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NATIVE, NON-NATIVE AND INVASIVE SPECIES OF ORNAMENTAL FISH TRADED IN KUPANG, EAST NUSA TENGGARA

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Abstract

Inter-country sales of ornamental fishes are one of the ways non-native and invasive fishes enter an aquatic ecosystem. This contributes greatly to the distribution and abundance of native fishes in the aquatic ecosystem. The aim of this study is to collect and identify quantitative baseline data on some information of ornamental fish species sold in ornamental fish shops in Kupang City. Results showed that there were 46 species recorded during the study and only 20% (n=9) of the species were native Indonesian species and 80% (n=36) of the species were non-native (1 hybrid species). In addition, it was recorded that 7% (n=3) of the total fish sold in Kupang City were invasive species. The invasive species were Carassius auratus, Xiphophorus helleri and Poecilia reticulata. These three species are included in the 80% non-native species.

Keywords: *Native and non-native species; Invasive species; Ornamental fish; Kupang; NTT*

Introduction

As a worldwide hobby, fishkeeping is favored by young and old alike [1]. Apart from being a hobby, keeping fish can also contribute to improving human welfare. One of the commodities that contribute to improving human welfare is ornamental fish. Selling ornamental fish is one of the most popular businesses that people engage in [2]. The beauty of the color and body shape is the reason ornamental fish are extensively kept [3]. The beautiful colors and unique body shapes make ornamental fish, mostly marketed as lives, popular both nationally and internationally [4]. The import of live aquarium species [5] has been going on for more than a century [6] and is one of the main potential vectors for the introduction of non-native aquatic species [7-10] into certain waters, including Indonesian waters, the introduction of non-native species into an ecosystem always has the potential to pose ecological risks [1, 11]. Resource competition, predation, hybridization, habitat modification, disease transmission (infection or

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parasitism) and genetic effects are impacts that often occur due to the presence of non-native fish [12]. With these impacts, Indonesia, with the second-highest freshwater fish biodiversity in the world [13] can decline due to the presence of non-native fish or invasive species.

Invasive species are defined as alien species (or introduced or non-native species) [14] that are considered the second leading cause of species extinction in the world [15], including in Indonesia [16, 17]. The ornamental fish trade is one of the causes of invasive fish entering Indonesia [18], including Kupang City. Kupang is one of the major provincial cities that trades ornamental fish, both freshwater and seawater ornamental fish [19]. Some ornamental fish shops operate in Kupang City and sell various types of freshwater and marine ornamental fish, including several types of ornamental fish native to Indonesia and several types of ornamental fish from abroad [19]. Identification of native, non-native and invasive ornamental fish species is important in Kupang City as basic information for the community, businesses and the government. The identification of potentially invasive non-native species, both now and in the future, is critical to inform stakeholders and environmental managers of the associated risks [20].

This research aims to assemble and identify quantitative baseline data on several ornamental fish species sold in ornamental fish shops in Kupang City. The data includes fish identification (order, family, genus, species), native and non-native species, native distribution areas and invasive species. This data is expected to contribute information to prevent the introduction of non-native ornamental fish species into the wild.

Materials and methods

Study area

Kupang City, East Nusa Tenggara, was the selected area for the research. The research was conducted from August to September 2023. There were 11 ornamental fish shops in Kupang City that were observed during the research. The shops are divided into several sub-districts, such as the Kelapa Lima sub-district, the Oebobo sub-district, the Kota Lama sub-district, the Kota Raja sub-district and the Maulafa sub-district.

Collecting data

The study was performed by using survey and observation methods. During surveys, forms were set up to conduct interviews and for observations, photographs of fish specimens were taken. Photos of fish samples were taken with an 8-megapixel camera. The photo results could show the actual color of the fish and the color scheme of the fish so that it could be easily identified.

Data analysis

Fish identity data collected previously were categorized into Microsoft Excel and then were analyzed using Catalogue of Life, 2024 [21], Encyclopedia of Life (EOL), 2024 [22] and Global Biodiversity Information Facility (GBIF), 2024 [23], to acquire the whole identity of the fish, including order, family, genus, species (scientific title) and general name. Furthermore, the analysis was also conducted by adjusting fish features such as body color and body shape by contrasting photographs of fishes collected during data acquisition in the field with data in Froese and Pauly, 2024 [24] and Eschmeyer's Catalogue of Fishes, 2024 [25]. The classification process was modeled based on Froese and Pauly, 2024 [24], while invasive species were classified using data recorded from the Global Invasive Species Database (GISD) 2024 [26].

All data gathered will be presented in the form of tables, bar charts or pie charts. Fish identity (ordo, family, genus, scientific name and common name), native or non-native species and invasive species data will be presented in tabular form. The bars provide data on the number of families in all orders, the total number of species in each family and the total number of species in each natural distribution. Natural habitat, basic climatic zone, native range and conservation status will be presented as pie charts.

Results

The 11 fish shop sites surveyed in Kupang City can be seen in figure 1.

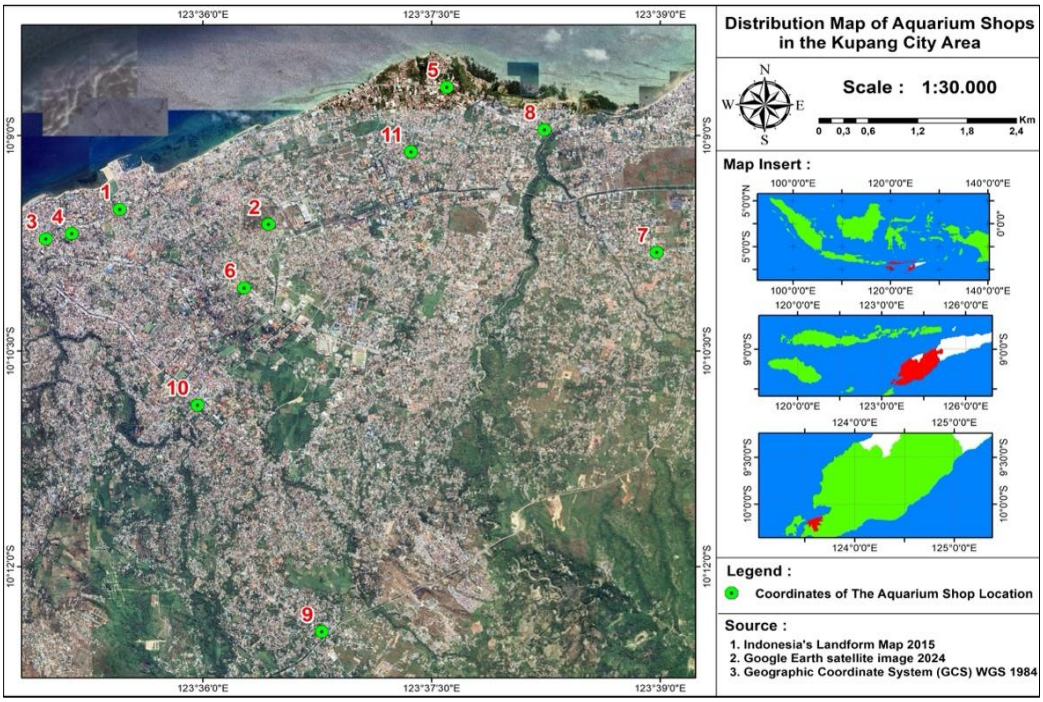

Fig. 1. The location of the fish shop that has been determined to collect data

Species checklist (ordo, family, genus and species)

Based on the study data, 46 species of ornamental fish were recorded, which were divided into 11 orders, 18 families and 39 genera (Table 1). One species was a hybrid species (*Amphilophus citrinellus* x *Cichlasoma trimaculatum*) and the genus is unclassifiable. From the 46 species recorded, 37 (80%) species live in freshwater, 3 (7%) species live in marine waters and 6 (13%) species live in fresh to brackish waters (Fig. 2).

Table 1. Species diversity (Fish identity) of ornamental fish that sold in Kupang City

Order	Family	Genus	Scientific name	Common name	Habitat	Native/ Non-Native
Characiformes	Characidae	*Gymnocorymbus*	*Gymnocorymbus ternetzi* (Boulenger, 1895)	Black tetra	F	NN
		Hyphessobrycon	*Hyphessobrycon eques* (Steindachner, 1882)	Jewel tetra	F	NN
		Moenkhausia	*Moenkhausia sanctaefilomenae* (Steindachner, 1907)	Red eye tetra	F	NN
		Paracheirodon	*Paracheirodon axelrodi* (Schultz, 1956)	Cardinal tetra	F	NN
		Paracheirodon	*Paracheirodon innesi* (Myers, 1936)	Neon tetra	F	NN
	Serrasalmidae	*Myloplus*	*Myloplus schomburgkii* (Jardine, 1841)	Disk tetra	F	NN
Cypriniformes	Catostomidae	*Myxocyprinus*	*Myxocyprinus asiaticus* (Bleeker, 1864)	Chinese sucker	F	NN
	Cyprinidae	*Barbonymus*	*Barbonymus schwanefeldii* (Bleeker, 1854)	Tinfoil barb	F	N
		Carassius	*Carassius auratus* (Linnaeus, 1758)	Goldfish	FB	NN

Order	Family	Genus	Scientific name	Common name	Habitat	Native/ Non-Native
		Cyprinus	*Cyprinus rubrofuscus* (Lacepède, 1803)	Koi	FB	NN
		Epalzeorhynchos	*Epalzeorhynchos frenatum* (Fowler, 1934)	Rainbow sharkminnow	F	NN
		Pethia	*Pethia conchonius* (Hamilton, 1822)	Rosy barb	F	NN
		Puntigrus	*Puntigrus tetrazona* (Bleeker, 1855)	Sumatra barb	F	N
		Dawkinsia	*Sahyadria denisonii* (Day, 1865)	Denison barb	F	NN
	Danionidae	*Boraras*	*Boraras maculatus* (Duncker, 1904)	Dwarf rasbora	F	N
		Danio	*Danio rerio* (Hamilton, 1822)	Zebra danio	F	NN
		Trigonostigma	*Trigonostigma heteromorpha* (Duncker, 1904)	Harlequin rasbora	F	N
	Gyrinocheilidae	*Gyrinocheilus*	*Gyrinocheilus aymonieri* (Tirant, 1883)	Siamese algae-eater	F	NN
Cyprinodontiformes	Poeciliidae	*Poecilia*	*Poecilia latipinna* (Lesueur, 1821)	Sailfin molly	FB	NN
		Poecilia	*Poecilia reticulata* (Peters, 1859)	Guppy	FB	NN
		Poecilia	*Poecilia sphenops* (Valenciennes, 1846)	Molly	FB	NN
		Xiphophorus	*Xiphophorus hellerii* (Heckel, 1848)	Green swordtail	FB	NN
		Xiphophorus	*Xiphophorus variatus* (Meek, 1904)	Variable platyfish	F	NN
Gymnotiformes	Apteronotidae	*Apteronotus*	*Apteronotus albifrons* (Linnaeus, 1766)	Black ghost	F	NN
Osteoglossiformes	Osteoglossidae	*Osteoglossum*	*Osteoglossum bicirrhosum* (Cuvier, 1829)	Arawana	F	NN
		Scleropages	*Scleropages formosus* (Müller & Schlegel, 1840)	Asian bonytongue	F	N
Acanthuriformes	Acanthuridae	*Paracanthurus*	*Paracanthurus hepatus* (Linnaeus, 1766)	Palette surgeonfish	M	N
	Lobitidae	*Datnioides*	*Datnioides microlepis* (Bleeker, 1854)	Finescale tigerfish	F	N
Anabantiformes	Channidae	*Channa*	*Channa marulioides* (Bleeker, 1851)	Orange snakehead	F	N
	Osphronemidae	*Betta*	*Betta splendens* (Regan, 1910)	Siamese fighting fish	F	NN
		Trichogaster	*Trichogaster lalius* (Hamilton, 1822)	Dwarf gourami	F	NN
Cichliformes	Cichlidae	-	*Amphilophus citrinellus x Cichlasoma trimaculatum* (Hybrid)	Louhan	F	NN
		Astronotus	*Astronotus ocellatus* (Agassiz, 1831)	Oscar	F	NN
		Chindongo	*Chindongo demasoni* (Konings, 1994)	Demasoni	F	NN
		Chindongo	*Pseudotropheus Socolofi* (Johnson, 1974)	Pindani	F	NN
		Cyphotilapia	*Cyphotilapia frontosa* (Boulenger, 1906)	Humphead cichlid	F	NN
		Heterotilapia	*Heterotilapia buettikoferi* (Hubrecht, 1881)	Zebra tilapia	F	NN
		Labidochromis	*Labidochromis caeruleus* (Fryer,1956)	Blue streak hap	F	NN
		Melanochromis	*Melanochromis auratus* (Boulenger, 1897)	Golden mbuna	F	NN
		Pterophyllum	*Pterophyllum scalare* (Schultze, 1823)	Freshwater angelfish	F	NN
		Symphysodon	*Symphysodon discus* (Heckel, 1840)	Red discus	F	NN
Siluriformes	Pangasiidae	*Pangasianodon*	*Pangasianodon hypophthalmus* (Sauvage, 1878)	Striped catfish & Striped catfish albino	F	NN
	Mochokidae	*Synodontis*	*Synodontis eupterus* (Boulenger, 1901)	Featherfin squeaker	F	NN
Ovalenteria	Pomacentridae	*Amphiprion*	*Amphiprion ocellaris* (Cuvier, 1830)	Clown anemonefish	M	NN
		Amphiprion	*Amphiprion percula* (Lacepède, 1802)	Orange clownfish	M	N
Polypteriformes	Polypteridae	*Polypterus*	*Polypterus Endlicheri* (Heckel, 1847)	Palmas & Palmas albino	F	NN

Note: F = Freshwater, FB = Freshwater Brackish M = Marine, N = Native, NN = Non-Native

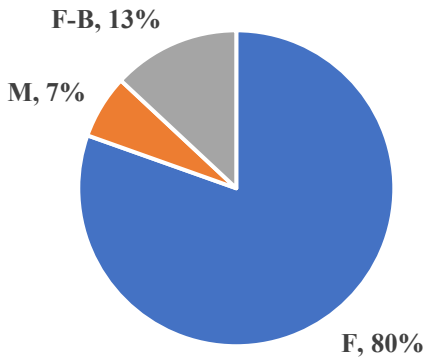

Fig 2. Number of species traded in fish shops in Kupang City according to their natural environment (F = Freshwater; M = Marine; F-B = Freshwater Brackish)

The orders found were *Anabantiformes*, *Acanthuriformes*, *Cichliformes*, *Characiformes*, *Cypriniformes*, *Cyprinodontiformes*, *Gymnotiformes*, *Osteoglossiformes*, *Polypteriformes*, *Siluriformes* and *Ovalenteria* (Fig. 3). From the total 46 species recorded, the majority belonged to the orders *Cypriniformes* (26%, n = 12), followed by *Cichliformes* (22%, n = 10), *Characiformes* (13%, n = 6) and *Anabantiformes* (7%, n = 3), *Acanthuriformes*, *Osteoglossiformes*, *Ovanlenteria* and *Siluriformes* (4%, n = 2), while *Gymnotiformes* and *Polypteriformes* (2%, n = 1).

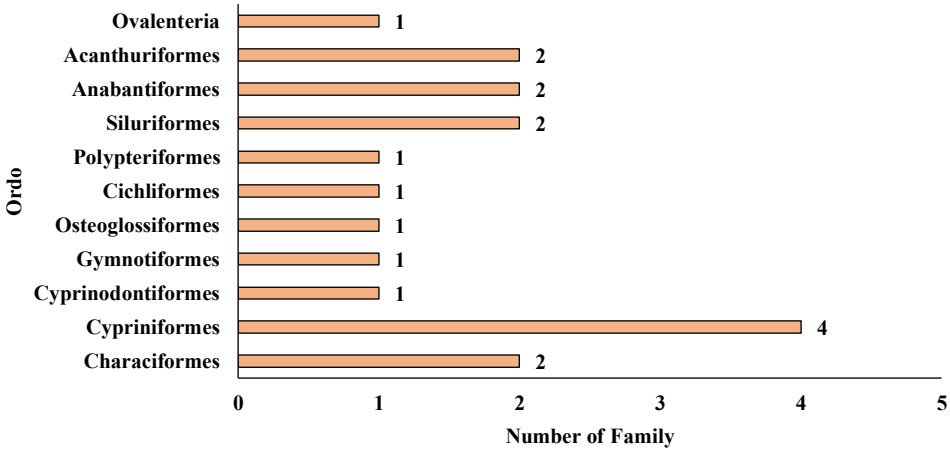

Fig 3. Number of family in each ordo

Families listed during the study were *Acanthuridae*, *Apteronotidae*, *Catostomidae*, *Channidae*, *Characidae*, *Cichlidae*, *Cyprinidae*, *Danionidae*, *Gyrinocheilidae*, *Lobitidae*, *Mochokidae*, *Osphronemidae*, *Osteoglossidae*, *Pangasiidae*, *Poeciliidae*, *Polypteridae*, *Pomacentridae* and *Serrasalmidae* (Fig. 4). In terms of family, most species belonged to the family *Cichlidae* (22%, n = 10), which is the only family in the order *Cichliformes*. The second position was taken by the family *Cyprinidae* (15%, n = 7), which is one of the families of the order *Cypriniformes*. The third position was occupied by the *Characidae* (11%, n = 5) and

Poecilidae (11%, n = 5) families. Both families are from different orders, namely *Characiformes* (*Characidae*) and *Cyprinodontiformes* (*Poecilidae*).

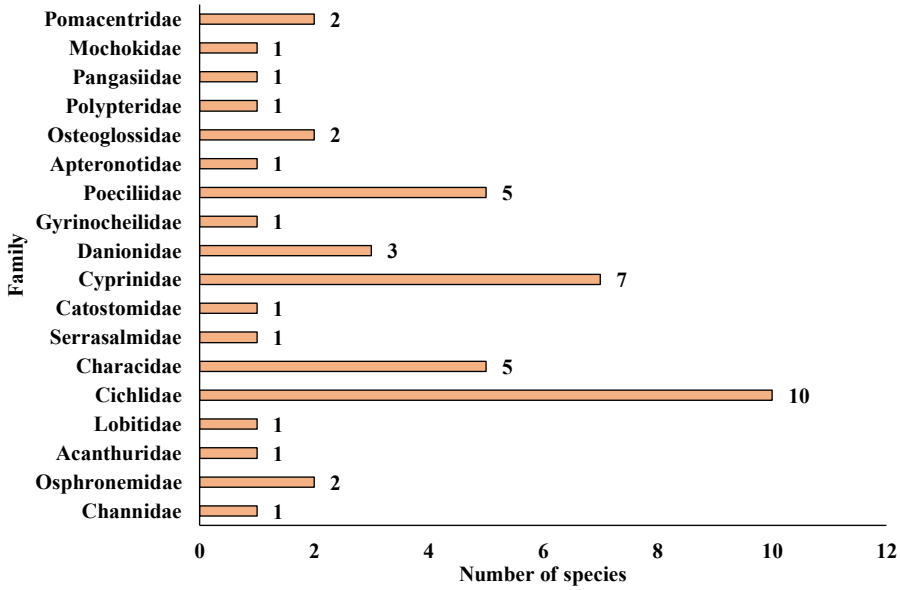

Fig. 4. Number of species in each family

For the genus recorded were *Paracheirodon*, *Gymnocorymbus*, *Moenkhausia*, *Hyphessobrycon*, *Myloplus*, *Myxocyprinus*, *Barbonymus*, *Epalzeorhynchos*, *Cyprinus*, *Carassius*, *Puntigrus*, *Pethia*, *Dawkinsia*, *Danio*, *Trigonostigma*, *Boraras*, *Gyrinocheilus*, *Xiphophorus*, *Poecilia*, *Apteronotus*, *Osteoglossum*, *Scleropages*, *Melanochromis*, *Pterophyllum*, *Astronotus*, *Heterotilapia*, *Labidochromis*, *Cyphotilapia*, *Chindongo*, *Symphysodon*, *Channa*, *Trichogaster*, *Betta*, *Paracanthurus*, *Datnioides*, *Amphiprion*, *Polypterus*, *Pangasianodon* and *Synodontis*. The most abundant species were from the *Poecilia genus*, with 7% (n = 3), followed by the *Paracheirodon*, *Xiphophorus*, *Chindongo* and Amphiprion genus with 2% (n = 2) and the others with 1% (n = 1).

Checklist: native, non-native, native range and invasive species

Based on the data collected, only 20% (n = 9) of the species are native to Indonesia and 80% (n=36) of the species are non-native (excluding 1 hybrid species). Based on the record of native species, 7 species are freshwater species and 2 species are marine water species. The species native to Indonesia are *Barbonymus schwanefeldii*, *Puntigrus tetrazona*, *Trigonostigma heteromorpha*, *Boraras maculatus*, *Scleropages formosus*, *Channa marulioides*, *Datnioides microlepis*, *Paracanthurus hepatus* and *Amphiprion percula*.

Furthermore, from the total of 80% non-native species sold in ornamental fish shops in Kupang City, 43% (n = 11) of fish species were from Asia, 29% (n = 12) were from South America, 19% (n=8) were from Africa, 5% (n = 2) were from North America and the remaining 2% (n = 1) were from North-Central America, the Indo-West Pacific and Central and North America (Figs. 5 and 6).

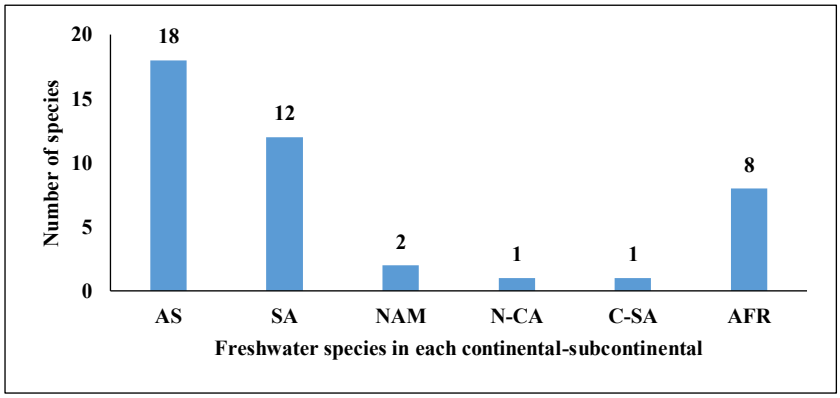

Fig 5. Native distributional range of freshwater ornamental fish species recorded in fish shops in Kupang City

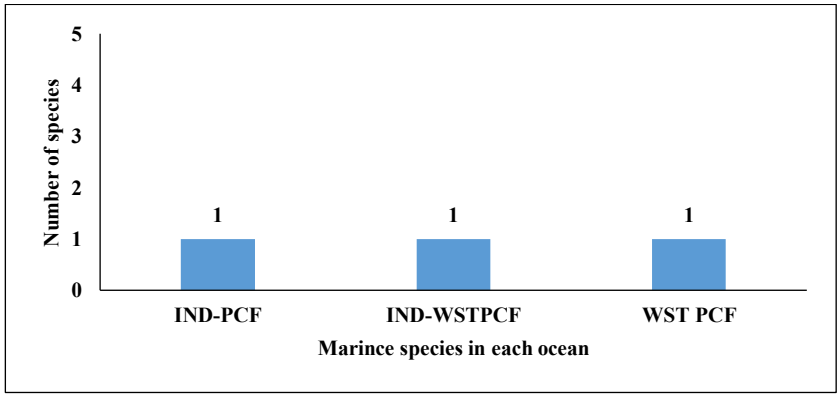

Fig 6. Native distributional range of marine ornamental fish species recorded in fish shops in Kupang City

On the other hand, based on information on the Global Invasive Species Database (GISD) 2024 page, it was stated that 7% (n = 3) of all fish sold in Kupang City were invasive species. These invasive species include *Carassius auratus*, *Xiphophorus helleri* and *Poecilia reticulata*. These three species are included in the 80% non-native species or alien species. Invasive fish species traded in ornamental fish shops in Kupang City can be seen in Table 2.

Table 2. Invasive ornamental fishes traded in Kupang City

Scientific name	Common name	Native to	Possible Impact
Carassius auratus (Linnaeus, 1758)	Goldfish	Asia (East Asia)	Stimulate Cynobacterial growth, algal blooms, increasing turbidity, depleting aquatic vegetation and eating eggs, larvae and adult native fishes [26, 27]
Xiphophorus hellerii (Heckel, 1848)	Green swordtail	North-Central America	Resource competition, fin nipping, aggressive nature and tadpole predation [10]
Poecilia reticulata (Peters, 1859)	Guppy	South America	Resource competition, egg predation, larval predation and spread of pathogens[10], which may effect native fish population [28]

Discussion

The number of total registered ornamental fish species, both freshwater ornamental fish and sea ornamental fish, found during the study was less than the number of ornamental fish species present in Surakarta City, Central Java and Bandung City, West Java, with a total number of species of 77 [3] and 55 species [29], respectively. The low diversity of ornamental fish species in Kupang City is probably related to the high interest of buyers in certain ornamental fish species that affect the number of species diversity sold in Kupang City. In addition to this, it is likely that there are several species of ornamental fish that had been sold out before the survey was carried out, so it is likely that certain species were not recorded during this study.

With a total of 46 species recorded, most of the species found were tropical species and these results are similar to previous studies [1, 6]. In addition to Indonesia's tropical climate (including Kupang City) and the high interest of buyers in certain species, the abundance of tropical species during the study is suspected to be due to the fact that ornamental fish species originating from the region are more likely to survive and breed, at least in a controlled environment [1]. The tropical species being sold in ornamental fish shops in Kupang City come from Asia, South America, North America, North-Central America, Central and South America, Africa, the Indo-Pacific, the Indo-West Pacific and the Western Pacific. Most of them originate from Asia, followed by South America and then Africa. One of the tropical species from Asia that is most commonly found in ornamental fish shops in Kupang city is *Danio rerio* [19].

Zebrafish (*Danio rerio*) is a tropical freshwater teleostei, which belongs to the *Cyprinidae family* [30]. In Asian countries, *Cyprinidae* is a very important family in the fishing industry [31]; this family is a freshwater fish family that has the highest diversity, morphological and behavioral traits and habitat requirements [32]. In addition to *Danio rerio*, there are two introduced species from the *Cyprinidae family* that are well developed in Indonesia, namely *Cyprinus rubrofuscus* and *Carissius auratus* [33]. However, *Cyprinus rubrofuscus* is a rapidly growing freshwater ornamental fish in Indonesia due to its high value and relatively stable price volatility in the international market [34]. This indicates that koi is one of the most popular ornamental fish species of the *Cyprinidae family*, so it can be found in most ornamental fish shops in Kupang City [19], as well as *Carissius auratus*.

Carissius auratus is a type of goldfish developed in America around the 19th century [35] and this fish is popular among ornamental fish hobbyists because of its attractive color and body style and can be kept in ponds and aquariums [36]. Although this fish is one of the most popular fish for ornamental fish hobbyists, it is also one of the fish species listed as invasive on the Global Invasive Species Database (GISD) website, along with *Xiphophorus helleri* and *Poecillia reticulata*, listed in this study. *Carissius auratus* or commonly known as goldfish, has been recorded as an introduced species in several public waters in Indonesia, such as in West Java [37, 38], but for public waters in NTT or Timor Island itself, there have been no reports of the presence of this species. According to [27] listed in the Global Invasive Species Database (GISD) page, 2024, that *Carissius auratus* can stimulate the growth of cyanobacteria through its digestive tract and also cause algae blooms through its eating habits, which is bottom-sucking feeding that scrambles the bottom of the waters so that eutrophication occurs, which ultimately causes algae blooms. In addition, the presence of this species can be a challenge to native species in terms of utilization of available resources [39].

The next invasive species are *Xiphophorus helleri* and *Poecilia reticulata,* which are both species from the *Poeciliidae family*. *Xiphophorus helleri* is the only North-Central American species recorded in this study. *Poecilia reticulata* is one of the 12 species from South America. Both species are highly productive [24], fast-growing and highly adaptable to different environments [40, 41]. Some literature has mentioned that *Xiphophorus helleri* has invasive potential and ecological impacts [42-45]. However, it doesn't define it clearly and the mechanism is not defined specifically [43, 46]. This species can be considered invasive when in large

numbers and in flocks with other poecilid species (*Gambusia*, *Poecilia* or *Xiphpophorus spp.*) [42, 47-50]. Although its presence has been recorded in several public waters in Indonesia [38, 51-53], just like *Carissius auratus*, this species has not been recorded in public waters in NTT, especially the island of Timor. Of these three species, only *Poecilia reticulata* has been found in public waters in Timor Island, NTT [54, 55]. It is suspected that this species was introduced before the study was conducted.

In addition to freshwater in the island of Timor, *Poecilia reticulata* has been introduced in several rivers in Indonesia, such as the Cisadane River [52], White Elephant River, Central Java [56], Belimbing River, East Lombok [53], Ranggeh River and Batang Air West Sumatra [57], Bedadung River, Jember [58], Lake Batur, Bali [38], Code River, Bantul, Yogyakarta [59] and Ciliwung River, DKI Jakarta [60]. Generally, *Poecilia reticulata* was introduced to public waters as a biological agent or predator of mosquito larvae [24, 26] before finally becoming one of the ornamental freshwater fish species that have high selling value in Indonesia [61]. The rapid development of the ornamental fish market in Kupang City is also thought to be an entry point for this species to be continuously introduced into fresh public waters and this could be a major problem for native or endemic fishes in fresh public waters on Timor Island, more specifically in the rivers in Kupang City. This species has also been recorded as a possible parasite carrier that can affect native species populations [28] in a water body and also act as an intermediate host and transmission vector for trematode parasites, posing threats to human health [62, 63].

The introduction of non-native species has been done both intentionally and unintentionally, but some of the introduced species have positive and negative impacts [64]. The presence of these three ornamental fish species in fresh public waters should be of special concern and high priority, considering the impact of each species is different, so it is necessary to implement urgent conservation measures to prevent the decline of native and endemic fish populations. One of the endemic species of the island of Timor [54] with critical endangered status [65], which is likely to be affected by the presence of these fish, is *Oryzias timorensis*. Initial efforts that can be made by the government are to forbid or not restock non-native fish in public waters. Furthermore, conducting routine research on the diversity of freshwater fish species in several rivers in NTT. This is a very important effort; in addition to updating data on the diversity of freshwater fish species, the research can confirm the number of native and non-native fish that are still present in the river waters. The results of routine research conducted will be a very important point to strengthen government policies in conservation efforts. The intended conservation effort is to make efforts to reproduce endemic freshwater fish species through fairy cultivation activities. If these efforts are successful, the following thing that can be done is restocking the cultured endemic fish into public waters to increase the population of these fish in public waters.

Conclusions

Based on the research data, 46 species of ornamental fishes were collected, divided into 11 orders, 18 families and 39 genera. From the 46 species recorded, only 20% (n = 9) are native species of Indonesia and 80% (n = 36) are non-native (excluding 1 hybrid species). The results of this study also recorded the existence of invasive species traded in Kupang. The invasive species are *Carassius auratus*, *Xiphophorus helleri* and *Poecilia reticulata*. These three species are classified as 80% non-native species.

The management of invasive, native, and non-native fish species must be carried out in an integrated approach through ongoing scientific research and targeted dissemination of information. These efforts include mapping distribution, analyzing ecological impacts, developing environmentally friendly control methods, and monitoring the potential for non-native species to become invasive. By integrating research findings into policy and raising public

awareness, we can prevent threats to biodiversity and ensure the sustainability of aquatic ecosystems for future generations.

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