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Non-native species existence and its potency to be invasive species on freshwater ecosystem in East Java Province, Indonesia

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ABSTRACT

The introduction of non-native species that have been carried out so far has raised several diverse opinions about the resulting impacts, either positive or negative. As one of the leading commodities in aquaculture, the significant impact of the culture of common carp species (*Cyprinus carpio*) has been felt by the community. That kind of fish has dominated for both consumption and ornamental fish production in East Java. This type of fish is considered equivalent to other native fish in this region, such as tawes (*Puntius javanicus*), catfish (*Clarias batracus*), and gourami (*Ospronemus gouramy*). However, the problem is if the non-native fish become invasive species in the open waters. When the spread of the non-native fish is out of control, it is feared will break down the food chain and community structure of other native fishes. As *Arapaima gigas*, the carnivore fish that are not native fish of Indonesia, which have found along the Brantas River, East Java, Indonesia. Rigorous precautions and regulations are needed so that introduced species become species that do not endanger their new habitat by considering ecological, economic, and other impacts. The study of genetic diversity and native species is essential to be done so that the database baseline is accurate and valid.

1. INTRODUCTION

Various human activities in fulfilling their lives have naturally damaged the barrier of the freshwater fish distribution, caused the geographical limitation, which is no longer a restraint in the spread of a species in the waters **(Su *et al.*, 2016)**. Meeting the need for food and protein sources is the main reason for introducing and moving a particular species to be developed in other areas that are considered to have a typical habitat through aquaculture activities **(Syafei & Sudinno, 2018)**. In addition to these objectives, some fish introductions are carried out to fulfill hobbies, recreation as well as for other economic reasons which have generally taken place in many parts of the world **(Kiruba-Sankar *et al.*, 2018)**. With the diversity of species introduced in an area, ultimately makes it unclear as to which boundaries are native and non-native species. It

becomes more complicated when the non-native species that are introduced can adapt and develop so that like native species, they even considered not to harm their new environment.

Non-native species, generally very similar to native species, have the potential to be fish that can be beneficial, dangerous, or can be neglected. Of the three things, when the non-native species cause some negative impacts, this species is only considered as an invasive. In other words, invasive species are non-native species that have the potential for adverse effects on the environment or have consequences that are not liked by humans and are considered dangerous. These effects can be categorized in three main ways, namely, economically harmful, posing a threat to human health, and having potentially destructive potential in ecological views **(Kiruba-Sankar *et al.*, 2018)**.

The introduction of a species will not directly become an invasive species but will undergo several stages **(Fig. 1)**. The stage will vary depending on various factors that support the entire life cycle of the new species **(Kiruba-Sankar *et al.*, 2018)**. The first stage of the process of changing the status of a species is the process of arrival in a new habitat area. This stage is better known as the introduction, which is the process of inserting a new species into an area with habitats that have similar or almost the same for a particular purpose, either intentional or unintentional **(Minchin *et al.*, 2013)**. If at this stage, the species already has the potential to be invasive, then the process of overcoming it is straightforward by refusing or preventing the species from entering an area.

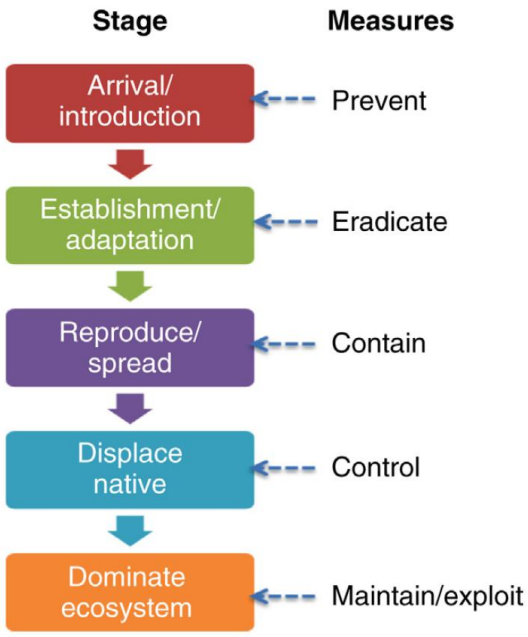

Figure 1. Stages of biological invasion **(Kiruba-Sankar *et al.*, 2018**)

The second stage is the adaptation process. A good adaptation process allows non-native species to live in new environments. This stage is characterized by the organism being able to live and show normal behavior without any symptoms of stress or the emergence of disease. Characteristics of species that are likely to become invasive; these

organisms can live in extreme environments **(McMahon, 2002)**. This situation will support non-native species able to explore and colonize in a new environment **(Kinnison *et al.*, 2008, Phillips *et al.*, 2006)**. If this stage happened and became an invasive species, and eradication can be carried out using chemicals or physically adapted to existing conditions. This extermination process is still possible because the introduced species are still under intensive supervision.

After being able to go through an adaptation process that is usually quite long time, the next stage is being able to reproduce in a new environment or habitat **(Kiruba-Sankar *et al.*, 2018)**. This stage shows that the level of adaptation has passed, and the species can produce offspring, even though they live in habitats that are dissimilar to their original habitat. With the process of reproduction, which may be faster or the same as native species, this allows non-native species to be able to replace the diversity of native species in nature. And, at the last stage in this process, non-native species are ready to dominate an ecosystem and can shift the abundance of native species. The characteristics of invasive species include as superior in genetic variability, lapidary on reproduction time, natural mechanisms for prompt dispersal, commensal with humans, and advanced of recruitment **(Ricciardi & Rasmussen, 1998)**. With these characteristics, it is possible to dominate in a short time. At this stage, controlling invasive species becomes very expensive and very difficult because it has taken many roles in these habitats that may be a source of animal protein for humans or have high economic value as ornamental fish. Some methods make a gradual reduction by doing genetic foundations that produce sterile (triploid) species. This species is expected to reduce the proportion of males and females in nature and reduce population growth. These infertile individuals are referred to as Trojan Y **(Thresher *et al.*, 2014)**.

2. TYPES OF FISH INTRODUCED IN INDONESIA

The existence of introduced fish in Indonesia has become a demand facilitated by the government in the development of aquaculture that was carried out before the 1900s **(Umar & Sulaiman, 2013)**. Introduced fish that are well known to the people of Indonesia are mujair (*Oreochromis mossambicus*) and Nile tilapia (*Oreochromis niloticus*) **(Wargasasmita, 2017)**. These two species of cichlid fish have high adaptability and can reproduce with short enough cycles so that shortly, the population of these species in nature is quite high. In the Philippines, these two species are also reported to be a threat to displace native species, for example against mullet fish (*Mugil cephalus*) and milkfish (*Chanos chanos*) which began to decline in their natural habitat with the introduction of this introduced species **(Bartley *et al.*, 2000)**.

The introduction of several fish species took place in the Dutch East Indies (1930-1940s) with more than 19 fish species **(Umar & Sulaiman, 2013)**. Before 1900, common carp had entered Indonesia with trade with Chinese traders during that time. Other species were also introduced from China, such as nilem fish, rainbow trout, and sepat fish **(Welcomme, 1988)**.

The introduction that has ever been done in Indonesia is more directed at increasing the amount of production and fulfillment of animal protein from the results of increased production of aquaculture activities. Although the purpose of the introduction is not only as an effort to diversify potential aquaculture commodities, it also has quite

extensive functions such as the recovery of endangered and endemic species populations, increasing fish meat production as a food supply, economic development interests and for ecological purposes such as biological pest control **(Kerr & Grant, 2000** and **Dabbadie & Lazard, 2010)**.

Almost all types of fish that are introduced are mostly consumption fish, while only a small group of ornamental fish such as Guppy (*Poecilia reticulate*) and Goldfish (*Carassius auratus*) **(Table, 1)**. From the list, not all types of fish introduced were successful in aquaculture activities. Many species such as *Cyprinus carpio, Osteochilus hasseltii*, *Channa striata*, *Osphronemus goramy*, *Clarias gariepinus*, *Helostoma temminckii*, and *Oreochromis niloticus* have been successfully cultivated **(Nugroho *et al.*, 2012)**. The fish has reasonably good adaptability so that it shows a high level of success even today being a common fish that is spread in Indonesia. While other types of introduced fish that are unable to adapt are salmon and rainbow trout. Both of these fish do not show good adaptation in the tropical environment of Indonesia (Papua), which is significantly different from their natural habitat in the Netherlands **(Umar & Sulaiman, 2013)**. However, in Papua it is reported that it has reasonably high endemic in freshwater fish species **(Kadarusman *et al.*, 2012)**, which should be maintained by germplasm.

3. FISH INTRODUCTION IN THE PROVINCE OF EAST JAVA

In mid-2018, *Arapaima gigas* was caught in the waters of the Brantas River, Sidoarjo, East Java **(Syafei & Sudinno, 2018** and **Fadjar *et al.*, 2019)**. Various electronic and print media reported the introduction of this introduced fish found by residents in the Brantas River. This discovery is an indication of carelessness and the absence of transparent law enforcement on the perpetrators who release non-native species in public waters in Indonesia. The species has been introduced for a long time and is very likely to become an invasive species, and even reported to enter China, the Philippines, Singapore, Thailand, Cuba, Bolivia, and Mexico as ornamental fish **(Goulding *et al.*, 1996)**. The study of the existence of *Arapaima gigas* fish along the Brantas River has not been carried out entirely, and the first report only caught three adult species of *Arapaima gigas* from the Brantas River region in Sidoarjo **(Fadjar *et al.*, 2019)**.

Although only *Arapaima gigas* is a concern, in East Java Province also has several introduced fish. A number of these introduced fish have even become leading commodities and become a source of food for the community. Referring to the potential of freshwater fisheries in East Java, the value of fisheries production, in general, contributes significantly to the economic activities of the region. From the East Java statistics report in 2020, the aquaculture in the pond was able to produce 262,620.94 tons with a value of 4.4 trillion Rupias **(Fig. 2)**. Besides, in the form of fish ponds, aquaculture in East Java is also developed in other media such as the rice mina system, cages, floating cages, and brackish fish pond **(BPS-Jatim, 2020)**.

Table (1): List of fishes introduced from overseas and introduced domestically **(Umar & Sulaiman 2013)**.

No.	Local Name	Scientific Name	Introduction	Origin	Destination
1	Mas	*Cyprinus carpio*	before 1900	China	Indonesia
2	Nilem	*Osteochilus hasseltii*	1937	no information	Papua
3	Koan	*Ctenopharyngodon idella*	1964	Malaysia, Singapore, Thailand, and Japan	Indonesia
4	Mola	*Hypophthalmichthys molitrix*	1969	Japan and Taiwan	Indonesia
5	Karp lumpur China	*Cirrhinus chinensis*	1969	Taiwan	Indonesia
6	Karper China	*Hypophthalmichthys nobilis*	-	Japan	Indonesia
7	Karper China	*Hypophthalmichthys nobilis*	1969	Taiwan	Indonesia
8	Tawes	*Puntius gonionotus*	1963	no information	Papua
9	Tawes derbang	*Puntius orphoides*	1963	no information	Papua
10	Carp lumpur	*Cirrhinus molitorella*	-	Japan	Indonesia
11	Rainbow trout	*Oncorhynchus mykiss*	1929	Nederland	Indonesia
12	Rainbow trout	*Oncorhynchus mykiss*	1983	no information	Indonesia
13	Bintik putih (Panchax biru)	*Aplocheilus panchax*	no information	Indonesia (wester part of Wallacea)	Indonesia
14	Gurame	*Osphronemus goramy*	1937	no information	Papua
15	Sepat siam	*Trichogaster pectoralis*	1937	no information	Papua
16	Sepat siam	*Trichogaster pectoralis*	1930	Malaysia	Indonesia
17	Tambakan	*Helostoma temminckii*	1937	no information	Papua
18	Tambakan	*Helostoma temminckii*	-	Indonesia (Jawa)	Bali
19	Tambakan	*Helostoma temminckii*	-	Indonesia (Kalimantan)	Sulawesi
20	Betok	*Anabas testudineus*	no information	no information	Papua
21	Mujahir	*Oreochromis mossambicus*	1939	West Africa	Indonesia
22	Mujahir	*Oreochromis mossambicus*	-	Philippines	Indonesia
23	Nila	*Oreochromis niloticus*	1971	no information	Papua
24	Nila	*Oreochromis spp.*	1980	Philippines	Indonesia
25	Nila	*Oreochromis niloticus*	after 1980	Taiwan	Indonesia
26	Nila	*Oreochromis niloticus*	-	Philippines	Indonesia
27	Sidat	*Anguilla anguilla*	1992	England, France, Denmark	Indonesia
28	Koki	*Carassius auratus*	no information	China	Indonesia
29	Gabus	*Channa striata*	-	Southern China	Indonesia
30	Lele dumbo	*Clarias gariepinus*	mid of 1980	Nederland	Indonesia
31	Lele lokal	*Clarias batrachus*	1939	Indonesia (Jawa)	Sulawesi
32	Lele dumbo	*Clarias gariepinus*	1985	South Africa	Indonesia
33	Lele amerika	*Ictalurus punctatus*	1986	USA	Indonesia
34	Bawal	*Colossoma macropomum*	1986	Taiwan	Indonesia
35	Ikan nyamuk	*Gambusia affinis*	1929	Italy	Indonesia
36	Bintik mutiara	*Etroplus suratensis*	1979	Malaysia	Indonesia
37	Gupi	*Poecilia reticulata*	1920	no information	Indonesia
38	Salmon	*Salmo salar*	1929	Nederland	Indonesia
39	Salmon	*Salmo trutta fario*	1929	Nederland	Indonesia
40	Tench hijau	*Tinca tinca*	1927	Nederland	Indonesia
41	Pacu	*Piaractus brachypomus*	1985	Taiwan	Indonesia
42	Patin siam	*Pangasius hypophthalmus*	-	Thailand	Indonesia

The East Java Province Fisheries and Maritime Services Office have reported 17 species of introduced fish that has been developed as animal protein source. First, for the freshwater fish consists of common carp (*Cyprinus carpio*) dominates the most, followed by Nile tilapia (*Oreochromis niloticus*), Mujahir (*Oreochromis mossambicus*), Guoramy (*Osphronemus goramy*), Tawes (*Barbonymus gonionotus*), catfish, eel (Anguilliform sp.), two-spot gouramy (*Trichogaster sp.*), freshwater pomfret, and head snake fish (*Channa*

striata). The brackish water species are vanamae shrimp, *Litopenaeus vannamei;* tiger shrimp, *Penaeus monodon* and milkfish, *Chanos chanos* **(Kelautan, 2015)**.

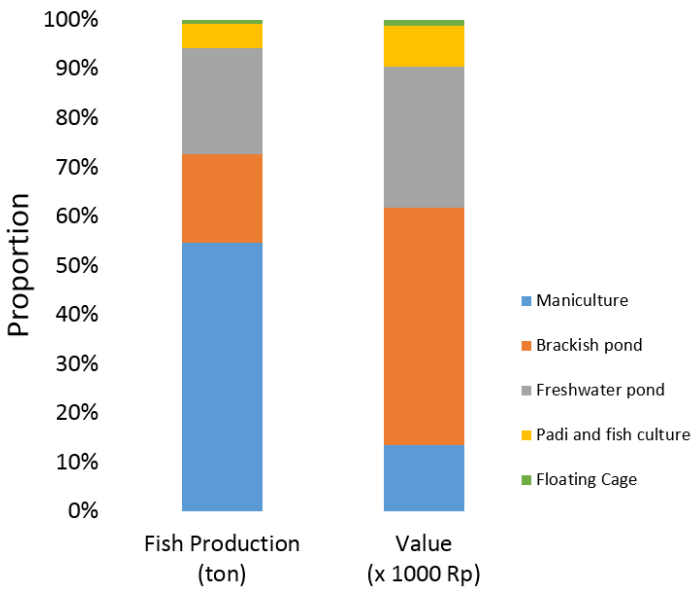

Figure 2. The proportion of fish production from several aquaculture activities in East Java Province.

Beside those non-native fish species, some fish have been also introduced as ornamental fish, with a highly economic value in East Java **(Triyanti & Yulisti, 2012** and **Kelautan, 2015)**. Various types of ornamental fish which are a mainstay of fishery commodity in East Java are presented in **Table 2**.

4. ECOLOGICAL ASPECTS OF INVASIVE SPECIES

Ecologically, the introduction of non-native species turned into Invasive alien species (IAS) has caused the damage and decreased biodiversity. The latest report stated that around 39% of fish species in the world have become extinct within 400 years due to the presence of IAS **(Kiruba-Sankar *et al.*, 2018)**. Previous studies show that aside of its benefits, the introduction of non-native species, especially in fish species, affects and changes the structure of freshwater ecosystems. For the management of freshwater areas **(Copp *et al.*, 2017)**, the fish introduction can cause unpredictable problems, especially for the local species that have existed **(Strayer, 2010)**.

Currently, studies on invasive species in Indonesia are still minimal and have not been well coordinated. Some species are even able to develop well in some introduced areas. Some negative impacts of the introduction of non-native species have been found in several waters **(Table 3** and **Figure 3)**.

Table 2. Ornamental freshwater fish production in East Java Province **(Kelautan, 2015)**

Local name	English name	Scientific name	Distribution	Number x1000	Proportion (%)
Koi	Common carp	*Cyprinus carpio*	Europe to Asia	292548.4	51.06
Molly	Molly	*Poecilia sphenops*	Central and South America: Mexico to Colombia	17036.1	2.97
Mas koki	Goldfish	*Carassius auratus auratus*	central Asia and China, Japan	21423.8	3.74
Barbir	Rosy barb	*Puntius conchonius*	Afghanistan, Pakistan, India, Nepal, and Bangladesh	382.8	0.07
Gapi	Guppy	*Poecilia reticulata*	South America: Venezuela, Barbados, Trinidad, northern Brazil and the Guyanas.	1112	0.19
Cupang	Siamese fighting fish	*Betta splendens*	Asia: Mekong basin	118569.8	20.70
Acara	Blue acara	*Andinoacara pulcher*	Central and South America: Trinidad and Venezuela	2018.5	0.35
Lalia	Dwarf gourami	*Colisa lalia*	Pakistan, India and Bangladesh	101	0.02
Manvis	Freshwater angelfish	*Pterophyllum scalare*	South America: Amazon River basin, in Peru, Colombia, and Brazil	6039.3	1.05
Oscar	Oscar	*Astronotus ocellatus*	South America: Amazon River basin in Peru, Colombia and Brazil	2085.9	0.36
Plati	Southern platyfish	*Xiphophorus maculatus*	North and Central America: Ciudad Veracruz, Mexico to northern Belize	24835	4.33
Rainbow	Red rainbowfish	*Glossolepis incisus*	Endemic to Lake Sentani in Irian Jaya, Indonesia	100	0.02
Sumatra	Sumatra barb	*Puntius tetrazona*	Sumatra and Borneo	2153.6	0.38
Louhan	Three spot cichlid	*Cichlasoma trimaculatum*	Central America: Pacific slope rivers of the Pacific slope from Mexico to El Salvador	85.1	0.01
Lele blorok	Philippine catfish	*Clarias batrachus*	Asia: Java, Indonesia	2587.2	0.45
Komet	Goldfish	*Carassius auratus*	Central Asia and China, Japan	63788.9	11.13
Blackgosh	Black ghost	*Apteronotus albifrons*	South America: Venezuela to Paraguay and Paraná rivers, the Amazon Basin of Peru	1.7	0.00
Kar tetra	Neon tetra	*Paracheirodon innesi*	South America: Blackwater or clearwater stream tributaries of the Solimões River.	3906	0.68
Molly marble	Molly	*Poecilia spp.*	Central and South America: Mexico to Colombia	6574.8	1.15
Golden Arwana	Asian bonytongue	*Scleropages formosus*	Asia: Southern Myanmar to Malay Peninsula and Indonesia, eastern Thailand to Cardamon Range	6.9	0.00
Disccus	Blue discus	*Symphysodon aequifasciatus*	South America: eastern Amazon River, Solimões Rivers	689.6	0.12
Zebra	Zebra danio	*Danio rerio*	Pakistan, India, Bangladesh, Nepal and Myanmar	30.6	0.01
Black molly	Molly	*Poecilia spp.*	Central and South America: Mexico to Colombia	13.9	0.00
Balasak	Tricolor shark minnow	*Balantiocheilos melanopterus*	Mekong and Chao Phraya basins, Malay Peninsula, Sumatra and Borneo	6.8	0.00
Red Fin	Rainbow sharkminnow	*Epalzeorhynchos frenatum*	Mekong, Chao Phraya and Xe Bangfai basins, Maeklong basin	674.4	0.12
Lemon	Blue streak hap	*Labidochromis caeruleus*	Endemic to Lake Malawi, Africa	2743.3	0.48

Niasa	Golden mbuna	*Melanochromis auratus*	Endemic to Lake Malawi, Africa	418.9	0.07
Lobster tawar	freshwater crayfish	*Cherax quadricarinatus*	tropical Queensland, the Northern Territory and southeastern Papua New Guinea	73	0.01
Silver Arwana	Arawana	*Osteoglossum Bicirroshum*	South America: Amazon River basin, Rupununi and Oyapock Rivers	156.7	0.03
Juani	Bluegray mbuna	*Melanochromis johannii*	Endemic to Lake Malawi, Africa	49.6	0.01
Patin albino	Striped catfish	*Pangasius hypothalmus*	Mekong, Chao Phraya, and Maeklong basins	2707.5	0.47

As happened example, nowadays now the endemic species in Lake Toba, North Sumatra, Batak fish (*Neolissochilus thienemanni*) is challenging to find in their original waters **(Syafei & Sudinno, 2018)**. Also, in Sulawesi where the extinction of endemic fish in this region reduced since the tilapia fish have introduced as a foreign species in 1951.

Where the extinction of endemic fish in this region occurred, the tilapia fish have introduced as a foreign species in 1951. Previously, the endemic fish, duck snout (*Adrianichthys kruyti*), *Adrianichthys oophorus* and *Xenopoecilus poptae* could be found in the Lake Poso, and *Xenopoecilus sinorum* from Lake Lindu, Sulawesi **(Whitten *et al.*, 1987)**. However, only the *Adrianichthys oophorus* that can still be found in Lake Poso, while the other three are thought to be extinct **(Gundo *et al.*, 2017)**.

Table 3. List of non-native species in several lake and reservoir in Indonesia

Local name	Species name	Location of Introduction	Introduction period	References
Bilih	*Mystacoleucus padangensis*	Toba Lake	2002-2003	(Koeshendrajana 2008)
Bandeng	*Chanos chanos*	Jatiluhur Dam	2008	(Kartamihardja 2012)
		Cirata Dam	2008	(Kartamihardja 2012)
Jelawat	*Leptobarbus hoeveni*	Teluk Lake	2006	(Amri *et al*. 2017)
Koan	*Ctenopharyngodon idella*	Kerinci Lake	1995	(Kartamihardja 2012)
	Ctenopharyngodon idella	Sentani Lake	2010	
Lohan	*Cichlasoma trimaculatum*	Matano Lake	2000	(Hedianto & Satria 2018, Sentosa & Hedianto 2019)
Mas/Koi	*Cyprinus carpio*	Blitar	2002	(Umar & Sulaiman 2013)
	Cyprinus carpio	Sentani Lake	2010	(Umar & Sulaiman 2013)
	Cyprinus carpio	Paniae Lake	2002-2010	
Mujahir	*Oreochromis mossambicus*	Wadaslintang Dam	1994	(Fatah & Adjie 2015)
Nila	*Oreochromis niloticus*	Kerinci Lake	2010	(Samuel *et al*. 2013)
	Oreochromis niloticus	Riam Kanan Dam	nd	
	Oreochromis niloticus	Wadaslintang Dam	1994-2001	(Fatah and Adjie 2015)
	Oreochromis niloticus	Sentani Lake	2010	(Umar & Sulaiman 2013)
	Oreochromis niloticus	Paniae Lake	2002-2010	
Patin jambal	*Pangasius djambal*	Teluk Lake	2006	(Amri *et al.* 2017)
	Pangasius djambal	Juanda Dam	2000	(Kartamihardja 2008)
Patin Siam	*Pangasionodon hypophthalmus*	Cirata Dam	2002-2003	
	Pangasionodon hypophthalmus	Juanda Dam	1999	(Kartamihardja 2008)
	Pangasionodon hypophthalmus	Malahayu Dam	2009	
	Pangasionodon hypophthalmus	Gajahmungkur Dam	1999-2002	
Red devil/Oscar	*Amphilophus citrinellus*	Cirata Dam	nd	
	Amphilophus citrinellus	Juanda Dam	nd	(Kartamihardja 2008)
	Amphilophus citrinellus	Sentani Lake	nd	(Umar & Sulaiman 2013)
Sepat	Trichogaster pectoralis	Tempe Lake	1937	(Kartamihardja 2012)
Tawes	*Puntius javanicus*	Wadaslintang Dam	2002	(Yulianto & Asriyanto 2006)
Tambakan	Helostoma temminckii	Tempe Lake	1925	(Kartamihardja 2012)

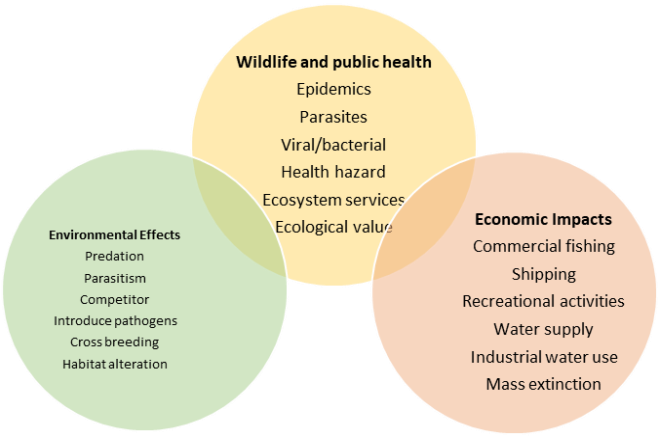

Figure 3.. Relationship of several effects of non-native species in the new habitat. Modification from (Kiruba-Sankar et al. 2018)

CONCLUSION

Several freshwater fish species have been introduced many years ago and have adapted to Indonesia's freshwater tropical aquatic habitats, including in East Java Province. Most of these are aquaculture commodities that have the potential to supply food and protein, and also become commercial commodities as ornamental fish. The high production value and production volume in East Java makes some species considered not as non-native anymore even as native fish. The study of genetic diversity among species that have been introduced is needed as a study material in knowing biodiversity and its effect on native species and the potential for breeding among these fish. Thus, the potential to become an invasive species can be handled well.

In addition to studies on genetic variation, law enforcement in the non-native introduction is necessary and, at the same time, regulates their circulation in nature so that cases of release of *Arapaima gigas* in public waters, which have occurred in Sidoarjo, East Java, are not repeated. Further studies on the discovery and release of *Arapaima gigas* in Indonesian waters should be conducted to anticipate the negative impacts produced. Besides, more research on the distribution of other non-native introduction species that have the potential to damage and danger the biodiversity of Indonesian freshwater fish are also expected to be carried out to support the provision of accurate and valid Indonesian freshwater fish biodiversity data.

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