathus aurifrons	Y	0.001970057	No culture record	2015	2012	Least Concern	10	30	external brooders
Serranidae	Pseudanthias cheirospilos	Y	0.001817523	No culture record	NA	NA	NA	NA	NA	NA
Syngnathidae	Dunckerocampus dactyliophorus	Y	0.001677183	Moderate	2016	2016	Data Deficient	10	24	external brooders
Muraenidae	Echidna nebulosa	Y	0.001453788	No culture record	2019	2011	Least Concern	60	62	
Haemulidae	Plectorhinchus chaetodonoides	Y	0.001302405	No culture record	NA	NA	NA	48.8	27	open water/substratum egg scatterers
Blenniidae	Meiacanthus oualanensis	Y	0.001263524	Moderate	2014	2009	Least Concern	10	1	nesters
Gobiidae	Elacatinus figaro	Y	0.00121682	Common	2022	2022	Vulnerable	10	1	
Acanthuridae	Acanthurus coeruleus	Y	0.001168506	No culture record	2012	2010	Least Concern	58.55	42	open water/substratum egg scatterers
Labridae	Cirrhilabrus aquamarinus	Y	0.001101097	No culture record	NA	NA	NA	NA	NA	NA
Labridae	Cirrhilabrus aurantidorsalis	Y	0.00086804	No culture record	2010	2009	Least Concern	10	1	
Labridae	Cirrhilabrus naokoae	Y	0.000829159	No culture record	NA	NA	NA	10	1	
Chaenopsidae	Acanthemblemaria macrospilus	Y	0.000809603	No culture record	2010	2007	Least Concern	10	2	
Syngnathidae	Hippocampus reidi	Y	0.000636823	Common	2017	2016	Near Threatened	11.63	21	external brooders

The full list can be found at https://ornamentalfish.org/cites-database/.

Example 3

38. This framework sorts species recorded as in trade in recent years (included in the associated database), and sorts those unassessed by IUCN and those assessed by IUCN to be Endangered, Vulnerable, Near Threatened, Data Deficient OR Least Concern over 10 years ago into the central box that assesses biological vulnerability to harvest. All species listed as Least Concern within the last 10 years by the IUCN Red List are categorised as Low Priority (green box). The threshold to assess whether a species is biologically vulnerable is either:

- A vulnerability score of 1.2 or lower from PSA analysis (as detailed in Box 1) OR
- A vulnerability score of 20 and above (based on the score in FishBase), or other indicators of vulnerability (e.g. high endemism or low fecundity).

Figure 3 - Schematic to illustrate the framework presented as Example 3 which shortlists species for further research or assessment based on various criteria (described in text). † Here "Commonly available as captive bred" refers to both featuring as Common on Coral magazine's captive bred list and in industry data where over 25% of stock is sourced from captive bred sources. It is worth noting that availability of captive bred stock will vary with proximity to captive breeding operations.

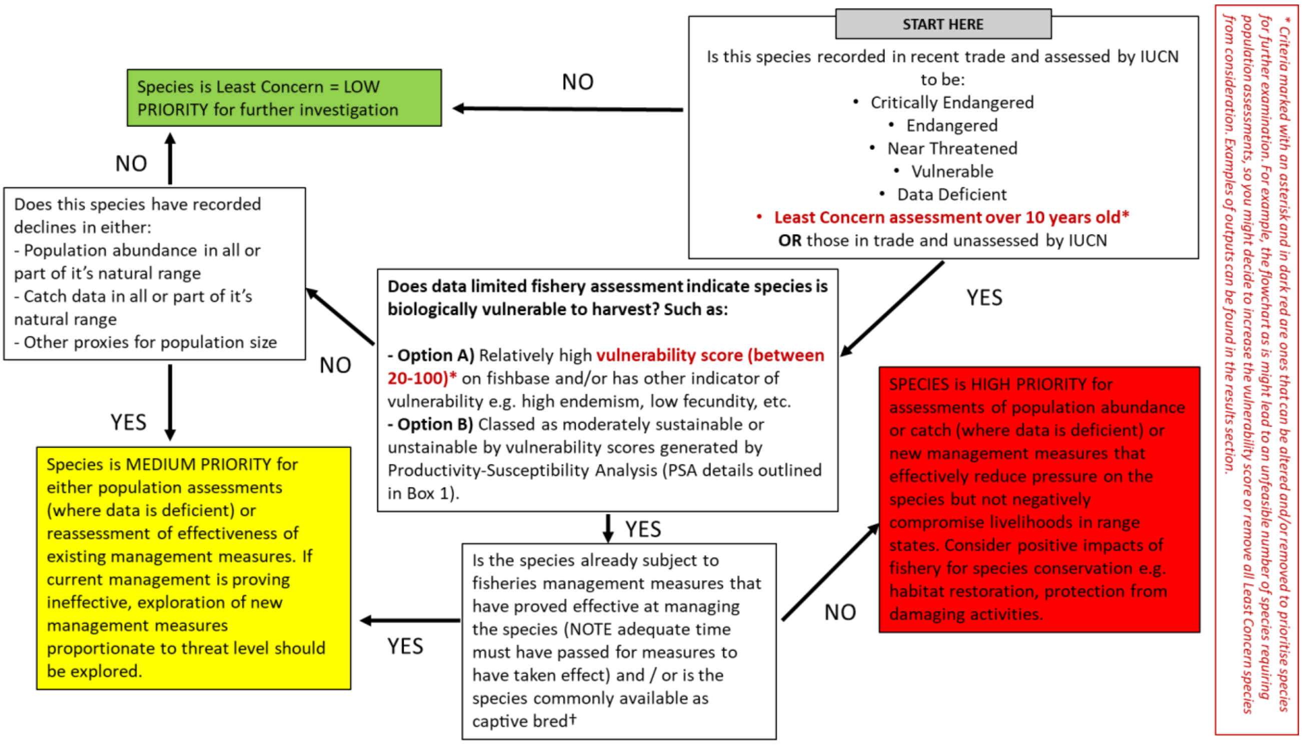

Table 3: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 3, utilising Option A as selection criteria.

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kaudemi	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Acanthuridae	Paracanthurus hepatus	Y	0.015947269	No culture record	2012	2010	Least Concern	21	45	open water/substratum egg scatterers
Acanthuridae	Zebrasoma flavescens	Y	0.01403933	Common	2012	2010	Least Concern	57.42	23	open water/substratum egg scatterers
Acanthuridae	Acanthurus leucosternon	Y	0.00771389	No culture record	2012	2010	Least Concern	41.6	25	open water/substratum egg scatterers
Acanthuridae	Naso elegans	Y	0.004920426	No culture record	2012	2010	Least Concern	41.96	24	open water/substratum egg scatterers
Acanthuridae	Acanthurus lineatus	Y	0.004765591	No culture record	2012	2010	Least Concern	22.89	56	open water/substratum egg scatterers
Pholidichthyidae	Pholidichthys leucotaenia	Y	0.004464665	No culture record	NA	NA	NA	24	8	
Acanthuridae	Zebrasoma velifer	Y	0.004294876	No culture record	NA	NA	NA	36.94	44	open water/substratum egg scatterers
Acanthuridae	Zebrasoma scopas	Y	0.004144413	No culture record	2012	2010	Least Concern	66.27	50	open water/substratum egg scatterers
Acanthuridae	Zebrasoma desjardinii	Y	0.003985897	No culture record	2012	2010	Least Concern	30	28	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Pomacanthidae	Pomacanthus imperator	Y	0.003344242	No culture record	2010	2009	Least Concern	67.79	58	open water/substratum egg scatterers
Acanthuridae	Ctenochaetus strigosus	Y	0.002797145	No culture record	2012	2010	Least Concern	28.11	16	open water/substratum egg scatterers
Ostraciidae	Ostracion cubicum	Y	0.002315386	No culture record	NA	NA	NA	35	61	open water/substratum egg scatterers
Acanthuridae	Naso lituratus	Y	0.002234633	No culture record	2012	2010	Least Concern	34.14	45	open water/substratum egg scatterers
Acanthuridae	Zebrasoma xanthurum	Y	0.002067375	Scarce	2012	2010	Least Concern	26.7	19	open water/substratum egg scatterers
Diodontidae	Diodon holocanthus	Y	0.001970517	No culture record	2015	2011	Least Concern	27.15	63	
Opistognathidae	Opistognathus aurifrons	Y	0.001970057	No culture record	2015	2012	Least Concern	10	30	external brooders
Acanthuridae	Acanthurus tennentii	Y	0.001943829	No culture record	2012	2010	Least Concern	21	22	open water/substratum egg scatterers

The full list can be found at https://ornamentalfish.org/cites-database/.

39. These examples illustrate the flexibility of the framework presented, allowing interested parties to prioritise species based on their policy priorities and on the importance of different metrics used – put simply the framework is not limited to the three examples presented here. For instance, it may be decided that a vulnerability score of 30 is a reasonable threshold to utilise, or one might include other life history metrics in the database. Parties may also wish to use other metrics within the database (e.g. number of individuals traded) to further sort species for assessment between medium and high priority.

Existing regulations/management measures

40. In 2014, a study outlined the existing strategies in place in source countries to manage the collection of marine ornamental fishes [18]. Building on the information presented in Dee et al (2014), a table has been produced of regulatory measures that govern collection marine ornamental fisheries, including as many known source countries as possible and updating (where known) any additional management measures introduced subsequent to the publication of Dee et al (2014). This table is not exhaustive and may not necessarily include more recent changes in fisheries management across different parties.

41. It is often suggested that there are no regulations and/or controls on the marine aquarium trade. This table debunks this suggestion, providing valuable detail for those who wish to assess the current sustainability of trade, highlighting the existing regulations and management measures in place. This also allows adequate assessment of existing measures before exploring other new forms of regulation or management that may have unintended negative consequences for conservation, enforcement and livelihoods.

Results

Number of species

42. This analysis found that of a total 2035 species recorded in the literature as traded as live marine ornamental fishes, only 1040 species were currently recorded in trade (traded in the last 5 years). This estimate of species traded is lower than other assessments of trade, in part due to corrections made for updated taxonomy (meaning that some species are amalgamated together), and also condensing entries into single species where they feature as different colour morphs (for example, one aquaculture company alone produces 26 varieties of *Amphiprion ocellaris*) [45]. It is also possible that other assessments of the trade may overestimate the number of species traded by the inclusion of species that are very rarely traded for public aquaria but sourced under the same harmonised commodity code [11], [43]. Although this data does not explicitly exclude specimens intended for public aquaria, it will more accurately demonstrate the relatively low volumes of specimens for this purpose compared with the much larger private aquarium market.

Numbers of individuals traded

43. Estimation of the total number of individuals traded globally was undertaken through utilisation of data gathered from industry sources and UN Comtrade data from 3 significant exporting nations of marine ornamental fishes – Philippines, Sri Lanka and Indonesia. These three countries were chosen as they are known source countries of marine ornamental fishes and ranked highly in terms of trade volumes of the relevant source code (03011900). The percentage contributions of importing nations to the total weights and values of marine ornamental fishes traded from these 3 countries was ranked. Using this data it was possible to extrapolate global figures for total number of individuals traded based on both weight and value rankings, generating upper and lower estimates of global take. This estimated that between 22.7 and 31.0 million individuals of marine ornamental fishes are traded annually. The top 80% of the trade by volume is made up from 114 species, the top 50% from just 25 species. The top 3 species make up 21% of total trade. Most species are traded in volumes of approximately 1000 to 1,999 individuals per year.

Table 4: Top ten most popular families in terms of species number and volumes (# of individuals) in trade

Family	Number of species	Family	Percentage of individuals in trade	Family	Low estimate volume	High estimate volume
Labridae	190	Pomacentridae	29.86%	Pomacentridae	6,646,450	8,859,406
Pomacentridae	96	Labridae	10.69%	Labridae	2,492,213	3,266,500
Chaetodontidae	82	Gobiidae	9.66%	Gobiidae	2,253,451	2,995,244
Gobiidae	76	Acanthuridae	8.98%	Acanthuridae	2,074,940	2,945,283
Serranidae	71	Apogonidae	6.30%	Apogonidae	1,341,050	1,799,685
Pomacanthidae	67	Serranidae	5.30%	Serranidae	1,187,462	1,808,289
Acanthuridae	57	Pomacanthidae	5.08%	Pomacanthidae	1,081,100	1,667,163
Blenniidae	37	Blenniidae	3.96%	Blenniidae	902,700	1,262,943
Pseudochromidae	28	Callionymidae	3.02%	Chaetodontidae	685,061	874,678
Balistidae	23	Chaetodontidae	2.97%	Microdesmidae	672,750	797,986

Table 5: Top ten most popular genera in terms of species number and popularity in trade

Genus	Number of species	Genus	Percentage of individuals in trade
Chaetodon	63	*Chromis*	10.151%
Cirrhilabrus	41	*Amphiprion*	8.922%
Acanthurus	31	*Chrysiptera*	5.590%
Halichoeres	29	*Valenciennea*	4.762%
Centropyge	27	*Pterapogon*	3.429%
Amphiprion	24	*Centropyge*	3.358%
Pseudanthias	17	*Pseudanthias*	3.246%
Chrysiptera	16	*Zebrasoma*	2.881%
Pseudochromis	15	*Acanthurus*	2.768%
Siganus	13	*Synchiropus*	2.580%

Table 6: Top ten most popular species in trade

Species	Percentage of trade	Cumulative percecentage	Cultured availability	IUCN assessment year	IUCN category
Chromis viridis	10.1%	10.1%	Captive breeding recorded	2021	Least Concern
Amphiprion ocellaris	7.3%	17.4%	Common	2021	Least Concern
Pterapogon kauderni	3.4%	20.8%	Common	2007	Endangered
Pseudanthias squamipinnis	2.3%	23.2%	Captive breeding recorded	2015	Least Concern
Labroides dimidiatus	1.9%	25.0%	Captive breeding recorded	2008	Least Concern
Chrysiptera parasema	1.8%	26.8%	Common	2021	Least Concern
Nemateleotris magnifica	1.7%	28.5%	No culture record	2009	Least Concern
Gramma loreto	1.7%	30.2%	Moderate	2011	Least Concern
Paracanthurus hepatus	1.6%	31.8%	Captive breeding recorded	2010	Least Concern
Valenciennea sexguttata	1.5%	33.4%	No culture record	2017	Least Concern

Table 7: Top 10 source countries with the greatest number of marine ornamental fish species.

Country	Number of species
Indonesia	621
Philippines	540
Australia	523
Papua New Guinea	498
Malaysia	494
Japan	478
Palau	454
Taiwan, Province of China	447
Solomon Islands	440
New Caledonia	406

Availability of captive-bred specimens

44. In line with recent research, availability of species as captive bred continues to grow. 121 species are now available as captive bred on the market, though the relative proportion of wild sourced vs captive-bred will differ between species dependent on a variety of factors, such as their life history characteristics, how long they have been bred in captivity for, feeding plasticity, etc. That said, based on known market trends, it is clear that over 10% of traded individuals are sourced from captive breeding, greater than previous estimates of the trade ranging from 1-5% [46], [47], with this figure likely to increase over time [10].

Table 8: Frequency of species available as captive bred in the market, these definitions are drawn from the Coral Magazine's annual assessment of captive breeding records [44] and supplemented where known with industry data.

Cultured availability	Number of species		Cultured availability	Percentage of individuals in trade
Common	82		Common	27.95%
Moderate	21		Moderate	3.27%
Scarce	18		Scarce	2.05%
Captive breeding recorded	123		Captive breeding recorded	24.85%
No culture record	796		No culture record	41.88%

Conservation status of marine ornamental fish species

45. Species recorded in trade by the associated database were assigned their IUCN Red List category alongside other recorded factors by IUCN (e.g. Threat level, year of assessment). The majority of traded individuals (88.8%) in trade are assessed as Least Concern by IUCN, with 3.43% of trade being in species that are assessed as Endangered, 1.84 % in Vulnerable and 0.24% as Near Threatened. This analysis also highlighted that the conservation status of some species in trade is unknown to the Red List, with 1.31% of trade being in species that are considered data deficient and 4.38% still unassessed by IUCN. There is also a wide distribution in the timing of species assessments by IUCN, as shown in Table 7. Given over 40% of species in trade were last assessed over 10 years ago, and 4.38% remain unassessed, this evidences the need for more recent population assessments of the species in trade.

46. This analysis also shows the distribution of species in trade in relation to their vulnerability index as found on FishBase [38], [39]. The majority of species (72.04%) fall below a score of 10/100, indicating low inherent vulnerability to fishing pressure due to their life history traits and ecology.

Table 9: Breakdown of species in trade that fall within each IUCN Red List category, along with the proportion of trade each category makes up.

IUCN Category	Number of species	Percentage of individuals in trade
Endangered	3	3.43%
Least Concern	867	88.80%
Data Deficient	39	1.31%
Vulnerable	14	1.84%
Near Threatened	10	0.24%
Critically Endangered	0	0.00%
Not Assessed	0	0.00%

Table 10: Number of species in trade by year of IUCN Red List assessment

Assess year	Number of species	Percentage of individuals in trade
2022	40	2.28%
2021	81	29.69%
2020	34	2.44%
2019	18	0.44%
2018	25	2.85%
2017	25	4.18%
2016	21	0.49%
2015	134	10.86%
2014	6	0.01%
2013	6	0.06%
2012	17	0.52%
2011	51	2.97%
2010	85	10.53%
2009	317	21.62%
2008	55	3.03%
2007	18	3.65%
Not Assessed	0	0.00%

Table 11: Number of species within vulnerability brackets derived from FishBase [38], [39].

Vulnerability bracket	Number of species	Percentage of individuals in trade	Cumulative percentage
0.1-10	619	72.04%	72.04%
10.1-20	143	11.08%	83.12%
20.1-30	87	9.45%	92.57%
30.1-40	67	2.40%	94.96%
40.1-50	39	1.66%	96.63%
50.1-60	26	1.83%	98.45%
60.1-70	13	0.80%	99.25%
70.1-80	6	0.07%	99.31%
80.1-90	7	0.03%	99.34%
90.1-100	0	0.00%	99.34%
Not Assessed	33	0.66%	100.00%

Shortlisting results for each example framework

47. In Table 12 below we present the number of species that are shortlisted for further examination under each different example of the framework using vulnerability and life history metrics from FishBase (Option A). Species lists for each example is available in detail at https://ornamentalfish.org/cites-database/. It is important to reiterate that the criteria in the framework can be adjusted according to the resources available to assess the species. In addition, species shortlisted into each of the final categories can be ranked in order of various different metrics used in the database, e.g. vulnerability score, captive bred availability. The "Number of species" column includes species that will need sorting into either Medium or High priority for further assessment of their populations or potential management measures. As discussed above, further work will be needed to determine which species fall within each category, in particular, assessment of current management measures in place and where necessary conducting further population assessments of some species.

Table 12: Number of species and volume of trade identified by each example framework using Option A selection criteria of vulnerability in each framework. *Does not include assessments that were conducted in 2013.

Example	IUCN Least Concern species	Vulnerability score	Number of species	Percent of trade
1	No least concern species included	>20	62	6.35%
2	Only those over 10 years included*	>40	119	9.54%
3	Only those over 10 years included*	>20	214	16.70%

48. Tables 13a-c show the different species identified by each example framework using Option A for assessing biological vulnerability. These are ordered by popularity in trade, but it is clear that each example selects a different subset of species due to the criteria used to shortlist.

Table 13a: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 1, utilising Option A as selection criteria.

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kauderni	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Pholidichthyidae	Pholidichthys leucotaenia	Y	0.004464665	No culture record	NA	NA	NA	24	8	
Acanthuridae	Zebrasoma velifer	Y	0.004294876	No culture record	NA	NA	NA	36.94	44	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Ostraciidae	Ostracion cubicum	Y	0.002315386	No culture record	NA	NA	NA	35	61	open water/substratum egg scatterers
Ostraciidae	Lactoria cornuta	Y	0.001888844	No culture record	NA	NA	NA	36	41	
Serranidae	Pseudanthias cheirospilos	Y	0.001817523	No culture record	NA	NA	NA	NA	NA	NA
Syngnathidae	Dunckerocampus dactyliophorus	Y	0.001677183	Moderate	2016	2016	Data Deficient	10	24	external brooders
Haemulidae	Plectorhinchus chaetodonoides	Y	0.001302405	No culture record	NA	NA	NA	48.8	27	open water/substratum egg scatterers
Gobiidae	Elacatinus figaro	Y	0.00121682	Common	2022	2022	Vulnerable	10	1	
Labridae	Cirrhilabrus aquamarinus	Y	0.001101097	No culture record	NA	NA	NA	NA	NA	NA
Labridae	Cirrhilabrus naokoae	Y	0.000829159	No culture record	NA	NA	NA	10	1	
Syngnathidae	Hippocampus reidi	Y	0.000636823	Common	2017	2016	Near Threatened	11.63	21	external brooders
Siganidae	Siganus uspi	Y	0.000535134	No culture record	2016	2015	Near Threatened	14	2	open water/substratum egg scatterers
Plotosidae	Plotosus lineatus	Y	0.000436666	No culture record	NA	NA	NA	28.28	58	nesters
Apogonidae	Ostorhinchus compressus	Y	0.000350391	No culture record	NA	NA	NA	10	15	external brooders
Labridae	Cirrhilabrus filamentosus	Y	0.000323013	No culture record	2010	2009	Data Deficient	10	2	
Serranidae	Chromileptes altivelis	Y	0.000290804	No culture record	2018	2016	Data Deficient	34	24	
Hemiscylliidae	Chiloscyllium punctatum	Y	0.000269408	Common	2016	2015	Near Threatened	79.2	17	open water/substratum egg scatterers
Opistognathidae	Opistognathus rufilineatus	Y	0.000266417	No culture record	NA	NA	NA	10	1	

Table 13b: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 2, utilising Option A as selection criteria.

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kauderni	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Acanthuridae	Zebrasoma flavescens	Y	0.01403933	Common	2012	2010	Least Concern	57.42	23	open water/substratum egg scatterers
Acanthuridae	Acanthurus leucosternon	Y	0.00771389	No culture record	2012	2010	Least Concern	41.6	25	open water/substratum egg scatterers
Acanthuridae	Naso elegans	Y	0.004920426	No culture record	2012	2010	Least Concern	41.96	24	open water/substratum egg scatterers
Acanthuridae	Zebrasoma scopas	Y	0.004144413	No culture record	2012	2010	Least Concern	66.27	50	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Pomacanthidae	Pomacanthus imperator	Y	0.003344242	No culture record	2010	2009	Least Concern	67.79	58	open water/substratum egg scatterers
Opistognathidae	Opistognathus aurifrons	Y	0.001970057	No culture record	2015	2012	Least Concern	10	30	external brooders
Serranidae	Pseudanthias cheirospilos	Y	0.001817523	No culture record	NA	NA	NA	NA	NA	NA
Syngnathidae	Dunckerocampus dactyliophorus	Y	0.001677183	Moderate	2016	2016	Data Deficient	10	24	external brooders
Muraenidae	Echidna nebulosa	Y	0.001453788	No culture record	2019	2011	Least Concern	60	62	
Haemulidae	Plectorhinchus chaetodonoides	Y	0.001302405	No culture record	NA	NA	NA	48.8	27	open water/substratum egg scatterers
Blenniidae	Meiacanthus oualanensis	Y	0.001263524	Moderate	2014	2009	Least Concern	10	1	nesters
Gobiidae	Elacatinus figaro	Y	0.00121682	Common	2022	2022	Vulnerable	10	1	
Acanthuridae	Acanthurus coeruleus	Y	0.001168506	No culture record	2012	2010	Least Concern	58.55	42	open water/substratum egg scatterers
Labridae	Cirrhilabrus aquamarinus	Y	0.001101097	No culture record	NA	NA	NA	NA	NA	NA
Labridae	Cirrhilabrus aurantidorsalis	Y	0.00086804	No culture record	2010	2009	Least Concern	10	1	
Labridae	Cirrhilabrus naokoae	Y	0.000829159	No culture record	NA	NA	NA	10	1	
Chaenopsidae	Acanthemblemaria macrospilus	Y	0.000809603	No culture record	2010	2007	Least Concern	10	2	
Syngnathidae	Hippocampus reidi	Y	0.000636823	Common	2017	2016	Near Threatened	11.63	21	external brooders

Table 13c: Top 20 species (ordered by popularity in trade) shortlisted for sorting into medium or high priority for further assessment under framework Example 3, utilising Option A as selection criteria.

Family	Species	In trade?	Percentage of trade	Cultured availability	Year	Assess year	Category	Vulnerability	Countries Fishbase	Breeding method
Apogonidae	Pterapogon kauderni	Y	0.034289987	Common	2007	2007	Endangered	19.08	1	external brooders
Acanthuridae	Paracanthurus hepatus	Y	0.015947269	No culture record	2012	2010	Least Concern	21	45	open water/substratum egg scatterers
Acanthuridae	Zebrasoma flavescens	Y	0.01403933	Common	2012	2010	Least Concern	57.42	23	open water/substratum egg scatterers
Acanthuridae	Acanthurus leucosternon	Y	0.00771389	No culture record	2012	2010	Least Concern	41.6	25	open water/substratum egg scatterers
Acanthuridae	Naso elegans	Y	0.004920426	No culture record	2012	2010	Least Concern	41.96	24	open water/substratum egg scatterers
Acanthuridae	Acanthurus lineatus	Y	0.004765591	No culture record	2012	2010	Least Concern	22.89	56	open water/substratum egg scatterers
Pholidichthyidae	Pholidichthys leucotaenia	Y	0.004464665	No culture record	NA	NA	NA	24	8	
Acanthuridae	Zebrasoma velifer	Y	0.004294876	No culture record	NA	NA	NA	36.94	44	open water/substratum egg scatterers
Acanthuridae	Zebrasoma scopas	Y	0.004144413	No culture record	2012	2010	Least Concern	66.27	50	open water/substratum egg scatterers
Acanthuridae	Zebrasoma desjardinii	Y	0.003985897	No culture record	2012	2010	Least Concern	30	28	open water/substratum egg scatterers
Callionymidae	Synchiropus sycorax	Y	0.003411652	No culture record	NA	NA	NA	10	1	
Pomacanthidae	Pomacanthus imperator	Y	0.003344242	No culture record	2010	2009	Least Concern	67.79	58	open water/substratum egg scatterers
Acanthuridae	Ctenochaetus strigosus	Y	0.002797145	No culture record	2012	2010	Least Concern	28.11	16	open water/substratum egg scatterers
Ostraciidae	Ostracion cubicum	Y	0.002315386	No culture record	NA	NA	NA	35	61	open water/substratum egg scatterers
Acanthuridae	Naso lituratus	Y	0.002234633	No culture record	2012	2010	Least Concern	34.14	45	open water/substratum egg scatterers
Acanthuridae	Zebrasoma xanthurum	Y	0.002067375	Scarce	2012	2010	Least Concern	26.7	19	open water/substratum egg scatterers
Diodontidae	Diodon holocanthus	Y	0.001970517	No culture record	2015	2011	Least Concern	27.15	63	
Opistognathidae	Opistognathus aurifrons	Y	0.001970057	No culture record	2015	2012	Least Concern	10	30	external brooders
Acanthuridae	Acanthurus tennentii	Y	0.001943829	No culture record	2012	2010	Least Concern	21	22	open water/substratum egg scatterers

Management measures

49. As Table 14 below illustrates, there is already considerable regulation of the marine aquarium industry in the majority of source countries. While it is clear that regulation/management measures exist and are widespread across source countries, it is unclear how and to what extent these are enforced. Effective enforcement and engagement with fisher communities will lead to best compliance and therefore sustainable use of marine ornamental fish stocks. Whilst every effort has been made to ensure the information in the table above is up to date, it is possible that some management measures or lack thereof may be out of date by time or publication OR not easily accessible online.

Table 14: Management measures governing marine ornamental fisheries in source countries – here “NA” indicates measures that were not available online.

Producing country or territory	Fisheries management plan Available online	Fisheries: Barriers to entry			Fisheries: Regulating commercial collection methods.									International trade	
		License or permit required	Limited licenses	Marine Protected Areas	Quotas for individual species	Total allowable catch	Size limits	Fishing season or seasonal closure by government	Catch Logging records	Gear restrictions	Anti-cyanide laws	Stock assessments for ornamentals	Bans or laws prohibiting catch of endangered species	Trade Restrictions (export inspection, quarantine laws)	OIE members
Australia	✓	✓	✓	✓	✓	✓	No	✓	✓	✓	✓	✓	✓	✓	✓
Bahamas	No	✓	No	✓	Conch only	No	No	No	NA	✓	✓	No	✓	No	✓
Brazil	✓	✓	✓	✓	NA	NA	NA	✓	NA	✓	✓	No	✓	✓	✓
Cook islands	Draft	✓	✓	✓	No	NA	NA	NA	✓	✓	✓	No	✓	✓	✓
Costa Rica	✓	✓	✓	✓	NA	NA	NA	NA	✓	✓	✓	NA	✓	✓	✓
Eritrea	No	✓	No	✓	No	No	No	NA	NA	NA	NA	NA	✓	✓	✓
Djibouti	NA	NA	NA	No	NA	NA	NA	✓	NA	NA	Ü	NA	✓	NA	✓
Fiji	✓	✓	✓	✓	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	✓
Federation State Micronesia	NA	✓	NA		NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓
French Polynesia	✓	✓	NA	No	✓	NA	✓	NA	NA	NA	NA	NA	✓	NA	NA
Haiti	NA	NA	NA	✓	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	✓
India	✓	✓	✓	✓	NA	✓	NA	NA	✓	✓	✓	NA	✓	✓	✓
Indonesia	No	✓	No	✓	✓	✓	No	No	NA	✓	✓	✓	No	No	✓
Kenya	Draft	✓	NA	✓	NO	No	NA	No	NA	No	✓	✓	✓	✓	✓
Kiribati	Draft	✓	No	✓	Flame Angelfish only	✓	1 species	No	NA	No	No	✓	No	✓	No
Maldives	Yes	✓	No	✓	✓	✓	No	No	NA	✓	✓	No	✓	✓	✓
Malaysia	✓	✓	✓	✓	No	No	No	No	✓	✓	✓	No	✓	✓	✓
Marshall Islands	✓	✓	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	No
New Caledonia	No	✓	✓	✓	NA	NA	NA	NA	NA	✓	NA	No	✓	✓	✓
Palau	✓	✓	✓	✓	NA	NA	NA	NA	✓	NA	NA	NA	✓	✓	No
Papua New Guinea	Draft	✓	No	✓	✓	✓	✓	No	✓	✓	✓	NA	✓	NA	✓
Philippines	At municipality level	✓	✓	✓	No	No	No	At municipality level	✓	✓	✓	No	✓	✓	✓
Solomon Islands	Draft	✓	NA	✓	NA	NA	NA	NA	NA	✓	NA	No	✓	✓	No
Sri Lanka	No	✓	No	No	No	No	NA	No	NA	✓	✓	✓	✓	✓	✓

Tonga	✓	✓	✓	No	No	✓	No	No	Ü	✓	✓	No	✓ (and clams)	✓	No
US (Florida)	✓	✓	✓	✓	✓	✓	✓	✓	NA	✓	✓	No	✓	✓	✓
US (Hawaii)	✓	✓	No	✓	No	No	✓	✓	NA	✓	✓	No	✓	No	✓
US (Guam)	✓	✓	No	✓	No	✓	✓	No	NA	✓	✓	No	Gold coral only	✓	✓
US (Puerto Rico)	✓	✓	✓	✓	✓	✓	No	✓	NA	NA	NA	✓	✓ (anemones)	✓	✓
Vanuatu	✓	✓	✓	✓	1 species	2 species	No	No	NA	✓	✓	✓	✓ (and clams)	✓	✓
Vietnam	NA	NA	NA	No	NA	NA	NA	NA	NA	✓	✓	No	NA	✓	✓

Key:

✓ = Yes, implemented.
NA = Not Available or no evidence of it at time of writing
No = Not implemented.

Discussion

50. This framework allows species to be prioritised for further examination based on their known biological vulnerability to harvest and draws on the best available data from a variety of respected and peer reviewed sources. Crucially, it starts from a realistic standpoint of species that are known to regularly be in trade by using information sourced from industry itself. This, along with the use of metrics and life history data from FishBase [38], allows species that are deserving of further focus to receive it whilst preventing unnecessary effort and resources being wasted on species that are likely not biologically vulnerable to harvest. In addition, it also provides valuable context for CITES Parties when considering management measures for species by building on existing research [18] to highlight current management measures in place in source countries that govern collection of marine ornamental fishes.

<u>Utilisation of the framework</u>

51. Whilst the framework draws on the best information available to shortlist species into its three categories (LOW, MEDIUM and HIGH PRIORITY for further assessment), it is worth noting the shortcomings of the metrics drawn upon. Although the IUCN Red List methodology can be varied in terms of the data it draws upon for assessment (see Introduction for detail), it was chosen for the initial assessment box to remove species that have already been assessed as being of relatively low priority for conservation efforts. The data limitations of IUCN (outlined in the introduction) are then addressed by FishBase derived information (Option A within the framework) in an effort to ensure that only species that are biologically vulnerable to harvest are examined further. Whilst FishBase contains a wealth of information at the species level on vulnerability and life history metrics, it is continually in a process of being updated and many species in the associated database had missing information on key life history traits, such as fecundity or spawning method. The vulnerability score is drawn from a paper that incorporates a range of key life history traits [39]. Whilst this score was the most appropriate to use on FishBase (versus resilience score), it is still flawed for solely assessing marine ornamental species. This score aims to incorporate all finfish and is parameterised using a range of species that do not feature in the trade, i.e. food fish species. Marine ornamental fishes are typically fast growing, small-bodied, short-lived species with relatively high fecundity and dispersal potential. This tends to put the majority of species in trade at the lower end of the scale (1-100). This was accounted for by a) setting a relatively low threshold for vulnerability of 20 and above, and b) including other key metrics for life history that would indicate vulnerability to high fishing pressure. As discussed above, the use of alternative tools such as PSA to generate vulnerability scores would greatly improve the functionality of this framework. In the absence of population or catch data to inform management decisions, PSA effectively weights life history characteristics against trade vulnerability, ecological niche and other metrics to generate a vulnerability score tailored to the conservation of the species groupings considered – in this case coral reef ornamental fish species.

52. If a species does not meet the biological thresholds for vulnerability (i.e. either through vulnerability scores or other life history traits) then the left hand box (see figures 1-3) that sorts into low or medium priority can act as a safety net to ensure species still are prioritised for attention if needed. Where there is evidence of declines in population (either in population abundance, catch data or other proxies) then these species can still be prioritised to medium category.

53. Those that wish to categorise species into medium or high priority for further management and research into their populations, will find the list of existing management measures useful in making these deliberations, as will the information on species that are captive bred and how widely available these are. Whilst every effort is made to ensure management measures for source countries are appropriate and effective, range states should be involved in discussions to determine whether other regulations/management governing particular species are in place before consideration of additional management measures. The list of management measures presented here should be examined for their effectiveness at governing the sustainability of marine ornamental fishes before the recommendation of further management tools. Failure to do this could lead to unintended consequences for conservation, livelihoods, engagement of fisher communities, compliance with regulations and ultimately the sustainable use of reef systems.

54. The inclusion of captive breeding as a tool for deliberating between medium and high priority categories was included for several reasons. If a species is being captive bred at scale (25% or more is used in the examples above but this can be altered as desired) that represents a significant pressure being removed from wild stocks of a given species. It is also expected that as time progresses, the efficiency of aquaculture operations will increase so that more individuals become available to meet consumer demand. This is evidenced by the growth of captive breeding in multiple species of marine aquarium fish, such that the majority of specimens traded are now sourced through aquaculture, such as the Banggai Cardinalfish [29], Common Clownfish [29], [45] and Seahorse species [52], [53]. That said, it should be considered that different markets will have differing levels of access to captive bred specimens depending on closeness to aquaculture operations. For example, markets within or in close proximity to the USA may have greater access to species bred by aquaculture operations that operate there.

55. When considering whether or not species are a high or medium priority for further management, Parties should consider if a) those with management measures already in place are effective and have had sufficient time since implementation to be effective and b) if the market has naturally reduced demand for wild specimens with growth in capacity of captive breeding enterprises.

How does this framework compare to other assessments?

56. There have been several assessments of the trade in the run up to the workshop on marine ornamental fishes, some of which have included methods to shortlist species for further examination/research. This assessment builds on some of this previous work by utilising industry data that has historically been unavailable for general examination. This gives a more realistic picture of species that are actually in trade and realistic numbers in which they are traded.

57. Other assessments of the marine aquarium trade have utilised data from public aquaria to assess which species are in trade. Whilst there is some crossover in species utilised by both public aquaria and private home aquaria, it should be noted that the majority of individuals traded that fall within the terms of reference of the CITES technical workshop [3] are destined for private home aquaria. The data and framework presented here primarily relates to individuals sourced for private home aquaria, however will include some individuals that are sourced for public aquaria through established supply chains. Alternative data sources alongside those presented here should be utilised to prioritise primarily public aquaria species (e.g. large bodied, temperate) that warrant further assessment of their populations and/or management.

58. The UNEP-WCMC report on marine ornamental fishes [26] drew on multiple data sources to summarise key statistics about the trade (e.g. diversity and volume) and to shortlist species that may be at risk of over-exploitation. Though UNEP-WCMC's report to CITES [26] included some preliminary results based on early iterations of what is presented in this report, its shortlisting relied on various official data sources (e.g. TRACES, LEMIS, other recorded trade data) as well as data from Aquariumtradedata.org [29], [30]. Whilst arguably the best assessment of the trade based on the information made available to UNEP-WCMC prior to the CITES 19th Conference of the Parties, the shortlisting of species likely to be threatened by trade carries errors resulting from the use of official datasets as discussed in the Introduction above, such as under and over representation of different taxa. As such, the shortlisting of "high likelihood of being threatened by trade" amounted to 80 species, only 41% of were recorded to be traded in the industry database presented here. That said, some species listed in the UNEP-WCMC report to CITES may feature in small numbers for public aquaria and not sourced through industry supply chains. In addition, the vulnerability thresholds that drew on FishBase [38], [39] data to assess vulnerability are typically higher than those used in the example frameworks above (see figures 1-3), with 60/100 considered the threshold for "high likelihood" species and 30-60/100 for "moderate likelihood of being threatened by trade" species. The frameworks presented in this paper opt for more conservative thresholds for prioritisation due to the limitations of the FishBase vulnerability scores discussed above. In addition, it should be noted that during the analysis of this database, discrepancies in vulnerability scores were found between those reported by UNEP-WCMC and the most recent update of FishBase, so the latter were used in the analysis shown here.

59. Multiple assessments of the trade drew upon data extracted from packing notices, either from Aquariumtradedata.org [28]–[30] or the tools presented in CITES COP19 Information Doc 68 by the Centre for Environment, Fisheries and Aquaculture Science (Cefas) [31]. These tools represent the most accurate recording of data on species traded and volumes by species. However, invariably these recording systems are resource limited so currently can only offer a snapshot over a given time in a specific country. Aquariumtradedata.org should be caveated in that it draws on USA import data, which itself is a producer of marine ornamental fishes through aquaculture and some collection effort. As such, drawing on this tool alone to extrapolate global trends (and therefore make global recommendations) is likely to underrepresent some species and over represent others. The results of the work presented in COP19 Inf.68 by Cefas [31] draws on snapshots of packing information from UK Imports between 2018-2019. These results, although not comparable in terms of global volumes trade by species, are highly correlated with the results obtained through this analysis. The Cefas report [31] identified the top 25 species which made up 49.6% of the individuals traded. Of those top 25 species found by Cefas, 72% (18 species) also featured in the top 25 species of this database, and the top 3 species were identical. It is also important to note that of the 28% (7 species) that did not feature, one was not found as the Cefas report recorded *Anthias* at genus level (compared with this industry database goes down to species level), and the other six were found in the associated database but outside the top 25 species. Five of these differed by less than 0.4% of the trade between lists. The listing of *Anisotremus* spp. as the fourth most popular species was surprising as these fish are not frequently traded for home aquaria (the associated database has one species at 0.02% of trade) which could suggest a recording error or a significant purchase for public aquaria. Cefas identified a total of 758 species traded whereas this analysis of industry data identified a total of 1040. The differences between the data presented here and the Cefas model [31] likely draws from the limited time period that was used: Cefas only collected data from a selection of consignments throughout 2018-2019 whereas data for this analysis encompasses multiple years' worth of data spanning from 2016-2022. This highlights the need for tools that draw information from packing data to be adequately resourced and funded in order to get the best data possible on trade trends. It is also worth noting that tools such as those developed by Cefas and the developers of Aquariumtradedata.org could potentially have much wider applications for understanding wildlife trade beyond marine ornamental fishes.

60. The information here represents a powerful tool to allow Parties to make species appropriate recommendations on marine ornamental fishes. From the data presented here and in the associated database it is clear that, whilst highly diverse, the trade is dominated by species that are categorised as Least Concern by the IUCN Red List (88.8%) and low biological vulnerability according to FishBase (72%). By using industry data and the framework provided, species in trade that may be biologically vulnerable to over-exploitation are highlighted for assessment of their populations or where appropriate, further management measures. Crucially, the framework is flexible, allowing Parties to alter criteria and rank species as needed depending on policy priorities. Further, the updated list of management and regulations in source countries can assist Parties in making informed decisions about management of species that may be at risk of unsustainable trade.

Conclusions

61. The modus operandi and terms of reference made during the 32nd meeting of the Animals Committee are far reaching and extend beyond the scope of this document. What should be considered by those that assess the trade is the need to base any recommendations on the best possible data available, and where necessary, support the collection of data where it is lacking. The trade in marine ornamental fishes is highly diverse in terms of the number of species it trades in and the regions and communities that it supports around the world. However, this diversity means that inevitably gaps in understanding persist regarding species population dynamics, sustainability and volume of take, and how management is applied in source countries.

62. What is clear however, is that the trade supports many of the most remote and poor communities around the globe, and that any future management of the trade must consider the likely impact on these communities of further restrictions on their livelihoods and any unintended consequences that might arise from suggested management measures [54]–[57]. It is imperative that the industry acts as good custodians and manages the natural resources they rely on in a sustainable

way as this is essential to protect the environment but also for those around the world who rely on the trade in marine ornamental fishes for their livelihoods.

63. Engagement of fisher communities prior to and during the implementation of management measures has been widely shown to improve compliance and engagement [58]–[61]. As such, any recommendations regarding management or any other assessments of this trade should be appropriate to the level threat posed to species by the trade and should engage with communities within source countries to ensure good compliance, engagement and continued conservation of reef populations.

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