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Aquarium Trade in Indonesia and Risk Assessment of Selected Species

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Aquarium Trade in Indonesia and Risk Assessment of Selected Species independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, August 12, 2020

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Brigitta P. D. Zámečníková-Wanma

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Abstract

Indonesia is one of the biggest worldwide suppliers and has been in the industry for a long time. Nonetheless, the information about both marine and freshwater species traded as ornamentals is lacking. This study aims to provide a list of freshwater and marine species exported from Indonesia, assess the risk of invasiveness in selected non-native iconic species, and to form suggestions for sustainable use of the traded species.

The list of species was obtained directly from Indonesian exporters. Additional data such as species conservation status and distributions were derived from qualified databases. Several non-native popular species were chosen for further analysis. Climate suitability was analysed using CLIMATCH 1.0. The Fish Invasiveness Screening Kit (FISK) was adopted for all selected species within Indonesia as Target Region.

The study found 1323 of total species exported as ornamental from Indonesia consisted of 773 marine species and 550 freshwater species. The biggest portion of the species came from class Actinopterygii. Additionally, several species of elasmobranch, invertebrates, and amphibians were also found to be traded. Four non-native iconic species were chosen to be assessed. *Betta splendens* was assessed to be a high-risk species in Target Region. Meanwhile, *Paracheirodon innesi*, *Poecilia reticulata*, and *Pterophyllum scalare* were rated as medium-risk species.

Betta splendens was found to have been established in Indonesian water. Most probably due to its widespread use as a mosquito bio-control agent. The utilisation of native Indonesian species for bio-control is highly recommended. Additionally, eco-certification should also be considered to protect and conserve the endemic and or endangered Indonesian species.

Keywords: Ornamental trade, Freshwater ornamental, Marine ornamental, Indonesia

Contents

List of tables

List of figures

List of the abbreviations used in the thesis

CBD	= Convention on Biological Diversity
CLIMATCH	= Climate Matching
CoL	= Catalogue of Life
CofF	= Catalog of Fishes
CV	= Commanditaire Vennootschap
EOL	= Encyclopedia of Life
FAO	= Food and Agricultural Organization
FISK	= Fish Invasiveness Screening Kit
GBIF	= Global Biodiversity Information Facility
IUCN	= International Union for Conservation of Nature
OATA	= Ornamental Aquatic Trade Association
RA Area	= Risk Assessment Area
TRID	= Temperature and Rainfall suitability for Indonesia
UK	= United Kingdom
USA	= United States of America
USD	= United States Dolar ($)
VBA	= Visual Basic for Application
WoRMS	= World Register of Marine Species

1. Introduction and Literature Review

Indonesia is the biggest archipelago country in the world with the ocean size of 6,653,341.439 km^2, covering 76.94% of the country's total size (Ramdhan & Arifin 2013) and is located within Coral Triangle Area, the most biodiverse coral reef in the world. The coral reef provides habitat for colourful attractive fishes and other groups of organisms that are suitable for trading as ornamentals.

The trade of marine ornamental fishes is not strictly limited to the group of fishes but also corals, echinoderms, crustaceans, etc. For instance, *Lobophyllia* coral species which has distribution throughout Indonesia was exploited for ornamental coral trade (Yusuf et al. 2019).

Fish species that are threatened and not much studied were as well exploited and traded as ornamental species. Endangered species such as *Pterapogon kauderni* or Banggai Cardinalfish is one example of favourite ornamental species that were exported from Indonesia, yet the trade was not properly monitored (Lunn & Moreau 2004). Rainbowfish and New Guinean crayfish were other examples of traded species from Indonesia.

It is also known that Indonesia is one of the biggest freshwater and marine ornamental exporters in the world (Wabnitz et al. 2003; Monticini 2010; Domínguez & Botella 2014). With the number of ornamental fish traded in 2018 as many as 1.8 billion individuals and its intention to achieve 2.3 billion fish in 2019, Indonesia continues its goal to become number one ornamental exporter in the world (The Jakarta Post 2019). Yet, data on exported species from Indonesia is lacking and hardly accessible.

It is expected that non-native and endangered endemic species are among the species traded from Indonesia. Satyani and Subamia (2009) reported that 56.5% of freshwater fishes exported from Indonesia are the introduced species. Furthermore, 78.3% species that are successfully bred in captivity for export effort consisted of introduced species (Satyani & Subamia 2009).

The high percentage of introduced fishes cultivated in Indonesian waters has the potential of unintentional release into water bodies. This has become a substantial

concern for the sustainability of native Indonesian fish. The adverse effects of introduced species on native species have been widely reported (Fritts & Rodda 1998; Bax et al. 2003; Morgan et al. 2004; Williams 2007; Cucherousset & Olden 2011).

The thesis provides information about marine and freshwater species that were known to be exported from Indonesia. Additionally, trade size and price, distribution and conservation status of the species were included. Several selected non-native popular species were assessed its establishment's and invasiveness potential in the wild. Thus, this information can be used to improve decision making on wildlife management in the country.

1.1. Aquarium Ornamental Trade

Trade in the ornamental aquatic industry referred to to the commercial exchange of goods between parties (King 2019). The aquarium ornamental trade includes the activity of selling and buying aquatic plants or animals species to be kept in aquarium or garden pool as pets or for fun and decorative purposes (Harsha et al. 2019; Sinansari & Priono 2019). These ornamental species usually possessed attractive and/or rare attributes, such as colouration, body shapes, or other specific characteristics (Gomelsky et al. 2016; Harsha et al. 2019).

It was estimated that around 1-2 billion and more live ornamental fish are moved worldwide every year (Monticini 2010; Evers et al. 2019). Indeed, the ornamental trade is an enormous worldwide business which includes a large number of individual's transfer. FAO started the ornamental trade tracking in 1976 with the report of 28 exporting countries (Monticini, 2010). The number of exporting countries (including re-export effort) is reported to reach 105 countries in 2004 and decreased to about 100 countries in 2007. Asian countries were counted as the biggest global ornamental contributors, supplying the world demand as much as 57% in 2014 (Evers et al. 2019)

Major countries known to export ornamental fishes are Asian countries including Indonesia, Singapore, Philippines, Sri Lanka, the United States of America (Hawaii), the Netherlands, Germany and some Central and Eastern European countries (the Czech Republic and Russia) (Townsend 2001; Wijesekara &

Yakupitiyage 2001; Monticini 2011; Evers et al. 2019). Meanwhile, the top global importers of aquarium fishes were the United States of America, European Union Countries and Singapore (Cheong 1996; OATA 2019). Singapore was known to be the main aggregator and exporter of fish across Asia by Export Value (Cheong 1996; Novalius 2018; Evers et al. 2019; OATA 2019). Thus, Singapore could be considered as the main ornamental fish' transit port.

Global ornamental fish trade came from both wild-caught and captive-bred species. King (2019) reported that approximately 90% of ornamental freshwater fish species traded were captive-reared, yet 90-95% of marine species traded were the product of wild-caught. Even though wild harvest may endanger the survival of native wild species and habitat destruction through over-fishing and the use of destructive fishing methods (Nurdin et al. 2016; Evers et al. 2019), some benefits could be gained from the industry if managed and controlled properly (Dykman, 2012; Domínguez & Botella 2014; Evers et al. 2019; King 2019).

The aquarium ornamental trade does not only consist of fishes. Bassleer (2015) reported that marine aquarium trade consisted of 35% invertebrates in the Netherlands and UK, and 60% invertebrates in the USA. Amphibians, molluscs, and crustaceans are also reported as species being in 25 top sellers of freshwater ornamental species traded in the USA (Bassleer 2015; Patoka et al. 2015; Patoka et al. 2017).

1.2. Aquarium Ornamental Trade in Indonesia

Information on the starting point of freshwater ornamental trade in Indonesia was not available. Nevertheless, marine ornamental trade in Indonesia was recorded since the 1960s with its first catching areas known from Seribu Islands, Jakarta, Indonesia (Sinansari & Priono 2019). Since then, Indonesia was known to be one of the top ornamental traders in Asia and the world, not only on marine species but also in freshwater species. The total export value of marine and freshwater ornamental trade in Indonesia from 2006 to 2017 is listed in Table 1.

Since 2006, Indonesia has always been in the top 20 of ornamental fish exporters in the world and settled on top 10 since 2009 (Table 1). In 2016 and 2017

Indonesia kept its position as the fifth main exporter in the world (Table 1). As a comparison, the biggest ornamental fish exporter in 2016 and 2017 was Singapore with export value as much as 42,974,938 USD (2016) and 38,983,262 USD (2017) (Fact Fish 2018b).

Table 1. Indonesia's world position as Ornamental live fish exporter based on the export value in USD

Year	World position	Export Value (USD)
2006	9th	9,433,513
2007	13th	8,175,359
2008	11th	8,924,676
2009	9th	11,660,944
2010	5th	19,766,172
2011	6th	19,895,702
2012	5th	21,015,310
2013	4th	24,197,497
2014	6th	20,860,227
2015	6th	19,668,907
2016	5th	24,641,463
2017	5th	27,609,865

Data based on Fact Fish (2018a)

Indonesia's ornamental fish export value is expected to increase in the following years. The Jakarta Post (2019) reported Indonesia's target to become the number one ornamental supplier in the world both on freshwater and marine fish. Even though Indonesian ornamental fish council reported that in 2016 ornamental fish was mostly exported to USA (Indonesian Ornamental Fish Council 2016), numerous ornamental fishes were also exported to Singapore due to the trade route (Pasopati 2017).

By the export value, Singapore had almost doubled its export value compared to Indonesia. On the other hand, General Directorate liable for Strengthening the Competitiveness on Marine and Fisheries Products (*Direktorat Jenderal Penguatan Daya Saing Produk Kelautan dan Perikanan*) stated that Indonesia had higher export volume compared to Singapore (Jurnas 2018; Novalius 2018).

Differently put, Indonesia had higher export volume, yet lower in its value compared to Singapore. This was probably due to the lower quality of ornamental fishes exported from Indonesia. Species exported by Indonesia were not selected for its best quality, exported to Singapore, selected and re-exported by Singapore

(Pasopati 2017; Jurnas 2018). Eventually, through selection, ornamental fishes traded by Singapore had indeed higher value.

Indonesian ornamental export value increased by 12.05% in 2017, as much as 27.61 million USD compared to the export value in 2016 (24.64 million USD) (Suhana 2018). In 2018, the export value of ornamental fishes reached 32.23 million USD and in the first semester of 2019, it reached 16.54 million USD, showing an increase of 2.56% compared to the first semester in 2018 (Suhana 2019).

Minister of Fisheries in Indonesia declared the governmental support for ornamental fish breeders to increase the quality of exported ornamental fishes (Pasopati 2017). Moreover, the Government of Indonesia conjointly planned to export ornamental fishes directly to its target countries without passing through Singapore (The Jakarta Post 2019). Thus, the aim of the country to be the biggest exporter in Asia could be achieved by reducing the re-exporting effort of Singapore.

1.2.1. Marine Ornamental Trade

Marine ornamental trade had been known as a popular activity among the aquarists. In the 1840s, the first public marine aquarium exhibit was introduced at the Zoological Gardens of Regent's Park in London (Palmtag 2017). Furthermore, the marine ornamental trade was not only consisted of fish only. It was reported that molluscs, gastropods, crustaceans, echinoderms, corals, anemones, and algae were among the species traded in the industry (Bassleer 2015; Barton et al. 2017; Palmtag 2017).

Indonesia was reported to be one of the biggest marine ornamental exporters in the world. For instance, most of the top 10 corals imported to the US were propagated in Indonesia (Barton et al. 2017) and most of the marine species entering Switzerland came from Indonesia (Biondo 2018). The target countries for marine ornamental species produced by Indonesia were the USA, China and European countries (Leal et al. 2015; Jurnal 2018).

Sinansari & Priono (2019) reported around 700 species of marine ornamental fishes existed in Indonesia from which only 480 species had been identified and 200 had been traded. Moreover, 95% of the marine species traded were harvested from the wild and only 5% of the traded species were cultivated. Most of the exporters were

situated in Jakarta and Bali. This was probably due to the available access from both cities to the USA and Europe (Sinansari & Priono 2019). Small quantities of export trade were also reported from Makassar (Sulawesi), Solo (Central Java), and Medan (Sumatra).

1.2.2. Freshwater Ornamental Trade

The Indonesian freshwater ornamental trade was reported to cover around 38.83% of the total ornamental fishes exported from the country and reached the value of 12.51 million USD in 2018 (Suhana 2019). It was also reported that the target countries for freshwater ornamental fishes were China, Japan, Singapore, USA, and the European countries (Jurnas 2018). Even though freshwater ornamental trade formed less than half of the total industry in the country, it composed the biggest portion of ornamental export trade to certain countries. For instance, in 2017 about 72% of ornamental fishes imported by the USA from Indonesia consisted of freshwater fishes (Laoli 2018).

Around 23-30% of the freshwater ornamental export's value was complied by Arowana fishes (family Osteoglossidae) (23-30%) (Jurnas 2018; Suhana 2019). The most popular variant of Arowana fish, the "super red", was reported to be sold at up to 10 million Indonesian rupiahs or around 680 USD (Satyani & Subamia 2009). Additionally, other popular native fishes exported from Indonesia were from the genera *Betta, Spaerichthys* and *Trichogaster,* which were mostly harvested from the wild except for *Trichogaster* (Satyani & Subamia 2009).

In addition to the native Indonesian species, non-native ornamental species originated from South America, Africa, and other Southeast Asian countries were also bred and exported from the country (Satyani & Subamia 2009; Dewantoro & Rachmatika 2016). Surprisingly, majority of native freshwater ornamental fishes from Indonesia was gained from the wild and those bred in captivity were more common on those introduced non-native species (Satyani & Subamia 2009; Evers et al. 2019). Furthermore, Satyani & Subamia (2009) also reported that fishes from families Bagridae, Balitoridae, Chandidae and Channidae were not yet bred in captivity and came from wild harvest.

Table 2. Number of native and introduced ornamental species exported from Indonesia

Fishes	Total	Cultured	Not cultured	In research
Native	141	44	97	30
Introduced	183	155	29	-
Total	324	198	136	30
Non-fish	12	8	4	3

Source: Satya & Subamia (2009)

Table 2 presented the number of native and non-native Indonesian ornamental fish that were being cultured and not yet being cultured. As it was already mentioned before, most of the captive-bred species were those of introduced species. Meanwhile, the native species were still under research to be able to be cultured in captivity. Additionally, some popular non-fish species being exported from Indonesia were crayfish *Cherax* sp. and shrimps *Caridinia* sp (Satya & Subamia 2009).

1.3. The Impacts of Ornamental Trade

The growing interest in Indonesia's aquatic ornamental trade has been reported to give detrimental effects to the marine and freshwater environment (Evers et al. 2019). Unsustainable destructive catching techniques such as the use of explosives, toxins, destructive traps and fishing techniques were reported to be practised in Indonesia and most probably are still performed (Pet-Soede & Erdmann 1998a; Pet-Soede & Erdmann 1998b; Pet & Pet-Soede 1999; Kramer et al. 2002; Bailey & Sumaila 2015; Sinansari & Priono 2019).

One of the most devastating impacts of the ornamental trade is the species invasion. Several species had been reported to established and showed significant detrimental effects on the environment and the native species (Milardi et al. 2018; Pennuto et al. 2018). For instance, competing over the native species, hybridisation, and extensive modification in the regional ichthyofauna (Cucherousset & Olden 2011; Magalhaes & Jacobi 2013).

Even though the negative impacts of ornamental trade had been widely known, some positive significances were also brought by the industry. Fishkeeping

in aquaria has been stated to improving the knowledge and conservation efforts of kept animals (Maceda-Veiga et al. 2016; King 2019). It also has become the source of income for people who make living out of wild-catching in a remote area and provided an additional and main source of income for farmers and entrepreneurs (Evers et al. 2019; King 2019; Prasadi 2019). Moreover, breeding in captivity means lower pressure to native populations.

2. Aims of the Thesis

Several aims to be achieved by the thesis are listed below:

1. Find, obtain, and analyse data from Indonesian exporters and producers of aquatic ornamental species.
2. Provide a list of freshwater and marine ornamental fishes exported by Indonesia.
3. Identification of potentially high-risk fish species.
4. Identification of the threats to endemic species.
5. Fill in the gap on information about marine and freshwater pet trade in Indonesia and to construct suggestions to improve wildlife management and conservation in the country based on the results of the thesis.

3. Methods

3.1. Data Collection

Data on species traded were collected directly from three ornamental fish exporters in Indonesia. The greatest number of data was acquired from John's Aqua and CV MAJU Aquarium. The data obtained from both exporters were the scientific name, market name, size and the price of the species. Some additional data were also attained from Indo Fish exporter.

3.2. Data Analysis

Data obtained from the whole sellers are checked for the validity of its names, both scientific and common name. The validity of the names is checked on several databases such as Catalogue of Life, FishBase, Eschmeyer's Catalog of Fishes and IUCN Red List.

Valid ornamental species were then written into a table with more information about their colour morphology, size, price, conservation status, population trend and distribution of the species. Distribution data were derived from several sources such as Catalogue of Life, FishBase, Eschmeyer's Catalog of Fishes and IUCN Red List. Furthermore, distribution data will be used for the Risk Assessment of selected species. The species were grouped taxonomically by the order, family, genus, and species into a table. Additional information such as price, size of the traded species (if available), conservation status and distribution data is then added to the table for further analysis.

3.2.1. IUCN Red List

The International Union for Conservation of Nature Red List (http://www.iucnredlist.org, here and after IUCN) is the world's broadest and most known database on the global conservation status of animals, fungi and plant species. IUCN Red List was utilised to escort scientific research, inform policy and conservation planning, improve decision making, educate and to raise awareness. It

provided even broader information of threats faced by the species, conservation actions taken to protect the species and researches needed on the species.

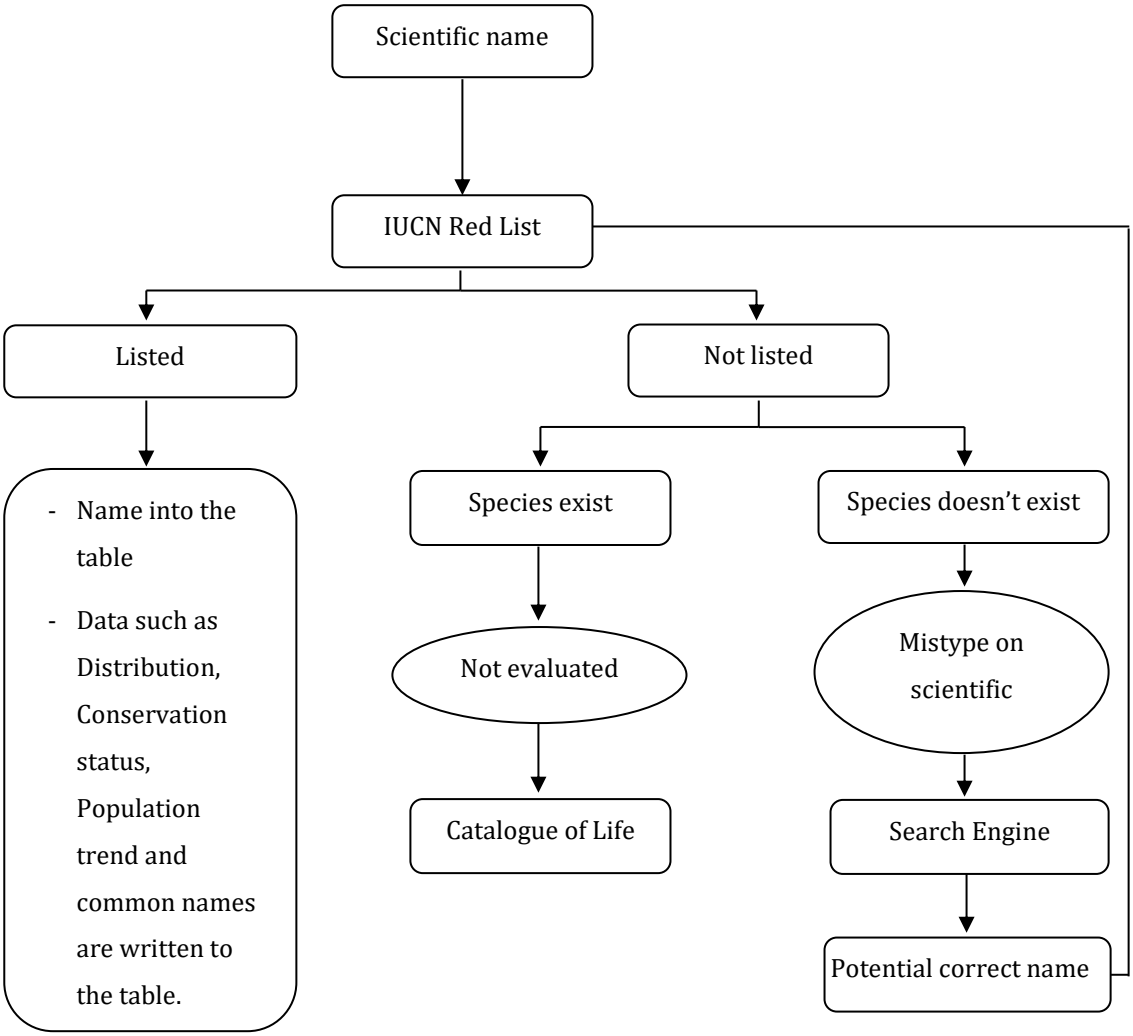

Figure 1. Workflow diagram of IUCN Red List.

Scientific names and the validity of species were checked on the IUCN Red List (see Figure 1.). Then, its conservation status, population trend, distribution and common name if available were listed on the table. Based on two possible results, whether it was listed on IUCN Red List or not, several steps then performed. If the species was not listed on IUCN Red List, there are two possible causes. Either it was not evaluated yet or the name obtained from the whole sellers was not written correctly. Species that were written correctly and not evaluated its conservation status yet, will exist in the Catalogue of Life. If it was not listed on Catalogue of Life, there would possibly be a mistake on the name obtained. If this is the case, the search engine will be utilised to find the potential correct name of the species. Furthermore, the

potential correct name will be again checked on the IUCN Red List and the process continues.

3.2.2. Catalogue of Life (CoL)

The ornamental species exported from Indonesia obtained from whole sellers were checked on Catalogue of Life (henceforth CoL) for its taxonomy. CoL version that was exerted to check the taxonomy was Catalogue of Life: 2019 Annual Checklist. The annual checklist was used with the reason of its fixed imprint while the Dynamic Edition of CoL changes constantly, and the changes are not trackable.

CoL is a comprehensive online global database of the world's species. It listed known animals, plants, fungi and microorganism's species across the globe which currently covers more than 1.8 million species. CoL united data of known species from several Global Species Databases (more than 130) and regional centre databases from Europe, North America, China, New Zealand, Brazil and Australia. It is recognised by the Convention on Biological Diversity (CBD), used as the principal taxonomic index in the Global Biodiversity Information Facility (GBIF) and Encyclopedia of Life (EOL) and served as the taxonomic backbone of IUCN Red List.

Data derived from CoL were mainly species hierarchical taxonomy, additional common names and distribution when available. Common names of the species in CoL were mostly available in several languages. Nevertheless, those that were derived from CoL, were the names in English. If the common name in English did not available, the given name from the whole seller was adopted to the table. Common names given by whole sellers were written to the table regardless of its availability on CoL.

3.2.3. FishBase

FishBase is a global Biodiversity Information System and Global Species Database on bony fishes. It contains extensive information about all known fish species and subspecies in the world such as its taxonomy, distribution, biology, trophic ecology, threats to human, conservation data, life history and uses, as well as historical data recorded in approximately last 250 years.

FishBase provides data and cooperates with CoL, aiming for an integrated database of known species worldwide. Nonetheless, FishBase is more of a database on fish systematics instead of a taxonomic database (Bailly 2010). The taxonomic and nomenclatural backbone of FishBase is assembled by Catalog of Fishes (CofF) developed by W.N. Eschmeyer (Bailly 2010). Therefore, the electronic version of CofF is also known as Eschmeyer's Catalog of Fishes.

Scientific names of fish species provided by FishBase can be compared to those in CofF (Chistensen & Maclean 2011). Nonetheless, there might be differences in the assessment of scientific names between FishBase and CofF due to different purposes of both databases and its independent initiatives (Bailly 2010). When discrepancies occur, the taxonomy of species will be derived from FishBase, as it provides the information to CoL and this work's taxonomical backbone was following CoL.

As previously stated, apart from taxonomical data, FishBase provides broader information about biological, ecological and conservation data of the species. Data such as distribution, IUCN Red List Status, threats to human and humans use especially as commercial aquarium species was noted and adopted to the table of species. Even though data of IUCN Red List Status was provided by FishBase, the conservation status of the species was verified on IUCN Red List database.

3.2.4. Eschmeyer's Catalog of Fishes (CofF)

Eschmeyer's Catalog of Fishes or Catalog of Fishes (California Academy of Sciences, (https://www.calacademy.org/scientists/projects/eschmeyers-catalog-of-fishes) is a global Biodiversity Information System and Global Species Database for fish species. CofF covers more than 61,700 fish species and subspecies with over 11,000 genera and subgenera (Eschmeyer et al. 2016).

The database featured a searchable on-line database for taxonomic fish species name that changes continuously. It kept records on the names of fish species used in older publications which are now known to be synonyms of another species. FishBase is working with CofF and utilised CofF as its taxonomical background.

Apart from taxonomy, CofF also provides data about fish species distribution and publications related to the species searched in the database. Unfortunately, CofF

could be used only for fish species and not the other groups of animals such as amphibia or mollusc.

3.3. Risk Assessment

To assess potentially high-risk species and the threats to Indonesian endemic species, Climate Matching (CLIMATCH) and Fish Invasiveness Screening Kit (FISK) were used. These assessments were performed on species listed in the final table. Ideally, those species to be assessed should be non-native to Indonesia and are perceived as the iconic species (Novák et al. 2020) or known as highly marketed species.

3.3.1. Climate Matching (CLIMATCH)

Climate Matching (v. 1.0 Invasive Animals Cooperative Research Centre, https://climatch.cp1.agriculture.gov.au/climatch.jsp, henceforth CLIMATCH) modelling is a simple approach to the problem of predicting species distribution, using only climatic variables developed by the Australian Government (Crombie et al. 2008). CLIMATCH had been widely used in forecasting the species distribution in some new region (Britton et al. 2010; Peacock & Abbott 2010; Weiperth et al. 2017). It predicts species potential range by matching climate data from the selected region or *Source Region* to the climate data in *Target Region*. Most of the climate data held by CLIMATCH comes from weather stations around the world.

The term “region” in CLIMATCH refer to the selected weather station in a certain area and defined by the user. *Source Region* identifies the current known geographic range of the selected species and the *Target Region* is the region to which the selected species is to be assessed its potential establishment (Figure 2).

Source Region was defined specifically for the selected species and was based on databases such as IUCN Red List (2019), FishBase (2019) or AquaMaps by Kaschner et al. (2019). Meanwhile, the *Target Region* to all selected species was Indonesia. It must be ensured that no weather station located in the sea was selected both in *Source* and *Target Region*. This was due to the reason that the selected species were solely freshwater.

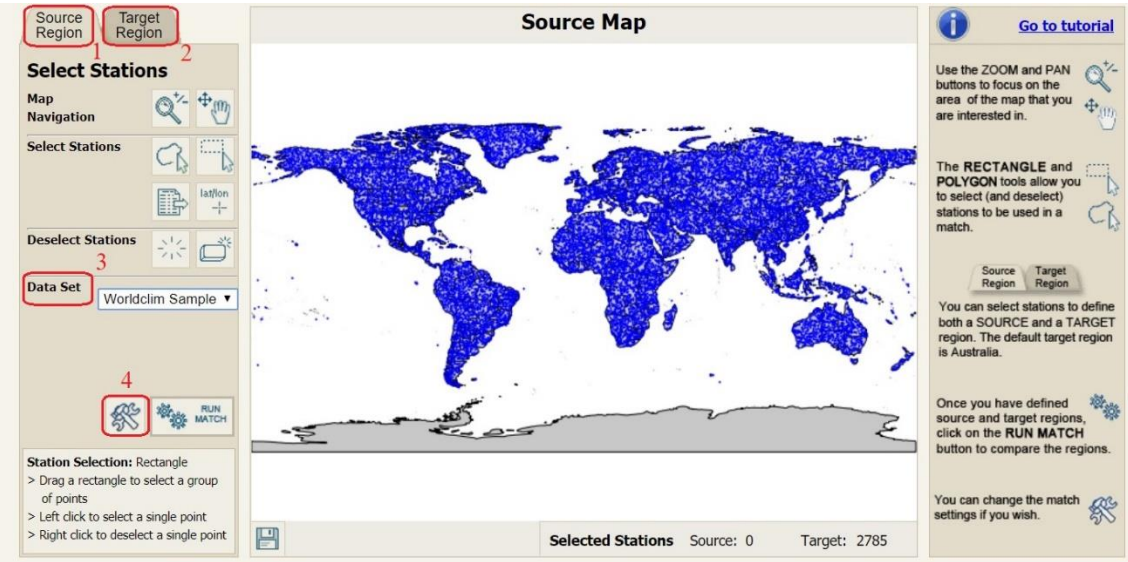

Figure 2. CLIMATCH layout on the webpage. Numbered red rectangular shapes on the left indicate important functions used in the assessment. 1) Source region, 2) Target region, 3) Data set, 4) Match settings.

Data sets for *Source Region* and *Target Region* was *Worldclim Sample* which was selected with a box or freehand cursor tool. Furthermore, climatic variables selected for the models (selected from the *Match Settings* function, see Figure 2. Red rectangular box numbered as 4) were annual temperature range, the temperature of coldest quarter, temperature of warmest quarter, temperature of wettest quarter, temperature of driest quarter, rainfall of the wettest quarter, rainfall of the driest quarter, rainfall of the coolest quarter and rainfall of the warmest quarter.

Rainfall was included in climatic variables since the Target Area was chosen to be Indonesia, where seasonal rainfall varied among islands in a year (Aldrian 2000). Apart from the temperature, rainfall was suspected to be a barrier to the success of invasive fish species establishment in the tropical area.

Analysis in CLIMATCH used Euclidean algorithm, a metric similar to Euclidean distance to calculate the similarity of climate between *Source Region* and *Target Region* (Crombie et al. 2008). The CLIMATCH analysis resulted in a scoring scale of a 0 (low match) to 10 (high match). The scoring scales were marked by graduated colours from blue as the lowest match to brown as the highest match (Table 3).

Table 3. CLIMATCH scoring indicated by graduated colours

Score	Colour	Count
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Graduated colour blue to brown showed the level of potential establishment of certain species in each given area.

The model predicted a relatively close climate match between *Source Region* and *Target Region* in the areas with the score greater and equal to 7 (Kalous et al. 2015). Temperature and rainfall suitability of each selected species in Indonesia would be presented in percentage (henceforth TRID). The threshold proposed for TRID value and the potential risk of the species was:

a. Low Risk, no station or 0% of selected stations had CLIMATCH score ≤ 7.
b. Medium Risk, up to 10% of selected stations had CLIMATCH score ≥ 7.
c. High Risk, more than 10% of the selected stations had CLIMATCH score ≥7.

3.3.2. Fish Invasiveness Screening Kit (FISK)

Fish Invasiveness Screening Kit (FISK, v. 2.03, Centre for Environment Fisheries and Aquaculture Sciences, (https://www.cefas.co.uk) is a freeware electronic tool kit used to assess the invasion risk of non-native fish species. FISK is linked through Visual Basic for Application (VBA) for Excel Programming and provides 49 sequential questions to be answered.

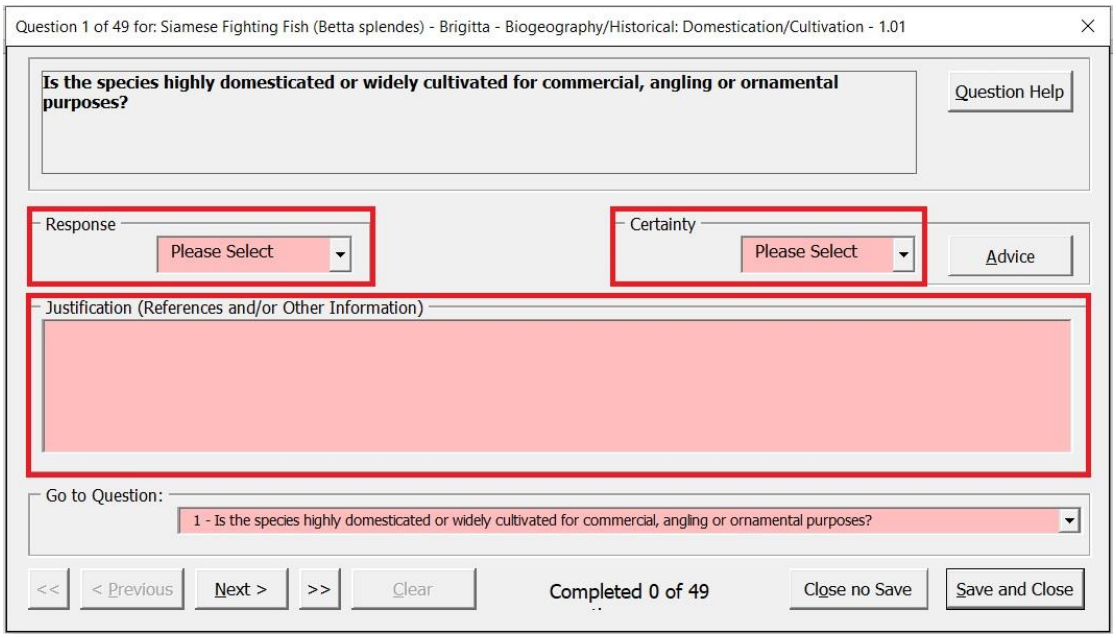

Figure 3. FISK sequential questions. The response, Certainty and Justification are marked by red boxes.

There are 3 possible response to the questions (Yes, No, Don't Know), 4 possible confidence level or certainty of the answer (Very Certain, Mostly Uncertain, Mostly Certain, Very Certain), and a box where the user must write a justification for the response (Figure 3). Scores were formulated from the responses and confidence level of the answer. Score threshold levels in this study was following the default (Copp et al. 2009):

a. Low (scores < 0 = low risk)
b. Medium (1-18 = medium risk)
c. High (≥ 19 = High risk)

Potential invasiveness was evaluated on all selected species regardless of its CLIMATCH score. Furthermore, Risk Assessment Area (RA Area) was defined to Indonesia as a whole country. Responses to the questions such as the species biology, ecology, biogeography, and undesirable attributes were derived from FishBase (Froese & Pauly 2019) and through scientific literature.

4. Results

4.1. Marine Species Exported by Indonesia

Marine species exported from Indonesia recorded in this study came from the class Actinopterygii (Ray-finned fishes), class Elasmobranchii (Sharks and rays), class Malacostraca (Lobsters, Crabs, Hermit crabs, Shrimps), phylum Cnidaria, phylum Echinodermata, phylum Mollusca, phylum Annelida, subphylum Tunicata, and phylum Porifera. In total, 773 marine species were found to be exported from Indonesia. It consisted of 513 species of fishes (ray-finned fish and cartilaginous fishes) and 260 species of non-fish species.

The biggest portion of marine species exported from Indonesia was from the class Actinoptergygii or the ray-finned fishes. It composed of 500 marine fish species of fish. The study also found that 341 species from the class Actinopterygii held Least Concern conservation status (68.2%), 127 species were not yet evaluated (25.4%), 18 species of Data Deficient (3.6%), 6 of Vulnerable species (1.2%), and 2 of Endangered species (0.4%). Meanwhile, the cartilaginous fishes (class Elasmobranchii) consisted of only 13 species. It was found that 7 of the species (53.9%) held Near Threatened conservation status, 1 species was found to be listed as Vulnerable species, and 1 species was an Endangered species.

Meanwhile, the majority of marine non-fish species exported from Indonesia, particularly 159 species (61.2%) from 260 species, was not evaluated its conservation status. Furthermore, 56 species (21.5%) were not identified to the species level. Thus, the conservation status of the species could not be determined. Additionally, 14 species were found to be Near Threatened and 10 species were listed as Vulnerable.

4.1.1. Actinopterygii (Ray-finned Fishes)

Most species exported was from the class Actinopterygii. It consisted of 500 species in 13 order and 53 families. The order recorded were Anguilliformes, Batrachoidiformes, Beryciformes, Gasterosteiformes, Gobiesociformes, Lophiiformes, Ophidiiformes, Perciformes, Pleuronectiformes, Scorpaeniformes, Siluriformes, Syngnathiformes and Tetraodontiformes. The highest percentage of

species traded were from the order Perciformes 79.6%, followed by order Tetraodontiformes (7.8%), Anguilliformes (4.4%) and Scorpaeniformes (3.4%).

4.1.1.1. Order Anguilliformes (Eels and Morays)

Twenty-two species in total were reported to be exported from order Anguilliformes. In which, eighteen species (82%) held Least Concern conservation status and four species (18%) were Not Evaluated yet (Table 4.). Seventeen species, that held Least Concern conservation status had unknown population trend except for two species. *Heteroconger hassi* and *Gorgasia preclara* were last assessed in 2016 and were known to have a stable population trend (Tighe et al. 2019a; Tighe et al. 2019b).

This study indicated the occurrence of 5 species in Indonesian water, which were not recorded in the IUCN distribution map. One species *Conger wilsoni* with Least Concern conservation status was found to be exported from Indonesia. *Conger wilsoni* was not included in distribution map provided by IUCN Red List (IUCN 2019), yet a computer-generated native distribution map provided by AquaMaps (Kaschner et al. 2019) showed 0.01-0.39 relative probabilities of its occurrence in Indonesia.

Table 4. Conservation status of marine species traded from the order Anguilliformes

No	Family	Conservation Status				Total
		NE	DD	LC	NT	
1	Congridae			4		4
2	Moringuidae	1				1
3	Muraenidae	2		14		16
4	Ophichthidae	1				1
	TOTAL	**4**		**18**		**22**

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Figure 4. Blue variant of Ribbon moray (*Rhinomuraena quaesita*) in Lembeh Strait, North Sulawesi, Indonesia. Photo: Petr Zámečník.

Four species that were traded and not yet evaluated its conservation status were found. Those species were *Moringua microchir*, *Gymnothorax reevesii*, *Gymnothorax reticularis* and *Myrichthys colubrinus*. Even though the conservation status nor the distribution range was not evaluated yet by IUCN, computer-generated maps by AquaMaps (Kaschner et al. 2019) showed high relative probabilities of occurrence of those species in Indonesia.

The fishes sold from this order were ranging from 1.01-17.70 USD. The cheapest species sold was *Conger wilsoni* and the most expensive species was the blue variant of *Rhinomuraena quaesita* (Figure 4). The size of species traded was available only on four species, *Gymnomuraena zebra*, *Gymnothorax favagineus*, *Gymnothorax flavimarginatus* and *Gymnothorax pictus*. All four species were sold in three size groups, 15-25 cm, 30-40 cm, and 45-60 cm which were sold at a various price depending on the species.

4.1.1.2. Order Batrachoidiformes (Toadfishes)

A single species, *Opsanus beta*, was traded from the Order Batrachoidiformes. The species held Least Concern conservation status and an Unknown population trend (Collette et al. 2019). Interestingly, the species distribution range was recorded in the entire Gulf of Mexico and surrounding area (Froese & Pauly 2019; IUCN 2019). This

study confirmed its occurrence in Indonesian water as Indonesia was indicated by AquaMaps (Kaschner et al. 2019) to be a suitable habitat for *Opsanus beta*.

Opsanus beta or Gulf toadfish was sold for the price of 1.19 USD per fish. Unfortunately, the market size of the fish traded was not available. It indicated that the species caught from the wild would be sold regardless of its size.

4.1.1.3. Order Beryciformes (Sawbellies)

Species sold from the Order Beryciformes were recorded from the genus *Myripristis* and *Sargocentron*. Identification to the species level was not available. Thus, precise conservation status and distribution of both of the fishes were not possible to ascertain. Nevertheless, according to Allen and Adrim (2003), 12 species of *Myripristis* and 15 species of *Sargocentron* were found across Indonesian water.

Figure 5. School of Soldierfish (*Myripristis* sp.), most probably *Myripristis pralinia* in Komodo National Park, Flores, Indonesia. Photo: Petr Zámečník.

Size of the individuals traded was not available. Nonetheless, the export price was noted to be 1.01 USD for *Myripristis* sp. and 1.37 USD for *Sargocentron* sp.

4.1.1.4. Order Gasterosteiformes (Sticklebacks and Seamoths)

Eurypegasus draconis and *Pegasus volitans* were the species recorded to be exported from the order Gasterosteiformes. Both species were known to be distributed widely in Indonesia (IUCN 2019; Kaschner et al. 2019).

Figure 6. Longtail seamouth (*Pegasus volitans*) in Swan River, Australia (Froese & Pauly 2019). Photo: Mark Madden

Both species were listed under IUCN Red List. *Eurypegasus draconis* was listed as Least Concern with Unknown population trend (Pollom 2017) and *Pegasus volitans* was listed as Data Deficient on a global scale with Unknown population trend (Pollom 2016). Even though there was inadequate information (Data Deficient) to assess *Pegasus volitans* globally, the species was assessed to have Least Concern conservation status in the Persian Gulf (Monroe & Feary 2015) and Vulnerable with Decreasing population trend for Philippines stock (Vincent 1996).

The market size of both species was not available. The price given for *Eurypegasus draconis* was relatively expensive. It was sold at 28 USD per fish. Meanwhile, *Pegasus volitans* was sold at a considerably lower price, at 2.79 USD.

4.1.1.5. Order Gobiesociformes (Clingfishes)

Solely one species, *Diademichthys lineatus*, was exported from the order Gobiesociformes by Indonesian exporters. It was listed as a Least Concern species with Unknown population trend (Smith-Vaniz & Carpenter 2016). It was also reported to be widely distributed in Indonesia (IUCN 2019; Kaschner et al. 2019). The species was sold at the price of 1.23 USD. Size of the traded species was anew not available.

4.1.1.6. Order Lophiiformes (Anglerfishes)

Overall, six species were identified to be marketed from the order Lophiiformes. Four species or 67% species sold were not yet evaluated its conservation status. Meanwhile, 2 species which represented 33% of the species marketed, *Antennarius striatus* and *Histrio histrio*, were listed as Least Concern species with Stable population trend (McEachran et al. 2015a; McEachran et al. 2015b).

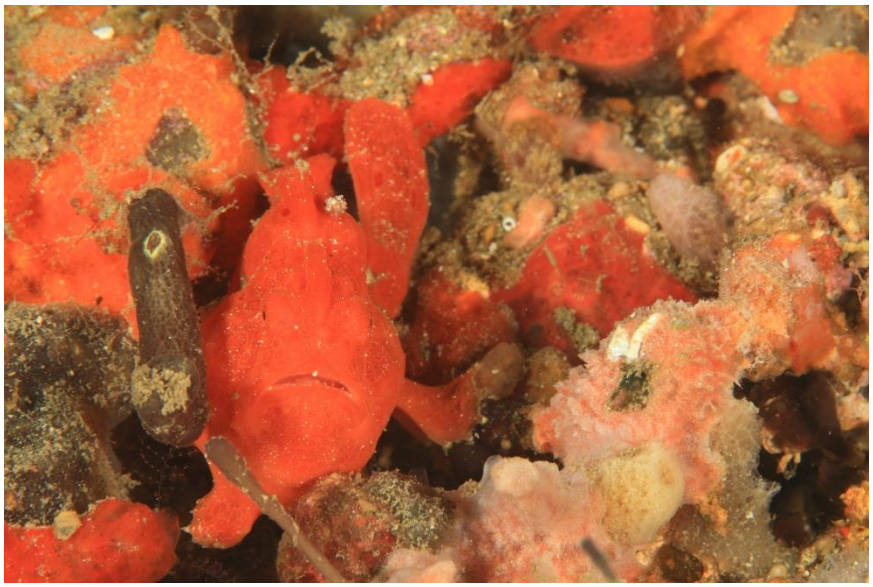

Figure 7. Painted frogfish (*Antennarius pictus*) among corals in Lembeh Strait, North Sulawesi, Indonesia. Photo: Petr Zámečník.

Several databases suggested that all Anglerfish species traded from this study were known to be widely distributed in Indonesia (IUCN 2019; Kaschner et al. 2019). Moreover, many species of anglerfishes were reported from Indonesia (Allen & Erdmann 2009; Prihadi 2015; Ho et al. 2016b) including several new species (Ho et al. 2015: Ho et al. 2016a).

The market size of the species traded from the order Lophiiformes was not available. However, the price of species traded was given. The fishes were sold in the price range of 2.29-50 USD with an average price of 20.35 USD. Highest export price was held by *Antennarius biocellatus* and 3 species of fishes, *A. hispidus, A. striatus* and *Histrio histrio,* were sold at the lowest price in the order 2.29 USD. Additionally, colour morphology of the individual resulted in price difference within species *Antennarius pictus*.

4.1.1.7. Order Ophidiiformes (Cusk Eels)

Data showed merely one species that was exported from the order Ophidiiformes. A species that was not yet evaluated its conservation status, *Diancistrus fuscus* (IUCN 2019). However, its distribution was reported to be native to Indonesia (Kaschner et al. 2019). The species was sold for 1.01 USD in most probably all body size. The market size of the species was not specified.

Figure 8. Dusky brotulis (*Diancistrus fuscus*), Palawan, Philippines. Photo: G. R. Allen (Froese & Pauly 2019).

4.1.1.8. Order Perciformes (Perch Like)

Three hundred and ninety-eight species were traded from the order Perciformes which came from 28 families. Most of the species exported were assessed as Least Concern (77.10%), followed by Not Evaluated species counted for 23.62%, and Data Deficient species 3.77% of the total species (Table 5). Three species were not identified to species level. Thus, the conservation status could not be determined and marked as Unknown.

Two Endangered species and four Vulnerable species were documented to be marketed from the order Perciformes. The Endangered species were *Pterapogon kaudernii* (family Apogonidae) that came from both wild harvest (Figure 11) and captive-bred, and *Amphiprion clarkii* (family Pomacentridae) that was assessed as Endangered in the scope of Persian Gulf and not globally. Meanwhile, the Vulnerable species exported from the order Perciformes were *Acanthurus chronixis* (family

Acanthuridae), *Amblyglyphidodon batunai* (family Pomacentridae), *Epinephelus fuscoguttatus* (family Serranidae), and one species that was evaluated as Vulnerable in Persian Gulf *Dascyllus trimaculatus* (family Pomacentridae).

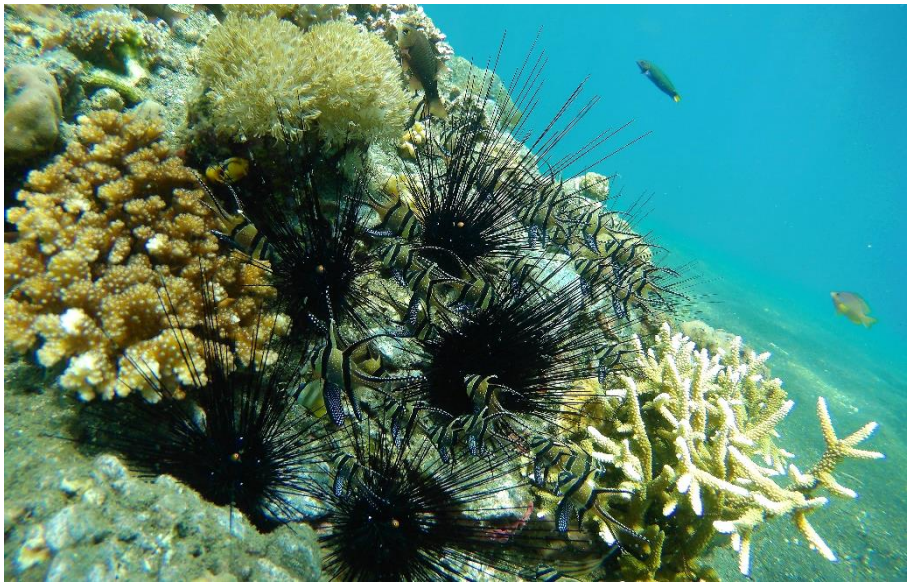

Figure 9. Banggai cardinal fish (*Pterapogon kaudernii*) among black sea urchins in Lembeh Strait, Indonesia. Photo: Brigitta Zámečníková-Wanma.

The most species exported was from the family Labridae (wrasses) which composed of 72 species, followed by 56 species from family Pomacentridae (Damselfishes), 41 species of Chaetodontidae (Butterflyfishes), 36 species of Serranidae (Sea basses: groupers and fairy basslets), 35 species of Gobiidae (Gobies), 30 species of Acanthuridae (Surgeonfishes, tangs, unicornfishes), and 27 species of Pomacanthidae (Angelfishes).

Among all species traded within the order, 22 species were found to be sold as juveniles where 6 species were exclusively marketed as juveniles. Table 6 presented the species traded as juveniles, its conservation status, and the price. Most expensive species sold was *Pomacanthus xanthometopon* which held the price of 17.14 USD per fish. Meanwhile, the cheapest species was *Pomacanthus semicirculatus* at the size of 2-3 cm sold for 1.00 USD per individual. A concerning finding showed that *Epinephelus fuscoguttatus*, a species holding Vulnerable conservation status with decreasing population trend was sold particularly as a juvenile.

Price range of species marketed from the order Perciformes was 0.5 – 107.14 USD. Highest priced species were *Odontanthias borbonius* (107.14 USD), *Pomacanthus xanthometopon* with the size larger than 21 cm (90 USD), *Pomacanthus imperator* (80 USD), *Pomacanthus annularis* (80 USD), *Acanthurus guttatus* (70.15 USD), and *Pomacanthus xanthometopon* with the size 16-20 cm (68 USD). By contrast, 25 cheapest fishes were observed from family Pomacentridae and sold for only 0.5 USD. Most of the cheapest priced species were not yet evaluated its conservation status. Nevertheless, 2 Vulnerable species (*Amblyglyphidodon batunai* – decreasing population trend; *Dactyllus trimaculatus* – stable population trend) and 2 Least Concern species (*Abudefduf saxatilis* – stable population trend; *Amblyglyphidodon curacao* – decreasing population trend) were among the cheapest fishes traded.

Additionally, the study found 11 species of fish that was not presented in databases to be distributed in Indonesia (Table 7). Three of the species, *Synchiropus circularis, Abudefduf saxatilis*, and *Chromis dimidiata* were modelled as suitable for establishing Indonesian water (Kaschner et al. 2019).

Table 5. Conservation status of marine species traded from the order Perciformes in each family

No	Family	IUCN Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Acanthuridae	1			28		1			30
2	Apogonidae	1	4		2[a]			1		8
3	Bleniidae				14					14
4	Caesionidae				2					2
5	Callionymidae		6		1					7
6	Carangidae				2					2
7	Chaetodontidae			1	39	1				41
8	Cirrhitidae				6					6
9	Echeneidae				1					1
10	Ephippidae		2		2					4
11	Gobiidae		16		19					35

Un* = Unknown – species cannot be assessed its conservation status because it was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. a = 1 species was assessed as Least Concern in Persian Gulf.

Table 5. Conservation status of marine species traded from the order Perciformes in each family (continued)

No	Family	IUCN Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
12	Haemulidae		3		2					5
13	Labridae		1	12	59					72
14	Lutjanidae				4					4
15	Malacanthidae		8							8
16	Microdesmidae		1		6[b]					7
17	Mullidae				3					3
18	Nemipteridae				2					2
19	Opistognathidae		1		1					2
20	Pinguipedidae		2							2
21	Plesiopidae		2							2
22	Pomacanthidae				27					27

Un* = Unknown – species cannot be assessed its conservation status because it was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. b = 1 species was assessed as Least Concern in Persian Gulf.

Table 5. Conservation status of marine species traded from the order Perciformes in each family (continued)

No	Family	IUCN Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
23	Pomacentridae		40		13		2[c]	1[d]		56
24	Psedochromidae		5	1	6					12
25	Scaridae				3					3
26	Serranidae	1	3	1	30		1			36
27	Siganidae				6					6
28	Zanclidae				1					1
	TOTAL	**3**	**95**	**15**	**278**	**1**	**4**	**2**		**398**

Un* = Unknown – species cannot be assessed its conservation status because it was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. c = 1 species was assessed as Vulnerable in the Persian Gulf, d = species was assessed as Endangered in the Persian Gulf.

Table 6. Marine species from the order Perciformes traded as juveniles

No	Family	Species		Conservation status	Price (USD)	
		Scientific Name	Common Name		Min	Max
1	Acanthuridae	*Acanthurus tristis*	Indian Ocean mimic surgeonfish	LC	4.80	4.80
2	Ephippidae	*Platax batavianus**	Humpback batfish	NE	12.27	12.27
3	Labridae	*Bodianus axillaris*	Axilspot hogfish	LC	2.57	2.57
		Bodianus mesothorax	Splitlevel hogfish	LC	1.53	1.53
		Epibulus insidiator	Sling-jaw wrasse	LC	3.67	3.67
		Labrichthys unilineatus	Tubelip wrasse	LC	1.23	1.23
		Novaculichthys taeniourus	Rockmover wrasse	LC	2.07	2.07
		*Pseudodax moluccanus**	Chiseltooth wrasse	LC	1.90	1.90
4	Lutjanidae	*Symphorichthys spirulus*	Sailfin snapper	LC	14.21	14.21
5	Pomacanthidae	*Apolemichthys trimaculatus*	Threespot angelfish	LC	6.20	6.20
		Chaetodontoplus melanosoma	Black-velvet angelfish	LC	11.10	11.10

* = Species sold only as a juvenile.

Table 6. Marine species from the order Perciformes traded as juveniles (continued)

No	Family	Species		Conservation status	Price (USD)	
		Scientific Name	Common Name		Min	Max
5	Pomacanthidae	*Pomacanthus annularis*	Bluering angelfish	LC	15.36	15.36
		Pomacanthus imperator	Emperor angelfish	LC	5.94	15.00
		Pomacanthus navarchus	Bluegirdled angelfish	LC	16.50	16.50
		Pomacanthus semicirculatus	Semicircle angelfish	LC	1.00	5.94
		Pomacanthus sexstriatus	Sixbar angelfish	LC	1.75	3.50
		Pomacanthus xanthometopon	Yellowface angelfish	LC	17.14	17.14
		Pygoplites diacanthus	Regal angelfish, Royal angelfish	LC	12.27	12.27
6	Serranidae	*Cephalopholis cyanostigma**	Bluespotted hind	LC	3.67	3.67
		*Epinephelus fuscoguttatus**	Brown-marbled grouper	VU	4.33	4.33
		*Epinephelus spilotoceps**	Foursaddle grouper	LC	1.91	1.91
		*Gracila albomarginata**	Masked grouper	LC	14.77	14.77

* = Species sold only as a juvenile.

Table 7. Records of exported marine fish species order Perciformes that were not recorded in databases

No	Family	Species		Known Distribution
		Scientific name	Common name	
1	Acanthuridae	*Acanthurus chronixis*	Chronixis surgeonfish	Caroline Islands, Federated States of Micronesia
2	Bleniidae	*Meiacanthus lineatus*	Lined fangblenny	Great Barrier Reef, Australia
3	Callionymidae	*Synchiropus circularis**	Circled dragonet	Mariana Islands, Western Pacific; Chesterfield Islands, New Caledonia
4	Gobiidae	*Gobiodon atrangulatus*		Japan and Fiji, Western Pacific
5	Labridae	*Anampses chrysocephalus*	Red tail wrasse	Hawaiian and Midway Islands, Pacific Ocean
		Halichoeres pelicieri	Peliciers wrasse	South Africa and Mauritius, Western Indian Ocean
6	Opistognathidae	*Opistognathus scops*	Bullseye jawfish	Gulf of California to Panama, Eastern Central Pacific
7	Pomacentridae	*Abudefduf saxatilis**	Sergeant-major	Canada to Rhode Island, Atlantic Ocean; USA to Uruguay, western Atlantic; Caribbean reefs
		*Chromis dimidiata**	Chocolatedip chromis	Restricted to Red Sea, Western Indian Ocean
		Neoglyphidodon polyacanthus	Multispine damselfish	Australia and New Caledonia, Western Pacific
8	Scaridae	*Cetoscarus bicolor*	Bicolour parrotfish	Endemic to Red Sea, Western Indian Ocean

Species distribution derived from IUCN Red List and FishBase (Froese & Pauly 2019). * = Indonesia was generated as suitable habitat for the species (Kaschner et al. 2019)

4.1.1.9. Order Pleuronectiformes (Flatfishes)

This study documented 2 species of flatfishes from 2 families that were exported from Indonesia. *Zebrias fasciatus* (family Soleidae), a species native to Indonesia (Kaschner et al. 2019) and not evaluated its conservation status was sold at the price of 2.07 USD. Meanwhile, the second species *Bothus lunatus* (family Bothidae, Figure 10) was not reported to be native to Indonesia, yet suitable to live in the area (Kaschner et al. 2019). The species was evaluated as a Least Concern species and sold at the price of 1.01 USD. The market size of both species was not specified.

Figure 10. Flatfish (*Bothus* sp.) on a sandy bottom, Komodo National Park, Indonesia. Photo: Petr Zámečník.

4.1.1.10. Order Scorpaeniformes (Scorpionfishes and Flatheads)

Seventeen species of scorpionfishes and flatheads from 5 families were exported from Indonesia. Fifteen of the species traded from the order (87.2%) held Least Concern conservation status (Table 8) including the popular *Pterois volitans*. Two species, *Inimicus didactylus* (family Synanceiidae) and *Ablabys taenianotus* (family Tetrarogidae) were not yet evaluated its conservation status.

Figure 11. Red lionfish (*Pterois volitans*) swimming on corals, Komodo National Park, Indonesia. Photo: Petr Zámečník.

Table 8. Conservation status of marine species traded from the order Scorpaeniformes

No	Family	Conservation Status				Total
		NE	DD	LC	NT	
1	Dactylopteridae			1		1
2	Platycephalidae			2		2
3	Scorpaenidae			11		11
4	Synanceiidae	1		1		2
5	Tetrarogidae	1				1
	TOTAL	**2**		**15**		**17**

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Scorpionfishes and flatheads were exported in the price range of 1.36-58.00 USD. Scorpionfish *Rhinopias eschmeyeri* and *Rhinopias frondosa* (family Scorpaenidae) were sold for 58 USD, the most expensive in the order. Meanwhile, the cheapest species sold for 1.36 USD was similarly grouped in family Scorpaenidae, *Dendrochirus zebra* and *Dendrochirus brachypterus*. Additionally, details on the size market of the species were not available apart from *Pterois volitans* (Figure 11) that was sold in a various group of size ranging from 3-18 cm for 3.07-9.06 USD.

4.1.1.11. Order Siluriformes (Catfish)

Data collected from the whole sellers listed a single species that was sold from the order Siluriformes. It was *Plotosus lineatus* from the family Plotosidae, the only catfish found in coral reefs (Froese & Pauly 2019). The species was sold for 0.51 USD. *Plotosus lineatus* was not evaluated its conservation status globally. Nevertheless, it held a Least Concern status in the scope of the Persian Gulf with unknown population trend (IUCN 2019).

4.1.1.12. Order Syngnathiformes (Pipefishes and Seahorses)

Total species of pipefishes and seahorses in this study that was exported from Indonesia counted for 8 species in 2 families. It consisted of 1 razorfish *Aeliscus strigatus* (family Centriscidae) and 7 species from the family Syngnathidae. Merely a single species of seahorse *Hippocampus kuda* was recorded from family Syngnathidae. The other species from the family were pipefishes. Namely, *Dunckerocampus dactyliophorus* (ringed pipefish) that had a decreasing population trend and Data Deficient conservation status (Figure 12).

Figure 12. Ringed pipefish (*Dunckerocampus dactyliophorus*), Lembeh Strait Indonesia. Photo: Petr Zámečník.

Two species traded from the order Syngnathiformes evaluated to have Data Deficient conservation status. Five species were listed as Least Concern and one Vulnerable species with a decreasing population trend. The vulnerable species *Hippocampus kuda* was sold for 14.29 USD, the most expensive among all. Meanwhile,

the cheapest fish *Aeliscus strigatus*, a Data Deficient species, was priced 0.61 USD. Additionally, a Least Concern species with a decreasing population trend (*Corythoichthys intestinalis*) was marketed for 1.40 USD. The prices recorded from the order was not size-specific since the data on size was not available.

4.1.1.13. Order Tetraodontiformes (Puffers and Filefishes)

The result gathered showed 39 species from 5 families of puffers and filefishes to be exported from Indonesia. Nineteen species were of Least Concern species, nineteen was not evaluated its conservation status yet, and 1 species listed as a Vulnerable species, *Oximonacanthus longirostris* (Table 9) One species (Figure 13), *Ostracion cubicus* (family Ostraciidae) was listed as Least Concern species in the Persian Gulf, its conservation status globally was not available.

Figure 13. Juvenile Yellow boxfish (*Ostracion cubicus*) in Lembeh Strait, Indonesia. Photo: Petr Zámečník.

Species in the order Tetraodontiformes were marketed in the price range of 1.04-80.00 USD. *Arotrolepis filicauda* (family Monocanthidae) and *Arothron manilensis* (family Tetraodontidae) were the cheapest species sold from the order. Contrary, the most expensive species sold was *Balistoides conspicillum* (family Balistidae) with the size greater and equal to 21 cm (Figure 14).

Table 9. Conservation status of marine species traded from the order Tetraodontiformes

No	Family	Conservation Status					Total
		NE	DD	LC	NT	VU	
1	Balistidae	14					14
2	Diodontidae	1		1			2
3	Monacanthidae			6		1	7
4	Ostraciidae	4		2[a]			6
5	Tetraodontidae			10			10
	TOTAL	**19**		**19**		1	**39**

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable.
a = one species listed as Least Concern in the scope of Persian Gulf (*Ostracion cubicus*).

Several species were documented to be sold as a juvenile (Table 10). Amongst, 2 species were exclusively marketed as a juvenile and priced above 5 USD. Furthermore, the Vulnerable species *Oxymonacanthus longirostris* with a decreasing population trend was traded for merely 2.8 USD. Additionally, it was found that *Diodon liturosus* was also exported from Indonesia, yet there was no data on the price of the species.

Figure 14. Clown triggerfish (*Balistoides conspicillum*), the most expensive fish sold from the order Tetraodontiformes, Raja Ampat, West Papua, Indonesia. Photo: Petr Zámečník.

Table 10. Price list of species traded as juveniles in the order Tetraodontiformes

No	Family	Species	Conservation Status	Price (USD)	
				Min	Max
1	Balistidae	*Xanthichthys auromarginatus*	NE	3.00	3.00
2	Ostraciidae	*Lactophrys bicaudalis**	LC	1.57	1.57
3	Ostraciidae	*Ostracion rhinorhynchos**	NE	2.29	2.29

NE = Not Evaluated, LC = Least Concern. * = species traded only as a juvenile.

This study found one species that was not mapped from Indonesia, *Lactophrys bicaudalis*. The species was known to inhabit Western Atlantic from Florida, Bahamas, the southern Gulf of Mexico to Brazil; and the Eastern Atlantic (Froese & Pauly 2019). Nevertheless, Indonesia was mapped as a suitable habitat for the species (Kaschner et al. 2019).

4.1.2. Elasmobranchii (Sharks and Rays)

In total, 13 species of sharks and rays were marketed. It consisted of 12 species exported as ornamental fish and 1 species was sold in the form of eggs (*Atelomycterus* sp.). The sharks exported from Indonesia was identified from the order Carcarhiniformes or Ground sharks (Table 11. number 1-3) and Orectolobiformes or Carpet sharks (Table 11. number 4-5). Whilst rays traded came from the order Myliobatiformes (Stingrays), Torpediniformes (Electric rays), and Rhinopristiformes (Shovelnose rays).

Table 11. Conservation status of sharks and rays exported from Indonesia

No	Family	Conservation Status						Total
		Un*	DD	LC	NT	VU	EN	
SHARKS								
1	Carcharhinidae				2			2
2	Scyliorhinidae	1			1			2
3	Ginglymostomatidae					1		1
4	Hemiscyliidae				2			2
5	Stegostomatidae						1	1
	TOTAL	**1**			**5**	**1**	**1**	**8**

Table 11. Conservation status of sharks and rays exported from Indonesia (continued)

No	Family	Conservation Status						Total
		Un*	DD	LC	NT	VU	EN	
RAYS								
1	Dasyatidae		1		2			3
2	Narcinidae	1						1
3	Rhinobatidae			1				1
	TOTAL	**1**	1	**1**	2			**5**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered.

Five species of sharks exported from Indonesia listed as Near Threatened with decreasing population trend except for two species, *Triaenodon obesus* (Figure 15) and *Atelomycterus marmoratus*. The Near Threatened species with decreasing population trend were *Carcharhinus melanopterus*, *Chiloscyllium arabicum*, and *Chiloscyllium punctatum*. Furthermore, a Vulnerable species *Nebrius ferrugineus* and an Endangered *Stegostoma fasciatum* were among the species exported from Indonesia. Both species were assessed to have a decreasing population trend.

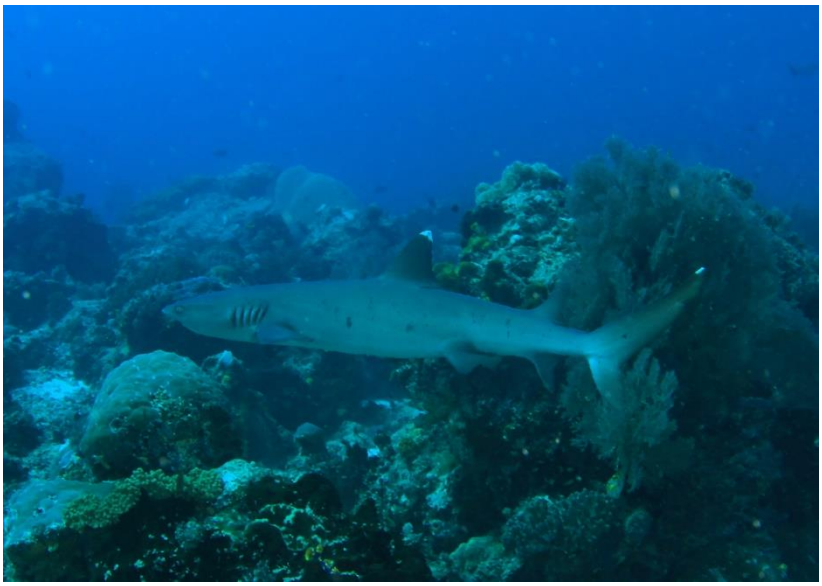

Figure 15. White-tip reef shark (*Triaenodon obesus*), a Near Threatened species with unknown population trend. Raja Ampat, Indonesia. Photo: Petr Zámečník.

Whereas 3 rays marketed from Indonesia were listed as Near Threatened, 1 species was listed as Least Concern, 1 species was of Data Deficient, and 1 species was

not determined due to its identification that was only to genus level (*Narcine* sp). All ray species possessed an unknown population trend. To name a few, rays traded were *Hemitrygon akajei*, *Neotrygon kuhlii*, *Taeniura lymma*, and *Aptychotrema rostrate*.

Generally, the price range of sharks was wider than the rays. Sharks documented to have a price range of 2-700 USD. The most expensive species traded was *Nebrius ferrugineus* (Tawny nurse shark) in the size of 100 cm. The second most expensive was *Traenodon obesus* (Figure 15), that was sold for 300 USD with the market size less than 70 cm. Meanwhile, the cheapest one was the eggs of *Atelomycterus* sp., that was sold for merely 2 USD. Amongst the cheapest were *Chyloscyllium arabicum* (7 USD), *Atelomycterus marmoratus*, and the Endangered juvenile *Stegostoma fasciatum* (12.85 USD).

Rays were traded in the price range of 4.66-9.56 USD. The most expensive species exported was *Aptychotrema rostrata* (Eastern shovelnose ray), followed by *Narcine* sp. that was sold for 8.21 USD. The cheapest marketed was *Taeniura lymma* with the size less than 15 cm (4.66-6.50 USD), followed by *Hemytrygon akajei* and *Neotrygon kuhlii* that was both sold for 5.50 USD.

Figure 16. Juvenile Brownbanded bamboo shark (*Chiloscyllium punctatum*), Lembeh Strait Indonesia. Photo: Brigitta Zámečníková-Wanma.

In addition to the trade of shark's eggs, some species were conjointly or distinctively traded as a juvenile. The Near Threatened Brownbanded bamboo shark (Figure 16) was likewise exported as a juvenile in the size of 20-30 cm for only 10.00-

19.22 USD. Unexpectedly, the Endangered Zebra shark (*Stegostoma fasciatum*) was sold only as a juvenile.

This study documented the trade of *Aptychotrema rostrate* (Eastern shovelnose ray), a species endemic to Australia and had never been reported to be found in Indonesia. It was also found that *Chiloscyllum arabicum* (Arabian carpet shark) and *Hemitrygon akajei* (Whip stingray), species that were not native to Indonesia were exported from the country. *Chiloscyllum arabicum* was known to be distributed in the Western Indian Ocean (India, Pakistan) and the Persian Gulf between Iraq and the Arabian Peninsula (Froese & Pauly 2019). Meanwhile, the native distribution of *Hemitrygon akajei* was mapped to be in Northwest Pacific, from central China to northern Japan. Nevertheless, the Indonesian ocean was generated to be a suitable habitat for *C. arabicum* and *H. akajei*. (Kaschner et al. 2019).

4.1.3. Malacostraca (Lobsters, Crabs, Hermit Crabs, Shrimps)

Two orders under the class of Malacostraca (subphylum Crustacea) were found to be exported from Indonesia. Species traded came from the order Decapoda (Lobsters, crabs, shrimps) and Stomatopoda (Mantis shrimp). In total, 53 species from 22 families of Malacostracans were traded. Majority of species traded was from the order Decapoda, reaching 96.23% of the total species traded from 21 families.

Table 12. Conservation status of marine species traded from the order Decapoda and Stomatopoda

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER DECAPODA							
1	Alpheidae	1	2				3
2	Barbouriidae		1				1
3	Calappidae		1				1
4	Diogenidae	2	7				9
5	Enoplometopidae			2			2
6	Hyppolytidae		3				3
7	Inachidae		1				1
8	Lysmatidae		3				3

Table 12. Conservation status of marine species traded from the order Decapoda and Stomatopoda (continued)

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER DECAPODA							
9	Majidae		1				1
10	Palaemonidae		5				5
11	Palinuridae				5		5
12	Pandalidae		1				1
13	Penaeidae		1				1
14	Percnidae		2				2
15	Pilumnidae		1				1
16	Porcellanidae		2				2
17	Portunidae	1	1				2
18	Rhynchocinetidae		2				2
19	Stenopodidae		3				3
20	Thoridae		1				1
21	Xanthidae		2				2
	TOTAL	**4**	**40**	**2**	**5**		**51**
ORDER STOMATOPODA							
1	Odontodactylidae	1	1				2
	TOTAL	**1**	**1**				**2**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable

A great quantity of traded species (77.36%) in the class Malacostraca were not yet evaluated its conservation status (Table 12). Five species were not known its conservation status due to the insufficient identification. Those species were identified only to its genus level, namely *Calcinus* sp., *Pagurines* sp., *Charybdis* sp., *Alpheus* sp., and *Odontodactylus* sp. Two species, *Enoplometopus daumi* and *E. debelius* were listed as Data Deficient. Moreover, 5 species of spiny lobsters from the family Palinuridae were of Least Concern species. The Least Concern species traded were *Palinurellus wieneckii*, *Panulirus femoristriga*, *Panulirus longipes*, *Panulirus ornatus*, and *Panulirus versicolor* (Figure 17).

Figure 17. Juvenile Painted spiny lobster (*Panulirus versicolor*), a Least Concern species, Lembeh Strait, Indonesia. Photo: Petr Zámečník.

The price of Malacostracans exported from Indonesia was relatively cheap. It was sold at the price of 0.20-9.60 USD. The cheapest species sold for 0.20 USD was a Hermit crab *Calcinus* sp. with the size of 1-2 cm. Meanwhile, the most expensive species that was sold for 9.60 USD was a Harlequin shrimp *Hymenocera picta* of the size greater than 3 cm. Peacock mantis shrimp *Odontodactylus scyllarus* (Figure 18) in the size of 12-15 cm was the second most expensive species, sold for 8.50 USD. Additionally, the Least Concern species were sold in the price range of 1.69-8.00 USD depending on the species and the size of the traded individual. For instance, the stripe-leg spiny lobster *Panulirus femoristriga* in the size of 2-4 cm was sold for 1.75 USD and was tagged for 8.00 USD in the size of 8-12 cm.

Figure 18. Peacock mantis shrimp (*Odontodactylus scyllarus*) in Lembeh Strait, Indonesia. Photo: Petr Zámečník.

Figure 19. Sugarcane shrimp (*Parhippolyte uvaea*), recently found in Indonesian anchialine systems. Photo: www.tropicalfavourites.com (Palomares & Pauly 2019).

This study found several species that were not known its distribution in Indonesia before, yet exported for ornamental species (Table 13). Moreover, a recently discovered species from anchialine systems in Indonesia, *Parhippolyte uvaea* (Becking et al. 2011) had been also found to be traded as ornamental species (Figure 19).

Table 13. Records of exported Malacostracans that were not recorded its distribution in Indonesia based on utilised databases

No	Family	Species		Known Distribution
		Scientific name	Common name	
1	Alpheidae	*Alpheiopsis yaldwyni*	Yaldwin's shrimp	Native to Australia and French Polynesia
2	Diogenidae	*Calcinus tibicen**	Orangeclaw hermit	Native to Brazil, South America
3	Hippolytidae	*Saron inermis*	Pinecone marble shrimp	Native to Australia
4	Lysmatidae	*Lysmata debelius*	Blood red fire shrimp	First described from Philippines[1]
5	Percnidae	*Percnon gibbesi*	Nimble spray crab	Native to tropical and subtropical Atlantic Ocean[2]; Introduced to Europe: Italy, Malta, Spain
6	Pilumnidae	*Zebrida adamsii*	Urchin crab	Native to Singapore and New Caledonia, threatened in Singapore
7	Rhynchocinetidae	*Rhynchocinetes durbanensis*	Hingebeak shrimp	Native to South Africa, Japan, Australia, Micronesia, and New Caledonia
8	Stenopodidae	*Stenopus zanzibaricus*	Zanzibar boxer shrimp	Native to French Polynesia, Eastern central pacific

Species distribution derived from SeaLifeBase (Palomares & Pauly 2019) and or literature reviews. * = Indonesia was generated as suitable habitat for the species (Kaschner et al. 2019). 1 = Bruce 1983, 2 = Azzurro 2016.

4.1.4. Phylum Cnidaria

This study found 115 species of cnidarians from 2 classes: Anthozoa (Sea anemones and corals) and Scyphozoa (True jellyfishes). One hundred and thirteen species (98.26%) of the species traded in the Phylum Cnidaria consisted of Sea anemones and corals. Seven orders of the Anthozoans were found traded from Indonesia, including Actiniaria (Sea anemones), Alcyonacea (Sea fans and Sea whips), Antipatharia (Black corals), Corallimorpharia, Pennatulacea (Sea fan), Scleractinia (Stony corals), and Zoantharia (Zoanthids). Meanwhile, the jellyfishes traded came from 1 order, Rhizostomeae (True jellyfishes).

Forty-two species counted for 36.52% of the species traded from the Phylum Cnidaria were not yet evaluated its conservation status. Meanwhile, 34.78% or 40 species traded were barely identified to the genus level. Thus, the conservation status of those species could not be determined. Furthermore, 9 species (7.83%) were evaluated as Least Concern, 14 species (12.17%) were Near Threatened, 10 species (8.70%) of stony coral held Vulnerable conservation status (Figure 20). A detailed record of species conservation status is presented in Table 14.

Table 14. Conservation status of marine species traded from the class Anthozoa (Sea anemones and corals) and Scyphozoa (Jellyfishes)

No	Family	Conservation Status						Total
		Un*	NE	DD	LC	NT	VU	
ORDER ACTINIARIA								
1	Actiniidae		3		1[a]			4
2	Actinodendridae		1					1
3	Cerianthidae				1[a]			1
4	Pymanthidae	1	2					3
5	Stichodactylidae		8					8
6	Thalassianthidae		2					2
	TOTAL	**1**	**16**		**2**			**19**

Un* = Unknown – species was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable. a = species was assessed as Least Concern in the Mediterranean, b = two species were traded in the market name that did not exist scientifically (*Discosoma marmoratus* and *Discosoma striata*), hence it was written only to genus level.

Table 14. Conservation status of marine species traded from the class Anthozoa (Sea anemones and corals) and Scyphozoa (Jellyfishes) (continued)

No	Family	Conservation Status						Total
		Un*	NE	DD	LC	NT	VU	
ORDER ALCYONACEA								
1	Acanthogorgiidae	2						2
2	Alcyoniidae	3	6					9
3	Briareidae		2					2
4	Clavulariidae	3						3
5	Gorgoniidae		2					2
6	Nephtheidae	3	1					4
7	Nidaliidae	1						1
8	Plexauridae	1						1
9	Subergorgiidae	1						1
10	Tubiporidae					1		1
11	Xeniidae	1	2					3
	TOTAL	**15**	**13**			**1**		**29**
ORDER ANTIPATHARIA								
1	Antipathidae		1					1
	TOTAL		**1**					**1**
ORDER CORALLIMORPHARIA								
1	Discosomidae	3[b]	5					8
2	Ricordeidae		1					1
	TOTAL	**3**	**6**					**9**

Un* = Unknown – species was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; Scleractinia incertae sedis* = a temporary name for species that were not yet classified to a certain family. a = species was assessed as Least Concern in the Mediterranean, b = two species were traded in the market name that did not exist scientifically (*Discosoma marmoratus* and *Discosoma striata*), hence it was written only to genus level.

Table 14. Conservation status of marine species traded from the class Anthozoa (Sea anemones and corals) and Scyphozoa (Jellyfishes) (continued)

No	Family	Conservation Status						Total
		Un*	NE	DD	LC	NT	VU	
ORDER PENNATULACEA								
1	Pennatulidae		1					1
	TOTAL		**1**					**1**
ORDER SCLERACTINIA								
1	Acroporidae	3						3
2	Dendrophylliidae	1	1					2
3	Euphylliidae					3	6	9
4	Faviidae	2						2
5	Fungiidae	1			2		1	4
6	Lobophyllidae	3			2	5		10
7	Merulinidae	4			3	1	1	9
8	Montastreidae	1						1
9	Poritidae	1				2		3
10	Scleractinia incertae sedis*	1				2	2	5
	TOTAL	**17**	**1**		**7**	**13**	**10**	**48**
ORDER ZOANTHARIA								
1	Hydrozoanthidae		1					1
2	Sphenopidae	2	1					3
3	Zoanthidae	1	1					2
	TOTAL	**3**	**3**					**6**
ORDER RHIZOSTOMEAE								
1	Cassiopeidae	1						1
2	Mastigiidae		1					1
	TOTAL	**1**	**1**					**2**

Un* = Unknown – species was not identified to the species level; NE = Not Evaluated; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; Scleractinia incertae sedis* = a temporary name for species that were not yet classified to a certain family.

Three Near Threatened species and one Vulnerable species were recorded in IUCN Red List as its synonyms. *Lobophyllia rowleyensis* (listed as not evaluated) and *Australomussa rowleyensis* (listed as Near Threatened) were both listed in IUCN Red List. Nevertheless, both species were the same, *Australomussa rowletensis* was the synonym for *Lobophyllia rowleyensis*. Thus, the accepted name was chosen and labelled as Near Threatened species. The same scenario was found on *Micromussa lordhowensis* (recorded in IUCN as *Acanthastrea lordhowensis*) and *Sclerophyllia maxima* (recorded in IUCN as *Acanthastrea maxima*). The Vulnerable species *Caulastraea curvata* was written as its synonym *Caulastrea curvata* in IUCN Red List.

Cnidarian species exported from Indonesia were sold in the price range of 1.37 – 150 USD. Four most expensive ornamental cnidarian species sold were sea anemones (order Actiniaria) and the fifth was stony coral (order Scleractinia). The most expensive species were *Stichodactyla gigantea* in red colour (150 USD), following *Stichodacyla haddoni* in blue (57.15 USD) and purple (55.70 USD), *Entacmaea quadricolor* (43.83 USD), and medium size of *Echinopora lamellose* (38 USD).

Figure 20. *Catalaphyllia jardinei*, one of 10 cnidarian Vulnerable species traded from Indonesia. Photo: Tim Wijgerde, IUCN.

Meanwhile, among the cheapest cnidarians marketed were sea anemones, jellyfish, sea fans, zoanthids, and stony corals. Those species were *Phymanthus* sp. (1.37 USD), *Mastigias papua* and *Sarcophyton* sp. (1.50 USD), *Cladiella* sp. (2 USD), *Hydrozoanthus gracilis* in yellow colour and *Cycloseris tenuis* that were both sold for 2.50 USD.

The largest number of species traded came from wild harvest. It was stated that only 6 species cultured for the trade, in which all belong to the order Scleractinia or stony corals. Four Vulnerable species were among these cultured species, namely *Euphyllia cristata*, *Fimbriaphyllia ancora*, *Fimbriaphyllia paraancora*, and *Fimbriaphyllia paradivisa*. Unfortunately, the wild colony of those species were still part of the trade. Additionally, *Acropora* sp. and *Montipora* sp. were also among the cultured species.

Sixteen species that were not recorded its distribution in Indonesia were found to be exported from the country. Detailed information about those species and its known distribution is presented in Table 15.

Table 15. Records of exported Cnidarians that were not recorded its distribution in Indonesia based on utilised databases

No	Family	Species		Known Distribution
		Scientific name	Common name	
1	Actiniidae	*Actinia equina**	Beadlet anemone	Africa: Algeria, Egypt, Libya, Morocco, Tunisia. Asia: Cyprus, Iran, Israel, South Korea, Syria, Turkey. Europe: Azores Island, Bosnia Herzegov., Croatia, France, Germany, Greece, Italy, Monaco, Montenegro, Slovenia, Spain
2	Cerianthidae	*Cerianthus membranaceus*	Tue dwelling anemone	Atlantic and Mediterranean. Native to Italy
3	Phymantidae	*Phymanthus crucifer*	Red beaded anemone	North Atlantic Ocean. Native to Belize
4	Stichodactylidae	*Stichodactyla mertensii*	Merten's sea anemone	Native to the Philippines
5	Thalassianthidae	*Heterodactyla hemprichii*	Hemprich's anemone	Native to Egypt, Tanzania, Israel, Japan, Saudi Arabia, Australia, Marshall Island, Papua New Guinea
6	Alcyoniidae	*Lobophytum pauciflorum*		Native to Ryukyu Island, Taiwan, New Caledonia, and Palau
7	Alcyoniidae	*Sarcophyton latum*		Native to New Caledonia
8	Alcyoniidae	*Sinularia brassica*	Cabbage leather coral	Native to Hong Kong, New Caledonia, Palau
9	Alcyoniidae	*Sinularia flexibilis*	Flexible leather coral	Native to New Caledonia and Palau
10	Alcyoniidae	*Sinularia polydactyla*	Finger leather coral	Native to New Caledonia and Palau
11	Briaridae	*Briareum stechei*	Pacific encrusting gorgonian	Native to New Caledonia
12	Gorgoniidae	*Guaiagorgia anas*	Gorgonian	Native to New Caledonia
13	Gorgoniidae	*Leptogorgia cardinalis**	Sea whip, Octocorals	USA and Canada

Number 1-5 were families from the order Actiniaria (Sea anemones); Number 6-14 were from order Alcyonacea (Sea fans). Species distribution derived from SeaLifeBase (Palomares & Pauly 2019), AquaMaps (Kaschner et al. 2019) and Catalogue of Life. * = Indonesia was generated as suitable habitat for the species (Kaschner et al. 2019).

Table 15. Records of exported Cnidarians that were not recorded its distribution in Indonesia based on utilised databases (continued)

No	Family	Species		Known Distribution
		Scientific name	Common name	
14	Xeniidae	*Xenia umbelatta*	Pom pom xenia	Indian Ocean, Madagascar, and South Africa
15	Pennatulidae	*Ptilosarcus gurneyi*	Orange seapens	Native to Alaska, Canada, USA
16	Lobophylliidae	*Sclerophylla maxima**	Acan maxima	Native to Djibouti, Somalia, Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, and Yemen

Number 5-14 were from order Alcyonacea (Sea fans); Number 15 was from the order Pennatulacea (Sea pen); Number 16 was from the order Scleractinia (Stony corals). Species distribution derived from SeaLifeBase (Palomares & Pauly 2019), AquaMaps (Kaschner et al. 2019) and Catalogue of Life. * = Indonesia was generated as suitable habitat for the species (Kaschner et al. 2019).

4.1.5. Phylum Echinodermata

Marine species exported from phylum Echinodermata counted for 39 species in total which were classified in 5 classes: Asteroidea (Seastar), Crinoidea (Crinoids), Ophiuroidea (Brittle star), Echinoidea (Sea urchins), and Holothuroidea (Sea cucumber). The biggest portion of echinoderms traded from Indonesia was represented by eighteen species of sea stars (46.15%). Further, followed by 9 species of sea urchin (23.08%), 6 species of brittle star (15.38%), 4 species of sea cucumber (10.26%), and 2 species of crinoids (5.13%).

Figure 21. *Holothuria atra* on a wood, Numfor Island Papua, Indonesia. The only Least Concern species traded from the phylum Echinodermata. Photo: Zámečníková-Wanma

A percentage of 89.74% of the species exported was not evaluated its conservation status. Three species from the genus *Asterina*, *Comaster*, and *Ophiocoma* could not be determined its conservation status due to the identification that was only to the genus level. Meanwhile, a species of the sea cucumber *Holothuria atra* (Figure 21) was found to be listed as Least Concern. Detailed information about the conservation status of traded echinoderms is available in Table 16.

Table 16. Conservation status of marine species traded from the phylum Echinodermata

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER SPINULOSIDA							
1	Echinasteridae		1				1
	TOTAL		**1**				**1**
ORDER VALVATIDA							
1	Archasteridae		1				1
2	Asterinidae	1					1
3	Asteropseidae		1				1
4	Goniasteridae		5				5
5	Ophidiasteridae		4				4
6	Oreasteridae		5				5
	TOTAL	**1**	**16**				**17**
ORDER COMATULIDA							
1	Comatulidae	1	1				2
	TOTAL	**1**	**1**				**2**
ORDER AMPHILEPIDIDA							
1	Ophiolepididae		1				1
2	Ophiotrichidae		1				1
	TOTAL		**2**				**2**
ORDER OPHIACANTHIDA							
1	Ophiocomidae	1	2				3
2	Ophiomyxidae		1				1
	TOTAL	**1**	**3**				**4**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Table 16. Conservation status of marine species traded from the phylum Echinodermata (continued)

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER CAMARODONTA							
1	Echinometridae		3				3
2	Temnopleuridae		2				2
3	Toxopneustidae		2				2
	TOTAL		**7**				**7**
ORDER DIADEMATOIDA							
1	Diadematidae		2				2
	TOTAL		**2**				**2**
ORDER DENDROCHIROTIDA							
1	Cucumariidae		3				3
	TOTAL		**3**				**3**
ORDER HOLOTHURIIDA							
1	Holothuriidae				1		1
	TOTAL				**1**		**1**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Echinoderms from Indonesia was exported in the price range of 0.60-6.20 USD. The most expensive echinoderm sold was *Protoreaster lincki*. Second most expensive was a sea cucumber *Pseudocolochirus violaceus* (4.81 USD), followed by sea star *Linckia laevigata* that was sold for 3 USD. Among the cheapest were sea stars, sea urchin and brittle stars. The cheapest echinoderm sold for 0.60 USD was a common sea star *Archaster typicus*. Sea urchins *Colobocentrus* (*Podophora*) *atratus* and *Echinometra mathaei* were sold for 0.63 USD. A brittle star *Ophiomastix annulosa* was sold for 0.85 USD and a sea urchin *Heterocentrotus mammilatus* (Figure 22) was sold for 0.86 USD. Meanwhile, the Least Concern species *Holothuria atra* was exported for 2 USD.

Figure 22. *Heterocentrotus mamillatus* held in hand by a kid in Numfor Island, Papua. A species among the cheapest of exported echinoderm. Photo: Zámečníková-Wanma.

This study found 12 species that were not recorded from Indonesian water in the databases. Two of them, *Protoreaster lincki* and *Colochirus robustus*, were not even known its distribution. The species and the known distribution based on databases is presented in Table 17.

Table 17. Records of exported Echinoderms that were not recorded its distribution in Indonesia based on utilised databases

No	Family	Species		Known Distribution
		Scientific name	Common name	
1	Goniasteridae	*Neoferdina cumingi*	Cuming's sea star	Native to China, Philippines, New Caledonia, Palau, Pitcairn
2	Ophidiasteridae	*Gomophia watsoni*	Watson's brittle star	Heron Island, Great Barrier Reef, Australia. Native to New Caledonia
3	Ophidiasteridae	*Nardoa novaecaledoniae*	Yellow mesh sea star	Native to Philippines, New Caledonia, and Palau
4	Oreasteridae	*Anthenea conjugens*	Mated sea star	Native to Australia
5	Oreasteridae	*Halityle regularis*	Mosaic cushion star	Native to Philippines, New Caledonia, and Palau
6	Oreasteridae	*Protoreaster lincki*	Red knob sea star	-
7	Ophiocomidae	*Ophiarthrum pictum*	White brittle star	Native to Philippines, Australia, Palau
8	Ophiocomidae	*Ophiomastix annulosa*	Chain-link brittle star	Native to China, Maldives, Philippines, Sri Lanka, Taiwan, Australia, Fiji, New Caledonia
9	Echinometridae	*Colobocentrotus (Podophora) atratus*	Shingle urchin	South African Exclusive Economic Zone
10	Cucumariidae	*Cercodemas anceps*	Pink cucumber	Native to Vietnam
11	Cucumariidae	*Colochirus robustus*	Yellow cucumber	-
12	Cucumariidae	*Pseudocolochirus violaceus*	Sea apple	East Africa, Indian Ocean, Madagascar, Mozambique, South Africa

Number 1-6 were families from the order Valvatida (Seastar); Number 7-8 were from order Ophiacanthida (Brittle star); Number 9 was from the order Camarodonta (Globular sea urchin); Number 10-12 were from the order Dendrochirotida (Sea cucumbers). Species distribution derived from SeaLifeBase (Palomares & Pauly 2019), IUCN, WoRMS, and Catalogue of Life.

4.1.6. Phylum Mollusca

This study found 44 species of molluscs in 27 families that were exported from Indonesia. Various species of mollusc came from three classes, Bivalvia (2.27%), Cephalopoda (6.82%) and Gastropoda (90.91%). Most species traded came from the class Gastropoda which was classified in 10 orders from the total of 12 orders traded from the phylum. Nevertheless, a species of gastropod from the family Plakobranchidae, *Elysia* sp., was not assigned its order yet. Thus, it was classified as a separate order.

Figure 23. *Hapalochlaena lunulata* or Blue ring octopus, one of Last Concern molluscs species that was exported from Indonesia. Lembeh Strait, Indonesia. Photo: Zámečník.

Thirty-eight species (86.36%) of total species exported from phylum Mollusca was not evaluated its conservation status yet (Table 18). One species of octopus, *Octopus chierchiae*, was listed as Data Deficient species. Furthermore, 3 Least Concern species was also included in the list namely *Hapalochlaena lunulata* (Figure 23), *Octopus cyanea*, and *Conus ebraeus*. Meanwhile, 2 species that were identified only to the genus level, *Elysia* sp. and *Discodoris* sp., were not known its conservation status.

Cephalopods were on the three topmost expensive molluscs. The most expensive mollusc sold was *Octopus chierchiae*, a Data Deficient Lesser Pacific striped octopus that was priced 40 USD per individual. Followed by two Least Concern species *Octopus cyanea* that was sold for 10 USD and *Hapalochlaena lunulata* (Figure 23) that was sold for the maximum price of 6.50 USD. Another Least Concern species *Conus ebraeus* was sold for merely 0.43 USD.

Table 18. Conservation status of marine species traded from the phylum Mollusca

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER LIMIDA							
1	Limidae		1				1
	TOTAL		**1**				**1**
ORDER OCTOPODA							
1	Octopodidae			1	2		3
	TOTAL			**1**	**2**		**3**
ORDER APLYSIIDA							
1	Aplysiidae		3				3
	TOTAL		**3**				**3**
ORDER CEPHALASPIDAE							
1	Aglajidae		1				1
	TOTAL		**1**				**1**
ORDER CYCLONERITIDA							
1	Neritidae		1				1
	TOTAL		**1**				**1**
ORDER LEPETELLIDA							
1	Fissurellidae		1				1
2	Haliotidae		1				1
	TOTAL		**2**				**2**
ORDER LITTORINIMORPHA							
1	Cypraeidae		2				2

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Table 18. Conservation status of marine species traded from the phylum Mollusca (continued)

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER LITTORINIMORPHA							
2	Strombidae		1				1
	TOTAL		**3**				**3**
ORDER NEOGASTROPODA							
1	Babyloniidae		1				1
2	Buccinidae		1				1
3	Conidae				1		1
4	Mitridae		1				1
5	Nassariidae		2				2
6	Pisaniidae		1				1
	TOTAL		**6**		**1**		**7**
ORDER NUDIBRANCHIA							
1	Chromodorididae		7				7
2	Coryphellidae		1				1
3	Discodorididae	1	2				3
4	Hexabranchidae		1				1
5	Phyllidiidae		1				1
6	Polyceridae		3				3
7	Samlidae		1				1
	TOTAL	**1**	**16**				**17**
ORDER PLEUROBRANCHIDA							
1	Pleurobranchidae		1				1
	TOTAL		**1**				**1**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Table 18. Conservation status of marine species traded from the phylum Mollusca (continued)

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER TROCHIDA							
1	Tegulidae		1				1
2	Trochidae		1				1
3	Turbinidae		2				2
	TOTAL		**4**				**4**
ORDER NOT ASSIGNED							
1	Plakobranchidae	1					1
	TOTAL	**1**					**1**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Among the cheapest of traded molluscs were *Atrimitra idae* (0.15 USD), *Tritia reticulata* (size 1-2 cm) and *Elysia* sp. both sold for 0.20 USD, *Tritia reticulata* (size 2-3 cm) and *Turbo bruneus* (size less than 3 cm) both sold for 0.25 USD and three other gastropod species that was sold for 0.30 USD namely *Mauritia arabica, Babylonia formosae* and *Turbo bruneus* (size 3-4 cm). The gastropods were sold in relatively low price compare to the cephalopods. The highest price of gastropod sold was 3.67 USD

Figure 24. *Goniobranchus kuniei* previously known as *Chromodoris kuniei* in Lembeh Strait North Sulawesi, Indonesia. Photo: Zámečník.

This study found 12 species that were not recorded its distribution in Indonesian water (Table 19). It consisted of one species of octopus and 11 species of gastropods. A nudibranch *Chromodoris quadricolor* was known to be introduced to Israel but no record of its origin. Furthermore, another species of nudibranch *Goniobranchus kuniei* (Figure 24) most probably occur in Lembeh Strait Indonesia (author's personal experience), even though it was not recorded to be distributed in Indonesian water based on the databases.

Table 19. Records of exported Molluscs that were not recorded its distribution in Indonesia based on utilised databases

No	Family	Species		Known Distribution
		Scientific name	Common name	
1	Octopodidae	*Octopus chierchiae*	Lesser pacific striped octopus	Native to Costa Rica and Panama. Other known distributions: Colombia, Ecuador, El Salvador, Guatemala, Mexico (Baja California), Nicaragua
2	Aplysiidae	*Aplysia dactylomela*	Black spotted seahare	Native to Cape Verde, Mauritius, Mozambique, South Africa, Philippines, Belize, Bermuda, Canada, Jamaica, Puerto Rico, USA, Australia, Kermadec Island, Lord Howe I., New Caledonia, New Zealand, Norfolk I., Brazil
3	Aplysiidae	*Bursatella leachi*	Ragged seahare	Native to Mozambique, South Africa, China, Iran, Japan, Philippines, United Kingdom, Canada, Panama, USA, Australia, Brazil. Introduced to: Tunisia, Israel, Lebanon, Turkey, Greece, Italy, Malta, Slovenia
4	Babyloniidae	*Babylonia formosae*	Formosan babylon	Native to western and Eastern Indian Ocean; Western central and Eastern central Pacific
5	Buccinidae	*Euthria cornea*	Striated buccinum	Native to Algeria, Morocco, Bosnia Hergezov., Croatia, France, Italy, Monaco, Montenegro, Slovenia, Spain
6	Chromodorididae	*Chromodoris quadricolor*	Pyjama nudibranch	Introduced to Israel

Number 1 was a family from the class Cephalopoda (cephalopods); Number 2-12 were from class Gastropoda (gastropods). Species distribution derived from SeaLifeBase (Palomares & Pauly 2019), IUCN, WoRMS, and Catalogue of Life.

Table 19. Records of exported Molluscs that were not recorded its distribution in Indonesia based on utilised databases (continued)

No	Family	Species		Known Distribution
		Scientific name	Common name	
7	Chromodorididae	*Goniobranchus kuniei**	Kune's chromodoris	Native to Christmas Island, Malaysia, Philippines, Australia, Marshall Island, New Caledonia, Papua New Guinea
8	Coryphellidae	*Fjordia lineata*	White stripped coryphella	Native to Belgium, France, UK
9	Mitridae	*Atrimitra idea*	Half-pitted miter	Native to Mexico and USA
10	Nassariidae	*Tritia reticulata*	Netted dog-whelk	Native to Algeria, Egypt, Libya, Morocco, Tunisia, Cyprus, Israel, Lebanon, Syria, Turkey, Albania, Bosnia Hergezov., Croatia. France, Greece, Italy, Malta, Monaco, Montenegro, Portugal, Slovenia, Spain
11	Pleurobranchidae	*Pleurobranchus forskalii*	Forskalls pleurobranch	Native to the Philippines and New Caledonia
12	Trochidae	*Trochus histrio*	Actor top	Native to Japan, Maldives, Philippines, Australia, French Polynesia, Guam, Marshall Island, Micronesia, New Caledonia, Palau

Number 1 was a family from the class Cephalopoda (cephalopods); Number 2-12 were from class Gastropoda (gastropods). * = not recorded on the databases but based on personal experience, it most probably present in Lembeh Strait Indonesia. Species distribution derived from SeaLifeBase (Palomares & Pauly 2019), IUCN, WoRMS, and Catalogue of Life.

4.1.7. Phylum Annelida

The study found 5 species from phylum Annelida that were traded from Indonesia. It was classified as species from 1 class Polychaeta in within 1 order Sabellida (Feather dusters). The conservation status of the species traded was either unknown or not evaluated yet (Table 20). Two species from family Sabellidae were identified to the genus level, thus its conservation status could not be identified. Meanwhile, 2 species from family Sabellidae (*Sabella spallanzanii* and *Sabellastarte spectabilis*) and 1 species from family Serpulidae *Protula bispiralis* were not yet evaluated its conservation status.

Table 20. Conservation status of marine species traded from the phylum Annelida

No	Family	Conservation Status					Total
		Un*	NE	DD	LC	NT	
ORDER SABELLIDA							
1	Sabellidae	2	2				4
2	Serpulidae		1				1
	TOTAL		**3**				**5**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened.

Marine annelids were exported from Indonesia in the price range of 1.00 – 16.95 USD. *Protula bispiralis* held the three topmost expensive species from the phylum. The most expensive one was the medium to the large size of the species in a red shade, followed by the yellow shade (14.77 USD) and red shade in small size (14.29 USD). Whereas, the cheapest species sold was the small size of *Sabellastarte spectabilis*, followed by *Sabellastarte* sp. (1.21 USD) and *S. spectabilis* in the medium size (1.5 USD).

Sabella spalanzanii or Peacock feather duster was reported to be distributed in Indonesia and has been introduced to Azores Island and Australia (Palomares & Pauly 2019). Furthermore, two other species non-native to Indonesia *Sabellastarte spectabilis* and *Protula bispiralis* were not recorded its presence in Indonesia. Nonetheless, this study found that the species were exported from Indonesia. Even though the origin of the species was not specified, most probably it came from wild harvest. Thus, indicated its presence in Indonesian water.

4.1.8. Subphylum Tunicata

The study found 2 species that were exported from subphylum Tunicata. Both species were classified as sea squirts or from the class Ascidiacea, namely *Clavelina* sp. (order Aplaousobranchia) and *Botrylloides* sp. (order Stolidobranchia). Due to insufficient identification, the conservation status of the species could not be specified and marked as unknown. Both species were sold as a medium-size product in the price range of 4.5-15 USD. The most expensive tunicate exported from Indonesia was *Botrylloides* sp. in neon colour morph.

4.1.9. Phylum Porifera

Marine sponge species from the phylum Porifera that was exported from Indonesia was recorded from the order Haplosclerida and Poecilosclerida. It consisted of only 2 species, *Haliclona* sp. and *Clathria* (*Wilsonella*) *rugosa*. The species *C. rugosa* was sold for 5 USD and not yet evaluated its conservation status. Meanwhile, *Haliclona* sp. was sold merely in small-size for 4.5 USD.

4.2. Freshwater Species Exported by Indonesia

Overall, 550 freshwater ornamental species were documented to be exported from Indonesia in this study. It comprised of 437 fish species (class Actinopterygii and Elasmobranchii) and 113 non-fish species (amphibians, crustaceans, and molluscs). The biggest portion of freshwater fish species exported from Indonesia came from class Actinopterygii (99.31%) and the class Malacostraca for the non-fish species (61.06%).

Up to 160 species of freshwater species or 36.61% traded as ornamentals were not evaluated its conservation status, 154 species (35.24%) were listed as Least Concern, 19 Endangered species (4.35%) and 13 Critically Endangered species (2.97%) were found to be part of the industry. Similarly, the greatest quantity of non-fish species exported as ornamentals was not evaluated its conservation status yet (36.28%). Furthermore, 29 non-fish species (25.66%) held Least Concern conservation status, 8 species (7.08%) were listed as Endangered, and 5 species (4.42%) were listed as Critically Endangered.

4.2.1. Actinopterygii (Ray-finned Fishes)

Most species exported was from the class Actinopterygii. It consisted of 434 species in 61 families placed in 18 orders. The highest percentage of species traded were from the order Perciformes (38.94%), followed by order Chariformes (12.90%), order Cypriniformes (12.67%), and order Atheriniformes (12.44%). Detailed data of family and species number per order is presented in Table 21.

Table 21. Percentage of freshwater ornamental ray-finned fishes exported from Indonesia in each order

No	Order	Tot. Family	Tot. Species	Percentage (%)
1	Anguilliformes	2	4	0.92
2	Atheriniformes	4	54	12.44
3	Batrachoidiformes	1	1	0.23
4	Beloniformes	2	9	2.07
5	Characiformes	8	56	12.90
6	Cypriniformes	4	55	12.67
7	Cyprinodontiformes	4	11	2.53
8	Gymnotiformes	1	1	0.23
9	Lepisosteiformes	1	1	0.23
10	Osteoglossiformes	3	5	1.15
11	Perciformes	13	169	38.94
12	Pleuronectiformes	1	1	0.23
13	Polyoteriformes	1	7	1.61
14	Scorpaeniformes	1	1	0.23
15	Siluriformes	12	48	11.06
16	Synbranchiformes	1	3	0.69
17	Syngathiformes	1	2	0.46
18	Tetraodontiformes	1	6	1.38
	TOTAL	**61**	**434**	**100.00**

No = number, Tot. family = total family, Tot. species = total species.

4.2.1.1. Order Anguilliformes (Eels and morays)

Indonesia was recorded to export 4 species of freshwater eels and morays that was identified to come from 2 families, family Anguillidae and Muraenidae. All four species

were noted to be native to Indonesia. Amongst, one species *Anguilla bicolor* (family Anguillidae) was listed as a Near Threatened species, two species *Gymnothorax polyuranodon* and *G. tile* (family Muraenidae) were listed as Least Concern species, and *Echidna rhodochilus* (family Muraenidae) was not yet evaluated its conservation status.

Figure 25. Shortfin eel (*Anguilla bicolor*) the cheapest species sold from order Anguilliformes and the Near Threatened species. Photo: FiMSeA, IUCN.

The price range of the species sold from order Anguilliformes was 0.80-60.00 USD. Surprisingly, the cheapest species sold was *Anguilla bicolor* (Figure 25) at the maximum size of 17.78 cm, the Least Concern species. Contrary, the most expensive species exported was *Gymnothorax polyuranodon* in the maximum size of 60 cm. The species *G. polyuranodon* was sold in several group size for the price ranging from 15-60 USD.

4.2.1.2. Order Atheriniformes (Silversides)

In total, 54 species of silversides from 4 families were exported as ornamental species from Indonesia. Twenty species (37.04%) were not evaluated its conservation status yet, 14 species (25.93%) were listed as Least Concern, 2 species were listed as Endangered, and 2 other species were listed as Critically Endangered. Detailed information on the conservation status of the species in every family is presented in Table 22.

Table 22. Conservation status of freshwater fishes from the order Atheriniformes exported from Indonesia

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Bedotiidae							1		1
2	Melanotaeniidae	3	15	6	10		5	1	2	42
3	Pseudomugilidae	1	5		4					10
4	Telmatherinidae						1			1
	TOTAL	**4**	**20**	**6**	**14**		**6**	**2**	**2**	**54**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Both of the Critically Endangered species (family Melanotaeniidae) were endemic to Papua Indonesia, namely *Chilatherina sentaniensis* (Figure 26) and *Glossolepis wanamensis*. Additionally, the other 2 Endangered species exported from Indonesia was *Melanotaenia boesemani* (family Melanotaeniidae) a species endemic to Indonesia, and *Bedotia geayi* (family Bedotiidae) a species endemic to Madagascar.

Figure 26. Sentani rainbowfish (*Chilatherina sentaniensis*), a Critically Endangered species endemic to Lake Sentani, Papua Province, Indonesia. Photo: G.R. Allen (Allen 1992).

The silversides were exported from Indonesia in the price range of 0.10-4.00 USD. Some of the cheapest species were *Melanotaenia praecox* (0.1 USD), *Iriatherina werneri* (0.12 USD), and *Marosatherina ladigesi* (0.14 USD). Meanwhile, the most expensive species were *Melanotaenia boesemani* (4 USD), an Endangered species. Unexpectedly, the Critically Endangered species *Chilatherina sentaniensis* and *Glossolepis wanamensis* were both sold for 2 USD. There was no specified size for both species which indicated that the species was sold for the price in all size possible.

Furthermore, the Endangered species *Bedotia geayi* was exported for the price of 0.27-0.70 USD. The other Endangered species *Melanotaenia boesemani* was sold for 0.23-4.00 where wild harvest from the specified area of the species was priced more expensive. *Melanotaenia boesemani* was harvested from Red Aves creek and Lake Aitinjo.

4.2.1.3. Order Batrachoidiformes (Toadfishes)

Merely a single species of toadfish was exported from Indonesia. *Halophryne diemensis* or commonly known as Banded frogfish (family Batrachoididae). The species was not evaluated its conservation status and reported to live in brackish and marine water (Froese & Pauly 2019), yet it was listed under freshwater species by the Indonesian whole seller. The species was sold for 40 USD.

4.2.1.4. Order Beloniformes (Needle fishes)

Nine species of needle fishes in two families were exported from Indonesia. Seven of the species were noted to be native to Indonesia, one species native to Malaysia and one species was identified only to its genus level. The detailed conservation status of the species is presented in Table 23. One Endangered species with a decreasing population trend *Oryzias woworae* was among the traded species. The species with unknown conservation status was *Nomorhamphus* sp.

Table 23. Conservation status of exported freshwater ornamental fishes order Beloniformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Adrianichthyidae				1			1		2
2	Zenarchopteridae	1	5		1					7
	TOTAL	**1**	**5**		**2**			**1**		**9**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Export price of freshwater needle fishes varied between 0.20-1.50 USD. Surprisingly, the cheapest species sold was the Endangered *Oryzias woworae* which commonly known as Daisy's ricefish. Meanwhile, the most expensive species sold for

1.50 USD was *Nomorhamphus* sp. The second most species sold for 1 USD was *Nomorhamphus liemi*.

4.2.1.5. Order Characiformes (Characins)

Fifty-six characins were found to be exported from Indonesia as ornamental fishes. Up to 82% of the total species (46 species) that were traded (Table 24) were not evaluated its conservation status yet. Additionally, 7 species were listed as Least Concern such as *Alestopetersius caudalis* and *Astyanax mexicanus*.

Table 24. Conservation status of exported freshwater ornamental fishes order Characiformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Alestidae				3					3
2	Anostomidae		4							4
3	Characidae	1	30	2	4					37
4	Chilodontidae		1							1
5	Ctenoluciidae		1							1
6	Gasteropelecidae		2							2
7	Lebiasinidae		2							2
8	Serrasalmidae		6							6
	TOTAL	**1**	**46**	**2**	**7**					**56**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

All 56 species from the order Characiformes that were exported from Indonesia was not native to Indonesia. Two of the species, *Copella arnoldi* and *Pygocentrus nattereri*, were even recorded to be successfully introduced outside its natural range (Froese & Pauly 2019). Furthermore, the export price range of characins was recorded to be between 0.05-25 USD. The cheapest species marketed at 0.05 USD were *Gymnocorymbus ternetzi*, *Hasemania nana*, *Hyphessobrycon anisitsi*, and *Paracheirodon innesi*. Contrary, the most expensive species sold for 25 USD was held by *Myloplus schomburgkii*. Additionally, the second most expensive species was noted to be *Myloplus rubripinnis* (8 USD).

4.2.1.6. Order Cypriniformes (Carps)

Carps made up 12.67% of total freshwater ornamental fish species exported from Indonesia. In total, 55 species were recorded to be sold in which 25 species (45.45%) were listed as Least Concern species (Table 25). Additionally, 4 Endangered and 2 Critically Endangered species were included in the export list from Indonesian whole sellers. These Critically Endangered species were *Epalzeorhynchos bicolor* and *Trigonostigma somphongsi*, both species were known to be endemic to Thailand. Meanwhile, the Endangered species traded were 2 species known to be endemic to Myanmar: *Danio erythromicron* and *Sawbwa resplendens*; and 2 species known to be endemic to India: *Dawkinsia arulius* and *Sahyadria denisonii*.

Table 25. Conservation status of exported freshwater ornamental fishes order Cypriniformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Balitoridae				1	2				3
2	Cobitidae		1		5	1				7
3	Cyprinidae	2	10	3	18		5	4	2	44
4	Gyrinocheilidae				1					1
	TOTAL	**2**	**11**	**3**	**25**	**3**	**5**	**4**	**2**	**55**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

The export price range of ornamental species from the order Cypriniformes ranged between 0.06-20.00 USD. The cheapest species sold was *Puntius sachsii* and the most expensive species was held by an endemic Indonesia Least Concern species *Chromobotia macracanthus*. Moreover, the Critically Endangered species were priced under 1 USD. The *Epalzeorhynchos bicolor* was sold at 0.35-0.70 USD and the Somphong's rasbora *Trigonostigma somphongsi* was sold for 0.65 USD.

4.2.1.7. Order Cyprinodontiformes (Rivulines, killifishes and live bearers)

Eleven species of Cyprinodontiformes were recorded to be marketed from Indonesia as ornamental species. Amongst, 10 species were known to be originated from other countries. The non-native species exported from Indonesia were *Aplocheilus*

lineatus, Jordanella floridae, Epiplatys annulatus, Fundulopanchax gardneri, Poecilia latipinna, Poecilia reticulata, Poecilia sphenops, Poropanchax normani, Xiphophorus hellerii, and *Xiphophorus maculatus*. Additionally, the only native Indonesian species exported was *Aplocheilus panchax*.

Table 26. Conservation status of exported freshwater ornamental fishes order Cyprinodontiformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Aplocheilidae				2					2
2	Cyprinodontidae		1							1
3	Nothobranchiidae				2					2
4	Poeciliidae		1	1	4					6
	TOTAL		**2**	**1**	**8**					**11**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Majority of the species traded from the order Cyprinodontiformes was listed as Least Concern species (Table 26). Meanwhile, the export price of the species from order Cyprinodontiformes was considerably low. It was recorded to be around 0.04-1.00 USD. The cheapest price was held by *Xiphophorus maculatus* and the most expensive species was recorded on *Poecilia reticulata* in the size of 3-4 cm.

4.2.1.8. Order Gymnotiformes (Knifefishes)

This study found only one species of knifefish that was exported from Indonesia. The species was not native to Indonesia (Froese & Pauly 2019). It was *Apteronotus albifrons* (family Apteronotidae) or commonly known as the Black ghost. The conservation status of the species was not evaluated yet and it was marketed in several sizes ranging from 5-31 cm. In the meantime, the price was ranging between 0.37-15.00 USD depending on the size of the individual.

4.2.1.9. Order Lepisosteiformes (Gars)

Only a single species from order Lepisosteiformes was found on the freshwater ornamental export list from Indonesian whole sellers. A species non-native to Indonesia (Froese & Pauly 2019) and held a Least Concern conservation status, *Lepisosteus*

oculatus (family Lepisosteidae) or known also as Spotted gars. The species was marketed in the size range of 5-10 cm for 0.80-1.50 USD.

4.2.1.10. Order Osteoglossiformes (Bony tongues)

Five species of bony tongues were exported as ornamental fishes from Indonesia. Only one species was native to Indonesia, *Scleropages jardinii* (family Osteoglossidae) which was also sold as the most expensive species in the order Osteoglossiformes (20 USD). The other four species were not native to Indonesia, namely *Campylomormyrus elephas*, *Mormyrus longirostris*, *Osteoglossum bicirrhosum*, and *Pantodon buchholzi*. One species was not yet evaluated its conservation status (*Osteoglossum bicirrhosum*). Meanwhile, the other four species were listed in IUCN Red List as Least Concern species. Furthermore, the cheapest bony tongue species exported from Indonesia was *Mormyrus longirostris*, the Least Concern species that was sold for 0.56-1.00 USD.

4.2.1.11. Order Perciformes (Perch-like)

The order Perciformes formed the largest portion of freshwater ornamental fishes exported from Indonesia. This study recorded 169 species or about 38.94% of the total freshwater ornamental species. Sixty-seven species (39.64%) of the species were listed as Least Concern species and 41 species (24.26%) were not yet evaluated its conservation status (Table 27). Additionally, 9 Critically Endangered species and 10 Endangered species were part of the ornamental trade from the order Perciformes.

Table 27. Conservation status of exported freshwater ornamental fishes order Perciformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Ambassidae				1					1
2	Anabantidae				1					1
3	Badidae				1					1
4	Channidae				1					1
5	Cichlidae	6	26	2	30	1	3		3	71
6	Datniodidae		1		1					2

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Table 27. Conservation status of exported freshwater ornamental fishes order Perciformes (continued)

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
7	Eleotridae		3		4					7
8	Gobiidae	2	7	6	13	3		1		32
9	Monodactylidae				1					1
10	Osphronemidae	2	2	4	13	4	9	9	6	49
11	Scatophagidae		1							1
12	Terapontidae		1							1
13	Toxotidae				1					1
	TOTAL	**10**	**41**	**12**	**67**	**8**	**12**	**10**	**9**	**169**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

These Critically Endangered species recorded as ornamentals consisted of 3 non-native species and 6 native Indonesian species. The non-native Critically Endangered species exported from Indonesia where 2 species native to Malawi: *Aulonocara baenschi* (endemic to Malawi) and *Aulonocara maylandi*; and one species endemic to Madagascar. *Paretroplus menarambo*. Meanwhile, the Critically Endangered native Indonesian species were that of genus *Betta* and *Parosphromenus*: *Betta cracens*, *Betta hendra*, *Betta miniopinna*, *Betta rutilans*, *Betta* cf. *burdigala*, and *Parosphromenus gunawani*.

The Critically Endangered species were sold at a relatively low price, ranging from 0.35-5.00 USD. *Betta rutilans* was recorded as the cheapest among the Critically Endangered and the most expensive was *Betta* cf. *burdigala*. Furthermore, the cheapest species of Perch-like species was sold at 0.05 USD, a non-native Indonesian species from family Ambassidae *Parambassis ranga*. The most expensive species traded was a native Indonesian species *Datnioodes microlepis* and *Symphysodon* sp., both were sold at the price of 70 USD.

4.2.1.12. Order Pleuronectiformes (Flatfishes)

Tailed sole or *Leptachirus klunzingeri* (family Soleidae) was the only species recorded to be exported from the order Pleuronectiformes. This native Indonesian species was not evaluated its conservation status yet and was recorded only from Merauke River

in Papua, Indonesia (Froese & Pauly 2019). The species was exported for the price of 2.50 USD in the size of 5-6 cm.

4.2.1.13. Order Polypteriformes (Bichirs)

This study found 7 species of bichirs from family Polypteridae that were exported from Indonesia as ornamental fishes. All of the species marketed was not native to Indonesia. The species consisted of one not evaluated species *Polypterus bichir*, and 6 Least Concern species, *Polypterus delhezi*, *P. endlicherii*, *P. ornatipinnis*, *P. palmas*, *P. polli*, and *P. senegalus*.

Those species were sold in several group sizes at various prices. It ranged from 0.20 USD up to 10.00 USD. The cheapest species sold was *Polypterus senegalus* in the size of 5-6 cm. Meanwhile, the most expensive bichir exported from Indonesia was *Polypterus palmas* in the size of 5.08 cm that was marked to originate from Senegal River.

4.2.1.14. Order Scorpaeniformes (Scorpionfishes and flatheads)

A single species was noted to be exported from the order Scorpaeniformes. The species was a member of family Tetrarogidae, *Neovespicula depressifrons* or commonly known as Leaf goblinfish. It was known to be native to Indonesia (Froese & Pauly 2019) and was exported for the price of 0.25 USD.

4.2.1.15. Order Siluriformes (Catfish)

Forty-eight species of freshwater catfishes in 12 families were recorded to be exported from Indonesia as ornamental fishes. A hybrid of *Pharactocephalus hemiliopterus* and *Pseudoplatystoma fasciatum* was found to be part of the trade. Its family could not be determined, thus written separately as a hybrid. Half of the total species traded were not yet evaluated its conservation status and 29.17% of the species held Least Concern conservation status (Table 28). Amongst, two Endangered species were found to be part of the ornamental trade, namely *Pseudomystus heokhuii* and *Pangasianodon hypophthalmus*.

Table 28. Conservation status of exported freshwater ornamental fishes order Siluriformes

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Bagridae			1	3	1		1		6
2	Callichthyidae		13		2	1				16
3	Clariidae				1					1
4	Doradidae		2							2
5	Heteropneustidae				1					1
6	Loricariidae	3	5		1					9
7	Mochokidae		1		5					6
8	Pangasiidae							1		1
9	Pimelodidae		2							2
10	Plotosidae		1		1					2
11	Siluridae					1				1
12	HYBRIDS	1								1
	TOTAL	**4**	**24**	**1**	**14**	**3**		**2**		**48**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

The export price of freshwater ornamental catfishes exported from Indonesia ranged in 0.09-60 USD. *Corydoras aeneus* and its albino form were both recorded as the cheapest species that was sold for 0.09 USD. Meanwhile, the most expensive species recorded was a species endemic to Brazil *Hypancistrus zebra*. Unexpectedly, both of the Endangered catfish species were marketed barely at the price between 0.12-1.00 USD.

4.2.1.16. Order Synbranchiformes (Spiny eels)

Three species of spiny eels from a single family were recorded to be marketed as ornamentals in Indonesia. All of it came from the family Mastacembelidae, native to Indonesia (Froese & Pauly 2019), and were listed as Least Concern species. Namely, *Macrognathus circumcinctus*, *Macrognathus* cf. *tapirus*, and the fire eel *Mastacembelus erythrotaenia*. The cheapest species sold was *Macrognathus circumcinctus* which was marketed for 0.50 USD. Contrary the other two species were exported at the maximum price of 30 USD.

4.2.1.17. Order Syngathiformes (Pipefishes and seahorses)

The study found 2 native Indonesian freshwater pipefish that were exported from Indonesia as ornamental species. The species were identified as members of the family Syngnathidae, *Doryichthys martensii* and *Doryichthys heterosoma*. One of the species, *Doryichthys heterosoma* was endemic to Indonesia and was known only from the Sambas River in West Kalimantan and Natuna Islands, Indonesia (Froese & Pauly 2019). Both species were evaluated as Data Deficient species in IUCN Red List. The pipefishes were sold in the size ranging from 12-15 cm for merely 0.60 USD.

4.2.1.18. Order Tetraodontiformes (Puffers and filefishes)

Six species of Puffers from a single-family Tetraodontidae was noted to be exported from Indonesia as ornamental fishes. Two of the species exported were not native to Indonesia, namely *Carinotetraodon travancoricus* and *Tetraodon lineatus*. Three species were not yet evaluated its conservation status, 1 species of Data Deficient, 1 species of Least Concern, and 1 Vulnerable species (*Carinotetraodon travancoricus*).

The price range of the species sold from order Tetraodontiformes was 0.35-5.00 USD. The cheapest species sold for 0.35 USD was *Dichotomyctere nigroviridis* and the most expensive species sold was *Pao palembangensis*.

4.2.2. Elasmobranchii

This study found 3 species of ornamental freshwater Elasmobranchii. The cartilaginous fishes exported from Indonesia were recorded to be stingrays from family Potamotrygonidae. It included a not evaluated species *Potamotrygon jabuti*, a Data Deficient species *Potamotrygon motoro* (Figure 27), and *Potamotrygon* sp. which noted as Black diamond stingray. Both species *Potamotrygon jabuti* and *Potamotrygon motoro* were not native to Indonesia.

Figure 27. South American freshwater stingray (*Potamotrygon motoro*).
Photo: A. Murch, FishBase

Potamotrygon jabuti and *Potamotrygon* sp. were marketed at the price of 500 USD. Both were the most expensive among the three species exported. Meanwhile, the *Potamotrygon motoro* or commonly known as South American freshwater stingray was sold for 70 USD. Nevertheless, the "Royal marble" strain of *Potamotrygon motoro* was sold for 200 USD, more expensive than its normal version.

4.2.3. Amphibia

This study found 6 species of frogs from the class Amphibia that were marketed as part of ornamental trade in Indonesia. The species came from 5 families, such as Dicroglossidae, Hylidae, Megophryidae, Pipidae, and Rhacophoridae. All six species were listed as Least Concern species. The species exported as ornamentals were *Occidozyga lima*, *Litoria caerulea*, *Megophrys montana*, *Hymenochirus boettgeri*, *Hymenochirus curtipes*, and *Rhacophorus nigropalmatus*.

Figure 28. The most expensive ornamental amphibian exported from Indonesia, *Megophrys montana*. Photo: Djoko Iskandar, IUCN

The export price range of ornamental amphibians from Indonesia ranged from 0.06-5.00 USD. The cheapest species sold was *Occidozyga lima* that was marketed in the size of 2.5-3.0 cm. Meanwhile, the most expensive species was held by an endemic Indonesian species distributed in the Island of Java with a decreasing population trend, *Megophrys montana* the Asian spadefoot toad (Figure 28).

4.2.4. Malacostraca

One order under the class Malacostraca (subphylum Crustacea) was found to be exported from Indonesia. The study found that all species exported came from the order Decapoda (Lobsters, crabs, shrimps). In total, 69 species from 9 families of Malacostracans were exported from Indonesia (Table 29). The biggest portion of species traded was caridean shrimp from the family Atyidae, reaching 36.23% of the total species traded from 9 families.

Table 29. Conservation status of exported freshwater ornamental malacostracans

No	Family	Conservation Status								Total
		Un*	NE	DD	LC	NT	VU	EN	CR	
1	Atyidae	4	3	1	8		3	1	5	25
2	Cambaridae	2		1	4			1		8
3	Coenobitidae	1	5							6
4	Gecarcinidae		3					1		4
5	Gecarcinucidae	1						2		3
6	Palaemonidae				1					1
7	Parastacidae	1	5	4	1		1			12
8	Sesarmidae	2	7							9
9	Varunidae		1							1
	TOTAL	**11**	**24**	**6**	**14**		**4**	**5**	**5**	**69**

Un* = Unknown – not identified to species level, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Twenty-four species (36.23%) were not evaluated its conservation status yet and eleven species were identified only to its genus level, yet the conservation status was unknown. In particular, 5 Critically Endangered species, 5 Endangered, and 4 Vulnerable species were found to be part of the trade. The Critically Endangered species were all

endemic to Indonesia with restricted distribution to one or two lakes in Sulawesi. It was found to be members of the family Atyidae, including *Caridina dennerli*, *Caridina glaubrechti* (Figure 29), *Caridina striata*, *Caridina woltereckae*, and *Caridina* cf. *spinata*.

Figure 29. Red orchid bee (*Caridina glaubrechti*), one of the Critically Endangered species endemic to Lake Towuti, Sulawesi, Indonesia. Photo: Chris Lukhaup, IUCN

The Endangered species consisted of 1 non-native and 4 native Indonesian species. The non-native species was described to be native to Mexico, *Cambarellus patzcuarensis*. Whilst the other Endangered species were reported from Sulawesi in which 2 species were documented only from Lake Towuti, Sulawesi. The native Indonesian Endangered species were *Parathelphusa ferruginea*, *Parathelphusa pantherine*, *Syntripsa matannensis*, and *Caridina holthuisi*. In addition to that, the Vulnerable species comprised of some species documented from Lake Poso, Sulawesi. For instance, *Caridina caerulea*, *Caridina ensifera*, and *Caridina longidigita*.

The export price of the freshwater decapods varied from 0.06-10.00 USD. The species sold at the lowest price were *Caridina* sp. and *Neocaridina denticulate*. Opposed to that, the most expensive decapods traded were *Macrobrachium gracilirostre* and *Cherax peknyi*. Notably, the Critically Endangered and Endangered species were among the cheapest. All of the Critically Endangered species was sold at barely 1.00 USD and the Endangered species were in the price range of 0.50-1.00 USD.

4.2.5. Phylum Mollusca

This study found 38 species of freshwater and brackish molluscs in 10 families that were exported from Indonesia. Various species of molluscs came from two classes, Bivalvia (7.89%) and Gastropoda (92.11%). Most species traded came from the class Gastropoda which was classified in 6 orders from a total of 8 orders. Nevertheless, 18 species of gastropods were placed in the unassigned order Caenogastropoda, 1 species in the family Planorbidae was not assigned its order yet. Furthermore, 1 species was not stated its scientific name and branded as "Turtle snail". Thus, it was classified as a separate order.

Up to 17 species (44.74%) of freshwater molluscs exported as ornamentals from Indonesia had not yet evaluated its conservation status and 8 species (21.05%) were identified only to its genus level. Furthermore, 1 Vulnerable and 3 Endangered species were among the traded species. These Endangered species were reported to be endemic to Sulawesi, Indonesia such as *Tylomelania gemmifera*, *Tylomelania patriarchalis*, and *Tylomelania sarasinorum*. Detailed conservation status of the traded molluscs is presented in Table 30.

Table 30. Conservation status of marine species traded from the phylum Mollusca

No	Family	Conservation Status							Total
		Un*	**NE**	**DD**	**LC**	**NT**	**VU**	**EN**	
ORDER UNIONIDA									
1	Unionidae				1				1
	TOTAL				**1**				**1**
ORDER VENERIDA									
1	Cyrenidae	1	1						2
	TOTAL	**1**	**1**						**2**
ORDER ARCHITAENIOGLOSSA									
1	Viviparidae		1						1
	TOTAL		**1**						**1**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened. Order Unionida and Venerida were from class Bivalvia. The other orders were from the class Gastropoda. Order Caenogastropoda was not assigned.

Table 30. Conservation status of marine species traded from the phylum Mollusca (continued)

No	Family	Conservation Status							Total
		Un*	NE	DD	LC	NT	VU	EN	
ORDER CAENOGASTROPODA*									
1	Pachychilidae	3	4		1			3	11
2	Semisulcospiridae		1						1
3	Thiaridae		4		2				6
	TOTAL	**3**	**9**		**3**			**3**	**18**
ORDER CYCLONERITIDA									
1	Neritidae	3	5		5				13
	TOTAL	**3**	**5**		**5**				**13**
ORDER NEOGASTROPODA									
1	Nassariidae		1						1
	TOTAL		**1**						**1**
ORDER NOT ASSIGNED									
1	Planorbidae						1		1
	TOTAL						**1**		**1**
UNKNOWN									
1	Unknown	1							1
	TOTAL	**1**							**1**

Un* = Unknown, species identified only to the genus level, NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened. Order Unionida and Venerida were from class Bivalvia. The other orders were from the class Gastropoda. Order Caenogastropoda was not assigned.

Freshwater ornamental molluscs were advertised in the price ranging at 0.10-0.80 USD, not even for 1 USD. Those among the cheapest were *Clithon diadema*, *Clithon* sp., and *Neritina* sp. Meanwhile, among the highest price sold at 0.80 USD were *Tylomelania scalariopsis* and *Tylomelania* sp. The Endangered species *Tylomelania gemmifera* and *T. patriarchalis* were sold for 0.40 USD. Additionally, the Endangered *Tylomelania sarasinorum* was traded for 0.50 USD.

4.3. Climate Matching (CLIMATCH)

Based on the data collected from Indonesian exporters and ornamental fish producers, all the "iconic species" based on Novák et al. (2020) were on the list of the species exported from Indonesia. Moreover, those iconic species: *Betta splendens*, *Paracheirodon innesi*, *Poecilia reticulata* and *Pterophyllum scalare* are non-native to Indonesia. Thus, it was ideal to be assessed.

4.3.1. *Betta splendens* (Siamese Fighting Fish)

Siamese fighting fish, a fish endemic to Mekong basin (Froese & Pauly 2019) was found to be exported from Indonesia. Nine teen selected stations from *Source Region* were put into CLIMATCH analysis to be compared with 189 selected stations in Indonesia as *Target Region*. Map produced by CLIMATCH is presented in Figure 30. Most stations in the map showed blue to the yellow colour range, this indicated that there was low climate matching between *Source* and *Target Region*. Detailed scores of selected stations from Indonesia is presented in Table 31.

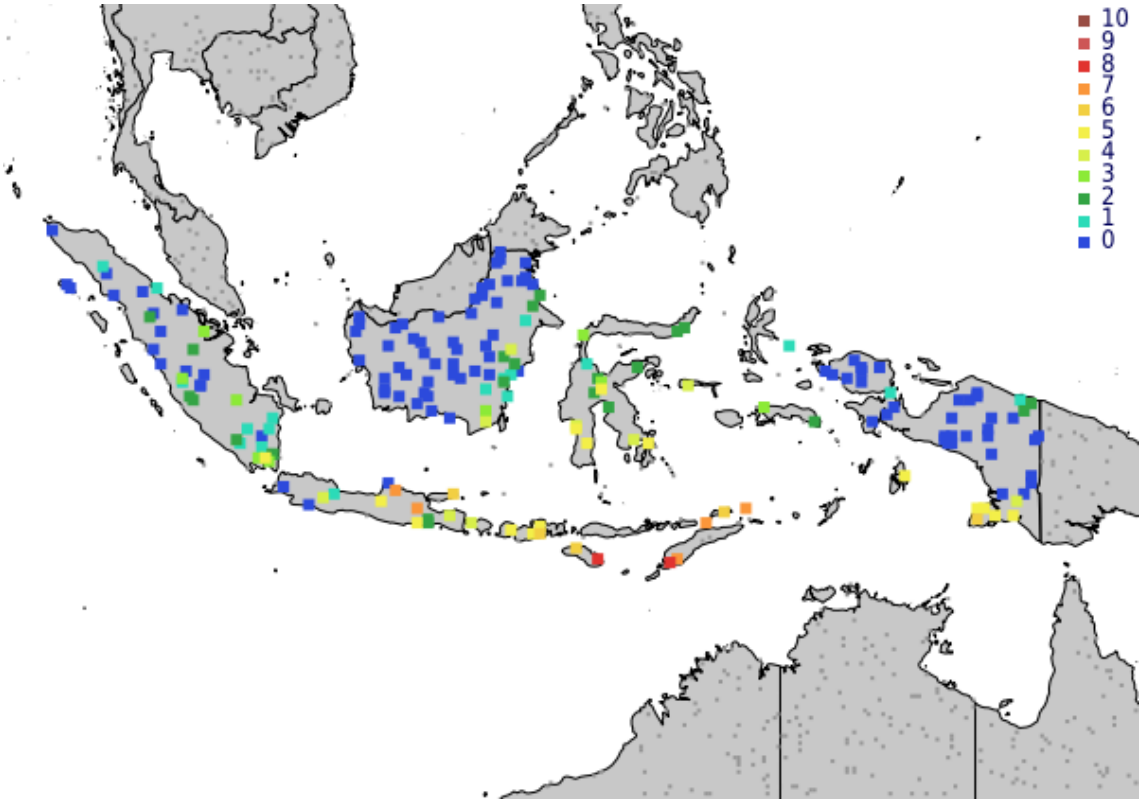

Figure 30. CLIMATCH analysis performed on *Betta splendens* with Indonesia as Target Region.

Table 31. CLIMATCH analysis score results for Betta splendens (Siamese fighting fish)

Score	Colour	Count
0		102
1		18
2		23
3		10
4		9
5		15
6		5
7		5
8		2
9		0
10		0

Majority of selected stations fell under the score of 7. It was found that 182 stations or 96.3% stations in Indonesia had low climate match to Mekong Basin where Siamese fighting fish originated. In other words, the TRID value is 3.7 (Table 35) which was proposed as a low-risk species by solely climatic modelling. This portrayed as the meaning that temperature and rainfall might serve as a limitation of species survival.

4.3.2. *Paracheirodon innesi* (Neon Tetra)

One of the popular ornamental non-native species found to be exported from Indonesia is *Paracheirodon innesi* or Neon tetra. The fish was reported to be originated from Blackwater or clearwater stream tributaries of the Solimoes River, South America (Froese & Pauly 2019). There were 290 selected stations in *Source Region* and 189 selected stations in *Target Region* involved in CLIMATCH analysis.

133 stations out of 189 stations had relatively close climate match compared to the *Source Region* (≥ 7). It represented TRID value as 70.37 (Table 35) which indicated that Indonesia as *Target Region* had High climate matching to the *Source Region* of *Paracheirodon innesi*. Map produced by CLIMATCH is represented in Figure 31 with detailed score available in Table 32. Five selected stations in Papua and West Papua displayed low CLIMATCH score (less and equal to two).

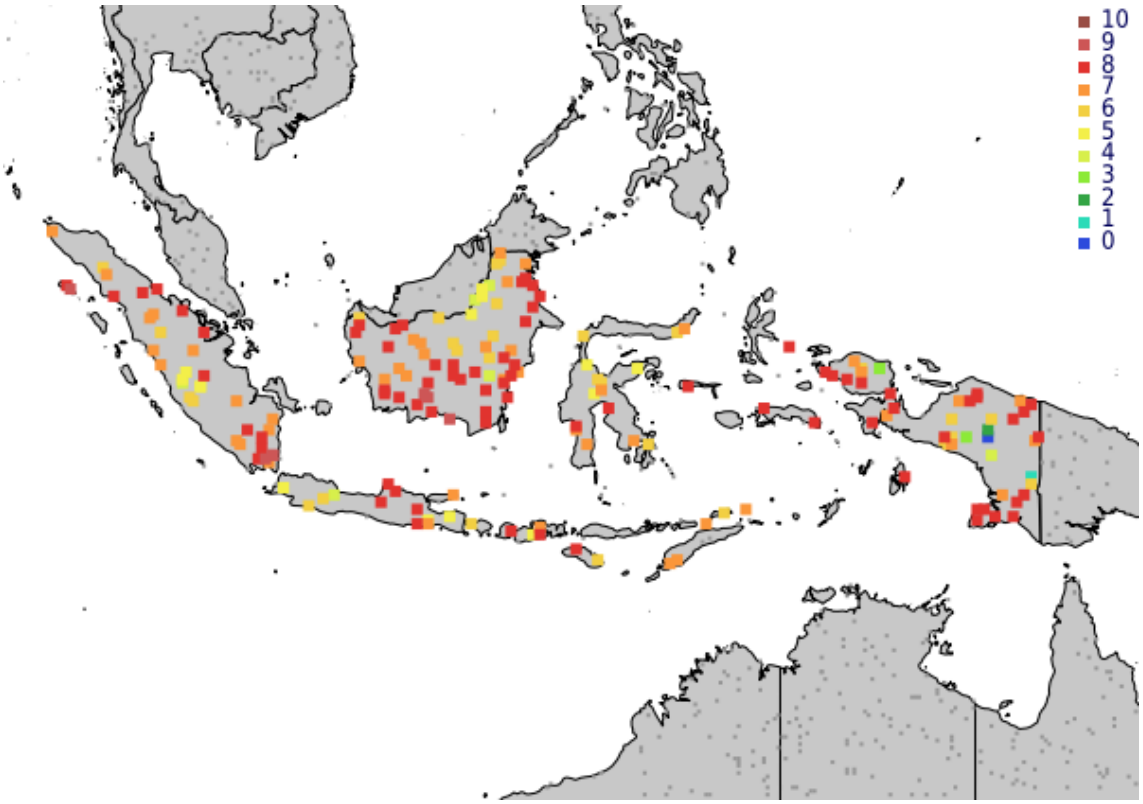

Figure 31. CLIMATCH analysis performed on *Paracheirodon innesi* with Indonesia as Target Region.

Table 32. CLIMATCH analysis score results for Paracheirodon innesi (Neon tetra)

Score	Colour	Count
0		1
1		1
2		1
3		2
4		7
5		14
6		30
7		47
8		79
9		7
10		0

4.3.3. *Poecilia reticulata* (Guppy)

Native *Source Region* of *Poecilia reticulata* was derived from AquaMaps (Kaschner e al. 2019) which showed that the species is distributed in most of the South American continent and part of North America. The *Source Region* of the species consisted of 1346 selected stations from Worldclim Sample dataset. Thereafter, CLIMATCH model produced a map that flashed orange to red in most of the Indonesian region that was defined as *Target Region* (Figure 32).

157 from 189 selected stations in *Target Region* showed relatively close climate to *Source Region* of *Poecilia reticulata*. Climate analysis of the species revealed the highest percentage of CLIMATCH score or TRID, counted for 83.06 (Table 35) compared to the other iconic species analysed in this study.

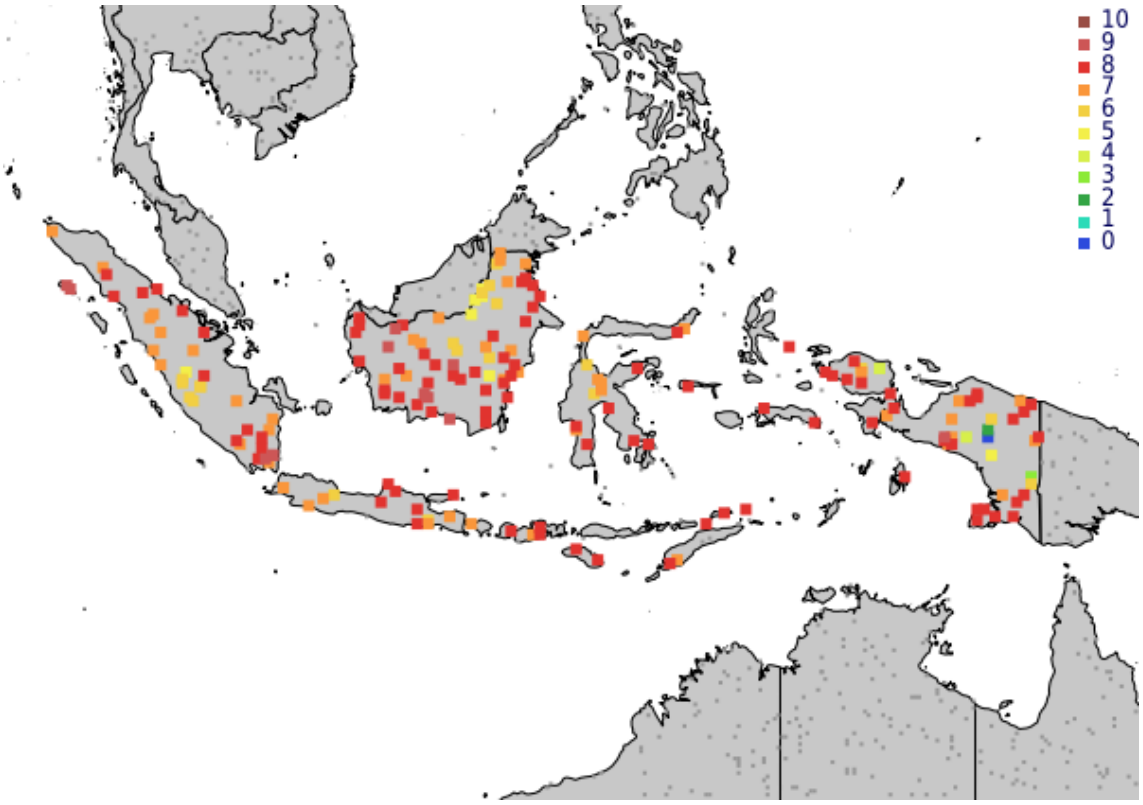

Figure 32. CLIMATCH analysis performed on *Poecilia reticulata* with Indonesia as Target Region.

Indonesia had High climate match to the climate of the area where *Poecilia reticulata* originated. Particularly, temperature and rainfall in Indonesia would not be a limitation of the survival of the species in the wild. With an exception of several areas in high lands that showed relatively low climate match. Detailed CLIMATCH score is presented in Table 33.

Table 33. CLIMATCH analysis score results for Poecilia reticulata (Guppy)

Score	Colour	Count
0		1
1		0
2		1
3		1
4		2
5		7
6		20
7		49
8		96
9		12
10		0

4.3.4. *Pterophyllum scalare* (Freshwater Angelfish)

Another iconic species which is non-native to Indonesia is *Pterophyllum scalare*. The species was known to be originated from South America (Kaschner et al. 2019) in the vicinity of Amazon River basin, in Peru, Colombia, and Brazil (Froese & Pauly 2019). The climatic analysis revealed a High climate match between Indonesia and the *Source Region* of *Pterophyllum scalare.*

Map produced by CLIMATCH is presented in Figure 33 and the detailed score result can be seen in Table 34. One hundred and one selected stations from Indonesia demonstrated a relatively close climate to the origin of the species. It represented the TRID value of 74.60 (Table 35). Identical to the other species with High climate match (*Paracheirodon innesi* and *Poecilia reticulata*), some stations on highlands of Indonesia (e.g. in Papua) showed low climate match compared to the *Source Region*.

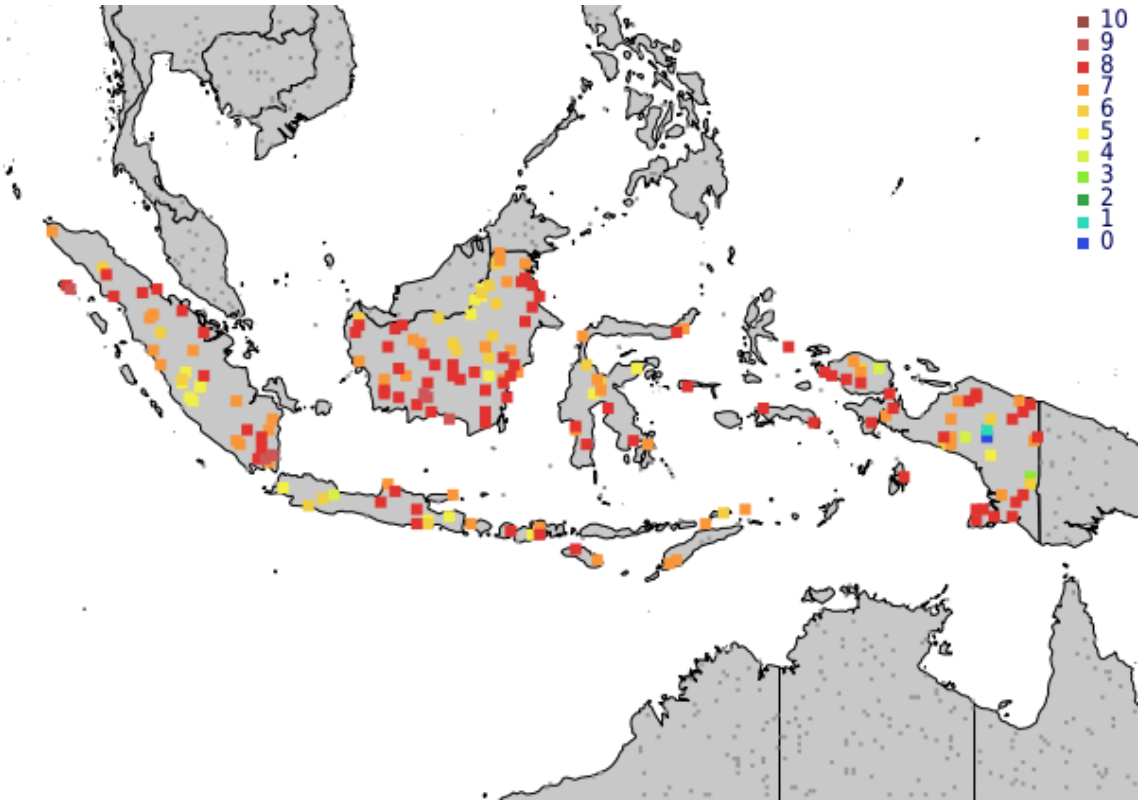

Figure 33. CLIMATCH performed on *Pterophyllum scalare* with Indonesia as Target Region.

Table 34. CLIMATCH analysis score results for Pterophyllum scalare (Freshwater angelfish)

Score	Colour	Count
0		1
1		1
2		0
3		1
4		3
5		18
6		24
7		50
8		84
9		7
10		0

4.4. Fish Invasiveness Screening Kit (FISK)

FISK scoring analysis on the selected non-native popular fishes traded from Indonesia showed 3 species as medium risk species and 1 species as high-risk species. *Poecilia reticulata* or also known as Guppy was the species assessed as high-risk species to Indonesian waters, with a score of 32 (Table 35). Furthermore, *Paracheirodon innesi* and *Pterophyllum scalare* with the FISK score of 9 signified medium-risk species. *Betta splendens* exhibited the FISK score of 8, which was the lowest score among all selected species, was likewise found to be a medium-risk species to Indonesian water bodies.

Table 35. CLIMATCH and FISK score of the selected animal species

Species	Family	CLIMATCH		FISK	
		TRID	Category	Score	Category
Betta splendens (Regan, 1910)	Osphronemidae	3.70	low risk	8	Medium
Paracheirodon innesi (Myers, 1936)	Characidae	70.37	high risk	9	Medium
Poecilia reticulata (Peters, 1859)	Poeciliidae	83.06	high risk	32	High
Pterophyllum scalare (Schultze, 1823)	Cichlidae	74.60	high risk	9	Medium

CLIMATCH = Climate Matching (Bureau of Rural Sciences), TRID = Temperature and rainfall suitability in *Target Region* Indonesia in percentage [%], FISK = Freshwater Fish Invasiveness Screening Kit.

5. Discussion

The ornamental trade from Indonesia, both marine and freshwater covered a huge quantity of species. Overall, this study found 1,323 aquatic ornamental species involved in the industry. These number might even be higher in reality, since some species were identified only to its genus level and or harvested from isolated places from all over the country. This poor identification technique that was mostly done morphologically might underestimate the total number of traded species. Especially those that were harvested from the remote wilderness of Indonesia.

The exotic, sometimes new and or undescribed species that were harvested from the wild quickly entered the ornamental trade industry. For instance, shrimp *Parhippolyte uvaea* (sugarcane shrimp), a recently discovered species from anchialine systems in Indonesia has entered the ornamental trade (Becking et al. 2011).

Furthermore, the greatest quantity of the traded species was those that were not evaluated its conservation status. Yet, had been circled the ornamental trade industry. Some endemic species such as *Doryichthys heterosoma* and *Melanotaenia irianjaya* were also documented to be exported from Indonesia. Some of these endemic species were even listed as Critically Endangered and Endangered. The pressure from overharvesting to satisfy market demand might worsen the number of wild endemic populations, such as the case of clown loach *Chromobotia macracanthus* in Sumatra and Borneo (Evers et al. 2019).

Satyani and Subamia (2009) documented that several species such as *Balantiocheilos melanopterus*, *Chromobotia macracanthus*, and some *Puntius* species were being scarce in the market, some were even absent from the export list. The scarcity and or absent of highly marketed species that were harvested from the wild might be a suggestion of some potential overharvesting practices.

Contrary to what expected, the Critically Endangered and Endangered species were rarely to be found amongst the most expensive. In total, the study found 18 Critically Endangered species, 30 Endangered, and 46 Vulnerable species that were traded as both marine and freshwater ornamental species. It suggested that the exporters or the market price were not decided based on the conservation status of the species. The pressure of

ornamental trade had potential harm to the wild population, especially on those endemics with complex reproductive strategies (Bender et al. 2013).

Even though several negative impacts arose from ornamental trade, it has the potential to secure new broodstocks if successfully bred in captivity. Sustainability of ornamental traded can be achieved if managed and appropriately supervised (Evers et al. 2019). One way to accomplish it is by Eco-certification such as the one initiated by the Marine Aquarium Council for marine ornamental trade (Shuman et al. 2004; Dykman, 2012).

This study found many species that are not native to Indonesia, yet was exported from the country. Besides the over-harvesting and habitat destructions, another important threat of the non-native species in the industry is the species invasion (Cucherousset & Olden 2011; Magalhaes & Jacobi 2013). Further analysis of the selected iconic non-native species found that the high-risk species *Poecilia reticulata* has established in Indonesian water. Meanwhile, the reports on the establishment of other selected species were lacking, yet bred all over the country. The species *Betta splendens* and *Poecilia reticulata* were even intentionally released to the wild as a biocontrol agent against the mosquito (Taviv et al. 2010; Dai 2015; Mutmainah et al. 2017; Syafei 2017; Rahmi et al. 2018; Harsono & Sri 2019).

5.1. *Betta splendens* (Siamese Fighting Fish)

Betta splendens appeared to be a medium-risk species for Indonesian water if intentionally or unintentionally released to the wild. CLIMATCH analysis showed that Indonesian climate, in general, was not suitable for the species survival (Figure 30). Nevertheless, seven climate stations on the southmost part of the country (Bali and Nusa Tenggara) showed relatively close climate to the climate of the species origin. This was an alarming finding since the species have been reported to be the first serious invasive species in the Northern Territory of Australia (Hammer et al. 2019), close to Bali and Nusa Tenggara.

The species have been reported to be introduced to several places such as Spain, Singapore, Philippines, Malaysia, Indonesia, Colombia, Brazil, USA, and Dominican

Republic (Froese & Pauly 2019). Furthermore, Froese & Pauly (2019) also described that there was probably an established population of *Betta splendens* (Figure 34) in Indonesia.

Figure 34. Siamese fighting fish (*Betta splendens*). Photo: Juan Carlos Palau D, FishBase.

Siamese fighting fish or *Betta splendens* is one of several popular fish species that were utilised as mosquito control in Indonesia. An experimental study by Tarihoran (2006) in Sumatra Indonesia showed that *Betta splendens* could consume fewer mosquito larvae compared to *Pterophyllum scalare*. Nonetheless, the utilisation of *Betta splendens* as a biocontrol to reduce the spread of dengue fever was recommended across Indonesia (Taviv et al. 2010; Dai 2015; Mutmainah et al. 2017; Rahmi et al. 2018; Harsono & Sri 2019). Furthermore, the use of *Betta splendens* as biocontrol was more favoured by local people compare to the usage of larvicide (Taviv et al. 2010) and claimed to be more effective in consuming mosquito larvae compared to *Poecilia reticulata* (Mutmainah et al. 2017).

Besides the use of *Betta splendens* as mosquito biocontrol across the country, the high economic value and available potential markets favoured the species to be chosen as ornamental fish bred in house scale. Prasadi (2019) reported that the ability of the species to survive in low oxygen condition was an advantage to new fish breeders, where the house yard can be optimised and implemented as its artificial breeding ground. The spread of breeding techniques was also performed and reported to increase farmer's income in Serang, Banten, as much as 3,390,000 IDR/1.5 months (Diani et al. 2005) which added income of 59.8% of the monthly minimum wage in the regency per 2020 (Gajimu.com/Garmen 2020).

These activities, regardless of its potential benefits, are not without risk. The high utilisation of *Betta splendens* through its use as a biocontrol of mosquito larvae (intentional release) and ornamental fish (unintentional release) has the risk of species being released to the local river systems. Several publications had reported the escape of fish and other aquatic species from its breeding facility (Povž 2017; Tuckett et al. 2017) and some have been reported to have adverse impacts to the ecosystem (Cucherousset & Olden 2011; Crego-Prieto et al. 2015; Milardi et al. 2018).

Even though *Betta splendens* was classified as medium-risk species in Indonesia, its establishment in the wild may have detrimental impacts on native species. The establishment of the species population in Indonesia has not been confirmed yet. Nonetheless, several introduced species were reported to establish in the wild in a long period which appeared to be 'dormant' after its introduction (Pusey at al. 2006).

Currently, the potential impacts of *Betta splendens* in the wild is not much known yet. Moreover, standardised fish sampling to assess negative and positive impacts of *Betta splendens* occurrence in the wild would be difficult, especially if established in habitats where researches were difficult to conduct (Hammer et al. 2019). The best possible practice is to prevent its intentional release to the wild. For instance, by utilising a local variant of *Betta* as an alternative to control mosquito larvae (e.g. *Betta smaragdina* var Sumatraensis) (Hermanto 2009).

Furthermore, the endemic rainbowfish *Melanotaenia arfakensis* from Manokwari West Papua was also reported to have the potential as mosquito control (Manangkalangi et al. 2015). It was documented to outperformed *Gambusia affinis* and *Aplocheilus panchax* (Manangkalangi et al. 2015). Thus, the introduction of *Betta splendens* as biocontrol can be avoided.

5.2. *Paracheirodon innesi* (Neon Tetra)

Neon tetra was assessed to be a medium-risk species to become invasive in Indonesia. The species was known to be introduced to several places and reported to successfully establish its population in Singapore and probably had several ecological impacts to the ecosystems (Ng et al. 1993; Froese & Pauly 2019).

Figure 35. Neon tetra (*Paracheirodon innesi*). Photo: M. Norén, FishBase

Table 36. Cities that sell or breed Neon Tetra in Indonesia

No	City	Province	Reference
1	Jakarta	Special Capital Region of Jakarta	Kontan.co.id 2009
	Bekasi	West Java	Kontan.co.id 2009
2	Bojong sari, Depok	West Java	Avianty et al. 2017; Anwar 2019
3	Parung, Bogor	West Java	Budiardi et al. 2008
4	Sawangan, Depok	West Java	Kontan.co.id 2009; Tsani 2016
5	Yogyakarta	Special Region of Yogyakarta	Kontan.co.id 2009
6	Kras District, Kediri	East Java	Pursetyo 2017
7	Bali	Bali	Kontan.co.id 2009

The presence of *Paracheirodon innesi* (Figure 35) in Indonesian waters was not found and its report across the globe was similarly deficient. Nonetheless, the ability of fish species to maintain herbivorous and detritivorous diets, such as that in neon tetra, had the potential to restructure ecosystem nutrient dynamics (Capps & Flecker 2013). Additionally, its shoaling behaviour might add to the invasiveness of the species. An experimental study showed that *Paracheirodon innesi* in smaller group size performed higher aggression and darting behaviour (Saxby et al. 2010).

Paracheirodon innesi was found to be mostly bred on the island of Java (Table 36). The occurrence of the species on the other Indonesian islands could not be found. Nonetheless, the importance of the species in ornamental trade to be utilised in the cosmetics was widely known among breeders in Java (Kontan.co.id 2009; Tsani 2016).

The limited occurrence of the species in Indonesia was thought to be of the suitable water condition for the breeding (Kontan.co.id 2009). Neon tetra required pH level of 5.0-7.0 (Froese & Pauly 2019), which was claimed to limit its breeding effort across Indonesia (Kontan.co.id).

5.3. *Poecilia reticulata* (Guppy)

Poecilia reticulata or Guppy (Figure 36) was found to be the only species among the other selected species in this study that was assessed as highly-risk fish species to be invasive in Indonesia. The species has been reported to be introduced in 61 different countries and had established in 45 countries where it was introduced including Indonesia bearing potential ecological effects to the country and listed as probably established in other 6 countries (Froese & Pauly 2019). Moreover, Deacon et al. (2011) reported that the worldwide distribution of the species was noticeably more comprehensive than previously described in the literature or any database.

Figure 36. The Guppy (*Poecilia reticulata*). Photo: J. Jensen, FishBase

The fish was recorded to be first introduced in Indonesia in 1920 of an unknown source of introduction (Umar & Sulaiman 2013). *Poecilia reticulata* was reported to be introduced to Indonesia as mosquito biological control agent (Mutmainah et al. 2017; Syafei 2017) intended to control the spread of mosquito-borne diseases such as malaria and dengue fever (Wargasasmita 2005; Mutmainah et al. 2017). Additionally,

unintentional release from floating net cages for aquaculture purposes was proposed to be the introduction route of the species to Lake Batur Bali (Sentosa & Wijaya 2012).

The risk of the species to enter natural water system in Indonesia is elevated by its wide-spread exploitations as a biocontrol agent, ornamental and cultured species. Substandard breeding systems and facilities such as floating net cages (Sentosa & Wijaya 2012), open pond and modified drainage (Hanny 2019) in Indonesia may also contribute to the species introduction to natural water bodies. Several studies on fish diversities have documented the presence of *Poecilia reticulata* across Indonesia, suggesting that the species have successfully thrived in Indonesian water bodies (Table 37).

Table 37. A summary of *Poecilia reticulata* (Guppy) presence across Indonesia

No	Locality	Province	Reference
1	Air hitam river, Pekanbaru	Riau	Firdaus et al. 2014
2	Tangun river, Pekanbaru	Riau	Usna et al. 2016
3	Angke-Kapuk Protected Forest, Penjaringan, North Jakarta	Special Capital Region of Jakarta	Wahyudewantoro 2015
4	Ciliwung River, Jakarta	Special Capital Region of Jakarta	Hadiaty 2011
5	Cisadane River, Jakarta	Special Capital Region of Jakarta	Hadiaty 2011
6	Mount Galunggung, Tasikmalaya	West Java	Haryono & Wahyudewantoro 2020
7	Rivers in Mount Halimun National Park, Bogor: Cisukawayana, Cimaja, Cibareno, Citaradje, Cisarua, Ciguyang, Ciminyak, Cimangeunteung, Cibeureum, Cidurian, Cilongok, Cikaniki, and Beunying.	West Java	Rachmatika 1998; Rachmatika &Wahyudewantoro 2006
8	Telaga Warna, Bogor	West Java	Sulistiono et al. 2010
9	Banjaran river, Purwokerto	Central Java	Prayitno & Rukayah 2019
10	Cikawung river, Cilacap	Central Java	Nuryanto et al. 2015
11	Gajah Putih river, Surakarta	Central Java	Panjaitan et al. 2016
12	Opak river	Special Region of Yogyakarta	Djumanto & Prabosunu 2011
13	Bureng river, Malang	East Java	Mahendra et al. unknown

Table 37. A summary of *Poecilia reticulata* (Guppy) presence across Indonesia (continued)

No	Locality	Province	Reference
14	Kalidami, Kenjeran, Kebonagung, Pegirian, Wonorejo, Darmo; Surabaya	East Java	Adro'i et al. 2018
15	Telaga Sari, Pasuruan	East Java	Rahayu et al. 2019
16	Batur lake, Bangli	Bali	Sentosa et al. 2011; Sentosa & Wijaya 2012
17	Beratan lake, Tabanan	Bali	Sentosa et al. 2011
18	Buyan lake, Buleleng	Bali	Pertami et al. 2020
19	Tamblingan lake, Buleleng	Bali	Parawangsa et al. 2019; Pertami et al. 2020
20	Bolano lake (Bolanosau)	Central Sulawesi	Herjayanto et al. 2019
21	Malili lakes drainage	South Sulawesi	Herder at al. 2012
22	Sahara river, Manokwari	West Papua	Manangkalangi 2020 (Personal communication)

The fish was also described as commonly found in West Java and Banten Indonesia and frequently found around agricultural area and villages (Rachmatika & Wahyudewantoro 2006). Even though no publication was found to demonstrate the presence of *Poecilia reticulata* in the eastern part of Indonesia, the species might occur in small rivers of Manokwari, West Papua (Figure 37). It was accidentally collected during fish sampling in Sahara river, Manokwari (Dr E. Manangkalangi, May 2020, personal communication). Consistent with the report by Rachmatika & Wahyudewantoro (2006), the species found in Sahara river was located in a highly-populated area surrounded by settlements, community gardens, farms, and shops located downstream (Irwan et al. 2017).

Presumably, *Poecilia reticulata* as introduced species prefered or at least thrived in an environment where the quality of the habitat has generally declined such as eroded riverbanks and river disturbed by sand mining (Rachmatika & Wahyudewantoro 2006). Casatti et al. (2006) described that the species showed higher abundance in more disturbed physical habitat conditions, illustrating the increase of richness with disturbance where species have been introduced. It is comparable to the condition of Sahara River in

Manokwari where the water quality was reported to exceed the water quality standard based on Indonesian Government Regulation No. 82 of 2001 (Irwan et al. 2017).

Figure 37. Plastic polluted small stream in Manokwari, West Papua. Likely habitat for *Poecilia reticulata*. Photo: Petr Zámečník.

Even though the species have been reported to occur across Indonesia, information about the population and the impact of the species on the local environment and Indonesian native species was limited. Nevertheless, *Poecilia reticulata* was reported to become invasive in the introduced area and displayed negative impacts such as contributing to the decline of native goodeid species in Mexico through heterospecific sexual harassment (Valero et al. 2008), and competed with or predated on native species and introduced unwanted parasites (Eldredge 2000; Kim et al. 2002).

Several factors that were described to contribute to the success of Guppy invasion were its reproductive strategy, behaviour, and resilience in broad environmental condition. A study by Reznick & Bryga (1987) described that the guppy population grew steadily after the introduction. Females of *Poecilia reticulata* were able to store sperm for future fertilisation and could produce young every four weeks (Froese & Pauly 2019). Moreover, Deacon (2010) reported that a single female of *Poecilia reticulata* had the potential to routinely establish a viable population which persisted in the experiment for at least 2 years. Thus, a single sexually mature female supplied by sperm can inhabit and invade the target area.

Sievers et al. (2012) studied the Guppy's grouping behaviour such as shoaling to avoid predator and mate choice that were thought to be important in the contribution of its invasiveness. Male Guppy was also reported to perform more aggressive mating effort towards a bigger sized female, even of different species (Valero et al. 2008). The aggressive mating behaviour towards other similar looking species is dangerous since the internal fertilisation performed by *Poecilia reticulata* could potentially cause cloacal damage of native species and disturb the reproductive ability of the native species.

The Guppy was well-known for its ability to live and successfully adapted in a wide range of environmental condition. Adro'i et al. (2018) presented the presence of various phenotypic characters of male Guppy inhabiting areas with different water quality, which was potentially caused by different nutrient content in the water. This suggested its excellent adaptability in the introduced area. Furthermore, it was capable of living in both brackish and freshwater (Froese & Pauly 2019), which was demonstrated by its presence in the mangrove forest, Angke-Kapuk Protected Forest (Wahyudewantoro 2015) and in Sahara river Manokwari (Dr E. Manangkalangi, May 2020, personal communication) where the river empties into the Gulf of Sawaibu Manokwari (Irwan et al. 2017). These excellent adaptabilities had indeed supported the high risk of the species to establish and become invasive in the introduced areas.

5.4. *Pterophyllum scalare* (Freshwater Angelfish)

Freshwater angelfish or *Pterophyllum scalare* (Figure 38) was assessed as a medium-risk species to become invasive in Indonesian water. Froese & Pauly (2019) reported that the species was probably established in Suriname and likewise introduced to Canada, Guyana, Israel, Spain, Philippines, and the United States of America. Furthermore, Mol et al. (2012) documented the presence of *P. scalare* in Suriname which may have been introduced accidentally into the Para River yet described as most certainly native to a tributary of Corantijn River.

The report of the species in Indonesian natural water bodies was not found. Nevertheless, angelfish *Pterophyllum scalare* was found to be widely bred and sold in Indonesia (Table 38), especially in the western part of the country. This study documented that Indonesia exported 19 strains of *Pterophyllum scalare* in the various price range. It

was sold for 0.2 USD – 5 USD, the most expensive strain was held by *P. scalare* in the market name “Bulgarian red chick”. Meanwhile, the “assorted”, “black”, and “tricolor angel” were sold at the price of 0.2 USD per fish.

Figure 38. Freshwater angelfish (*Pterophyllum scalare*). Photo: M. Landines, FishBase

Angelfish *Pterophyllum scalare* shared an important role in Indonesian ornamental trade. It was involved in a wide range of ornamental trade chain supply, from the small farmers, breeder, merchant middleman, retailer, and whole sellers (Ridwan 2005). Additionally, ornamental trade is a large source of income and supported by the government to increase the livelihood of small farmers in Indonesia (Gustiano et al. 2008; Karimah et al. 2012; Sutawijaya et al. 2013).

The widespread of the species among ornamental breeders and small farmers across the country (Table 38) is, therefore, concerning due to the probability of elevated risk of the spreading. Particularly the breeding technology used in the breeding of *Pterophyllum scalare* by small farmers. Despite that the fish was commonly bred in the recirculating facility and aquarium (Ridwan 2005; Siahaan 2013), several publications reported its breeding technique in concrete and traditional ponds (Ridwan 2005; Sutawijaya et al. 2013; Ekojono et al. 2018). These ponds were either rented (Sutawijaya et al. 2013) or owned and placed at home garden, dry land, or paddy fields (Ekojono et al. 2018). Moreover, the water source for ponds commonly came from natural and or artificial water bodies such as rivers, spring water, dams, or irrigation system (Subagyono et al 2010; Hasyimi 2014; Koten et al. 2015).

Even though reports on the species being present in the water systems in Indonesia was not found, the species might establish the population in wild. Additionally, the climate which was specified as temperature and rainfall was not limiting the species to survive in the wild. Moreover, parental care of angelfish *Pterophyllum scalare* (Froese & Pauly 2019) might enhance the survival rate of the species when established in the wild.

Table 38. Cities that sell or breed angelfish in Indonesia

No	City	Province	Reference
1	Pekanbaru	Riau	Adzhar et al. 2016
2	Jakarta	Special Capital Region of Jakarta	Karimah et al. 2012; Cahyanto et al. 2019
3	South Jakarta	Special Capital Region of Jakarta	Sutawijaya et al. 2013
4	Bogor	West Java	Cahyanto et al. 2019; Nuswantoro et al. 2019
5	Cibinong, Bogor	West Java	Siahaan 2013
6	Cilala Lake, Bogor	West Java	Patoka et al. 2016
7	Depok	West Java	Ridwan 2005; Satyani 2017
8	Semarang	Central Java	Andriadhi et al. 2016
9	Kediri	East Java	Weningsari 2013
10	Makassar	South Sulawesi	Asrul & Hidayatullah 2018

The potential spread of the species posed another risk, spreading of pathogens not only to the wildlife and native species of Indonesia, but also to the pet industry, fishes in trade, and other species including human (Smith et al. 2012). Animal movements and trade had been already reported as a possible introduction pathway for pathogens and diseases to a new area (Evans & Lester 2001; Travis et al. 2011; Mrugala et al. 2015). Siahaan (2013) documented the presence of nematode *Camallanus* in *Pterophyllum scalare* which was taken from raiser in Cibinong, Bogor, West Java. Furthermore, aquarium trade from Indonesia was also reported to introduce *Camallanus cotti* to Korea (Kim et al. 2002).

6. Conclusions

This research aimed to provide a list of freshwater and marine ornamental species traded from Indonesia, identify the potential high-risk fish on selected species and the threats to endemic species. Based on the data collected from the Indonesian exporters, it can be concluded that 72% of the Indonesian ornamental industry consisted of the species in class Actinopterygii. As expected, the result indicated a higher number of species in marine ornamental species than in freshwater species. Nonetheless, the total number of the species might be underestimated since lots of species were identified merely to its genus level.

Many non-native and endangered species were documented to be exported from Indonesia. The selected species *Poecilia reticulata* was evaluated as a high-risk species and has established in Indonesian water. Meanwhile, *Betta splendens*, *Paracheirodon innesi*, and *Pterophyllum scalare* were assessed to be of medium-risk species to Indonesia. Nonetheless, all species were found to be farmed as ornamental species across Indonesia. Two species, *Betta splendens* and *Poecilia reticulata* were intentionally released to nature as a biocontrol agent.

Based on these conclusions, the responsible authorities should consider utilising native Indonesian species as biocontrol. Thus, preventing the potential establishment of non-native species which has the potential to cause detrimental effects to the environment and the Indonesian native species. Concerning the trade of endemic and endangered species, eco-certification should also be acknowledged. Hence, the sustainability of the industry can be cherished.

In short, this research has contributed to the knowledge of marine and freshwater species traded as ornamental species from one of the biggest exporting country in the world. The results can be used as a basis on further researches such as the endemic species that had entered the ornamental industry yet not evaluated its conservation status, trading policy on endangered species, and further risk assessment of non-native species that present in the country.

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Appendices

(only on the electronic version of the thesis)

List of the Appendices:

Appendix I: List of the Freshwater Ornamental Species

Appendix II: List of the Marine Ornamental Species