Introduced fish species and their characters in Lake Maninjau, West Sumatra

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Abstract. The diversity of indigenous fish species in Lake Maninjau has been declining with the rise of local people’s activities. One of the causes is the invasive species, which are initiated by introduced species. This study aims to discover the species, distribution, growth pattern, and condition factor including information of the environmental condition, supporting the existence and growth of introduced fish species in Lake Maninjau. Sampling was conducted at four locations in Lake Maninjau; Bayur, Linggai, Sigiran, and Galapung. Fishes were collected by experimental gillnet which vary in mesh size, 0.5; 0.75; 1; 1.5; 2; 3; and 4 inches. These nets were set about 12 hours from 8 pm to 8 am on the next day, once a month in May, July, August, September, and October 2017. Four introduced fish species were observed and examined; there were Cichlasoma trimaculatum (Three-spotted cichlid), Oreochromis niloticus (Tilapia), Pterygoplichtys pardalis (Armored Catfish), and Oxyeleotris marmorata (Marble Goby). O. marmorata and O. niloticus were recorded at all of the sampling locations. C. trimaculatum was recorded in Galapung and Sigiran, while P. pardalis only found in Bayur. These dominant fish species have growth patterns each; there are negative allometric (O. marmorata), isometric (C. trimaculatum), and positive allometric (O. niloticus). Moreover, these three fish species have an almost 1.00 condition factor; there were 0.988, 1.024, and 1.001, respectively. Results and discussion infer that introduced fish species in Lake Maninjau were distributed at several locations with good growth and condition.

1. Introduction
Located in sub-district Tanjung Raya, Agam, West Sumatra, Lake Maninjau is a tecto-volcanic lake with 165 meters maximum depth and about 9,737.5 hectares surface area [1]. Lake Maninjau has several functions related to ecology, society, and economy, one of which is a habitat for aquatic biota. This ecological function plays a vital role in the existence of indigenous fish species of Lake Maninjau.

Indigenous fish diversity in Lake Maninjau has decreased in line with the rise of people’s activities around the lake. The first study about fish diversity in Lake Maninjau has recorded at least 33 indigenous fish species [2]. The indigenous fish’s existence was increasingly threatened until it reached the 14 and 13 species in 2008 and 2017, respectively [3, 4]. This decline is related to the impact of the interacted freshwater biodiversity threats, including habitat degradation, species invasion, current modification, overexploitation, and water pollution [5]. According to a previous study, alien invasive species are the three most significant causes of the IUCN Red List species in the European Union. Invasive alien fish species in a freshwater ecosystem are initiated by introduced fish
that fastly breed and subsequently threaten the indigenous fish [6]. Therefore, the introduced fish species has been a concern in inland water ecosystem conservation studies.

Alien/introduced fish is a species that is not lived in its original habitat/ecosystem due to direct or indirect human activities. This introduced fish can also occur at subspecies and even at lower taxon levels [7, 8]. Alien fish species might set in an aquatic ecosystem either from abroad or outside the region of their origin [9]. Initially, introduced fish species were intended for fisheries aquaculture. Later, people introduce alien fish species for other interests, such as sport (fishing), ecological niche, fisheries, biological control, and ornamental fish. On the other hand, introduced species also have several adverse impacts, such as competition, predation, hybridization, and disease infection [6].

To determine the growth pattern and the body fitness of fish in an aquatic ecosystem, length-weight relationship analysis, and condition factor examination are needed. The fish’s body’s condition is to know the health and plumpness for being eaten and determine the fat storage and gonad fish development [10].

This study aims to determine the species, distribution, growth patterns, and condition factor included information of the environmental condition, supporting the existence and growth of introduced fish species in Lake Maninjau.

2. Methods

2.1. Location, time, materials, and tools
Sampling was carried out at 4 locations in Lake Maninjau; Bayur, Linggai, Sigiran, and Galapung (Figure 1). Sampling locations were chosen by habitat characteristics and anthropogenic impact, such as floating net cages. Fishes were caught by experimental gill nets, which have 7 different mesh sizes (0.5; 0.75; 1; 1.5; 2; 3; and 4) inches. Gill nets were set about 12 hours, from 8 pm to 8 am (the next day). Fish sampling is conducted once a month in May, July, August, September, and October 2017.

![Figure 1. Sampling Location in Lake Maninjau.](image-url)
Fish samples were preserved by a 10% formalin solution and morphologically identified based on the book of fish species identification [11, 12]. After that, each species’ length and weight were measured at the Laboratory of Unit for Technology Transfer of Lake Restoration (LATPD) Indonesian Institute of Sciences (LIPI) Maninjau, West Sumatra.

2.2. Length-weight analysis
In analyzing a length-weight relationship, the Le Cren logarithmic transformation formula has been applied [13]. This analysis needs a length-weight formula to calculate the relationship between fish weight (g) and the total length of the fish (cm):

\[ W = aL^b \]  

(1)

The parameters ‘a’ and ‘b’ can be calculated by linear regression of the logarithmic transformation equation below:

\[ \log W = \log a + b \log L \]  

(2)

The constant of ‘a’ indicates the intercept, and ‘b’ shows the slope of a long-weight relationship. Moreover, the constant of ‘b’ indicates the fish growth pattern. If the ‘b’ is equal to 3.00, it can be determined that the fish growth pattern is isometric. If the constant of ‘b’ is less than 3.00, fish growth patterns are negative allometric. This condition indicates the weight gain is slower than the length increase. Meanwhile, if ‘b’ is more than 3.00, the fish has positive allometric growth [14]. Either environment or particular fish condition causes the ‘b’ deviation from the ideal value of 3.00.

2.3. Relative condition factor
The relative condition factor \( K_n \) is used to assess the fish condition by comparing the measured weight and the predicted weight. The relative condition factor is calculated by the formula below:

\[ K_n = \frac{W}{W'} \]  

(3)

W : Measured weight (gram)
W' : Predicted/calculated weight (gram)

A well-growing fish can be concluded if \( K_n \) is more than 1.00 in value. While fish in weak growth (compared to the average individual in the same length) if \( K_n \) is less than 1.00 in value.

3. Result and Discussion

3.1. Introduced fish species
This study has discovered four species of introduced fish (Figure 2), namely: *Cichlasoma trimaculatum* (Three-spotted cichlid), *Oreochromis niloticus* (Tilapia), *Pterygoplichthys pardalis* (Armored Catfish), and *Oxyeleotris marmorata* (Marble Goby), which is distributed in four sampling locations (Figure 3).

All of them are introduced fish species that come from another area outside Lake Maninjau. Moreover, *C. trimaculatum*, *O. niloticus*, and *P. pardalis* are alien fish species originating from elsewhere.
Figure 2. Introduced fish species caught in Lake Maninjau: (a) *Cichlasoma trimaculatum* (Three-spotted cichlid), (b) *Oreochromis niloticus* (Tilapia), and (c) *Oxyeleotris marmorata* (Marble Goby).

*C. trimaculatum* belongs to the Cichlidae family, where the family originates from Central and South America, Africa, Asia Minor, India, Sri Lanka [11]. In Indonesia, Cichlids are introduced fish in several lakes, such as Lake Batur [15] and Lake Matano, found evenly spread out [16]. While in Lake Maninjau, this fish was firstly reported in 2014 [17].

In addition to the Three-spotted cichlid, another introduced species from the Cichlidae family is *O. niloticus*. The Oreochromis genus is included in the Invasive Alien Species List by the Fish Quarantine and Inspection Agency, Ministry of Maritime Affairs and Fisheries, along with other Cichlids [18]. Fish Quarantine and Inspection Agency – Ministry of Marine Affairs and Fisheries (FQIA-MMAF) classifies three Oreochromis (*O. niloticus*, *O. mossambicus*, and *O. aureus*) as invasive fishes because of their ability to adapt and tolerant of various environmental conditions and can dominate a habitat in an aquatic ecosystem.

Tilapia’s introduction also occurs in Lake Batur, caused by restocking activity to increase the lake’s caught fisheries activities [15]. Later, because of its adaptability and reproductive ability, tilapia dominates fish communities in Lake Batur. However, it is relatively harmless because of the absence of indigenous fish. For local fishers, tilapia’s presence is worthwhile by making them the main target...
of fish catches. Tilapia’s existence in Lake Maninjau was discovered in 1978, and the first introduced fish was recorded in Lake Maninjau [19].

*P. pardalis* (Armored Catfish) belongs to the Loricariidae family, endemic in South America and Panama. Naturally, *P. pardalis* has existed in all Amazon River segments and Peru [20]. *Pterygoplichthys* is widespread outside its origin area as invasive fish species in Indonesia, Malaysia, Singapore, and Taiwan [21]. In Indonesia, a previous study recorded two species belong to the genus *Pterygoplichthys* in the Ciliwung River; there are *P. pardalis* and *P. disjunctive* [22]. Moreover, hybrid species from those two species are also found there. In Lake Maninjau, *P. pardalis* was firstly discovered in 2014 with no information on how it comes to the lake [17].

*O. marmorata* (Marble Goby) belongs to the Eleotridae family, an indigenous fish from the Mekong River, China. These fish distribution areas include the Mekong and Chao Phraya Basin, Peninsular Malaysia, Indochina, Thailand, Cambodia, Vietnam, Singapore, the Philippines, and entered Indonesia in 1927 [11, 23, 24]. The presence of marble goby in some aquatic ecosystems is caused by human activities, either intentionally or accidentally. In the case of Sempor Reservoir, Central Java, Marble Goby accidentally escaped from the aquaculture net cage [25]. Marble goby in Lake Maninjau was first reported in 2003 [26]. According to local fishers, marble goby was released into Lake Maninjau to increase the production of catch fishing and people’s income because of their high economic value in other areas. However, local people are more interested in tilapia and floating net cage aquaculture. This disinterest makes this marble goby frequently found in Lake Maninjau.

The introduced fish species in Lake Maninjau have been increased by number. In 2003 there were four species and has increased to six species in 2014 [17, 26]. Researchers recorded two introduced species that are not caught in this study; there are *Cyprinus carpio* (Common Carp) and *Pangasius sp.* (Shark Catfish) [3, 4]. Both fish species are consumed fish that escape from the ground pool and floating lift net aquaculture. This escape initially might make the number of introduced fish species has been increased. They are all then well-spawn breed in the waters because of environmental suitability, which appropriates to the ecological requirement of their viability and growth. Moreover, introduced fish species have a wide tolerance for various water quality.

3.2. Distribution

The distribution of fish species in an aquatic ecosystem is closely related to the habitat where they inhabit. This study also describes the habitat condition in all four sampling locations (Table 1).

| Habitat Description | Bayur | Linggai | Galapung | Sigiran |
|---------------------|-------|---------|----------|---------|
| **Location**        | North East | North | South | West |
| **Depth (m)**       | 2     | 2       | 6       | 5       |
| **Fish Cage Net**   | Yes   | Yes     | Yes     | Yes     |
| **Landuse**         | Paddy field (dominant), villages, hostelry | Villages, paddy field | Forest (dominant), paddy field, and villages | Villages |
| **Bottom Substrate**| Gravel (dominant), sand, stones, rocky sand | Sandy mud (dominant), sand, mud, gravel | Rocky sand, gravel | Stones and rocks |
| **River/stream**    | Small trench from paddy field | Permanent river/stream | Intermittent stream | Intermittent stream |
| **Aquatic Vegetation** | Water hyacinth (few) | Water hyacinth | *Elodea densa* (few), riparian vegetation | *Elodea densa* |
| **Transparency**    | Clear | Blackish | Clear | Clear |
| **T; pH; DO**       | 28°C; 8.29; 6.86 mg/l | 28°C; 8.15; 6.22 mg/l | 24.3°C; 6.66; 5.58 mg/l | 28.7; 8.78; 5.84 mg/l |
Marble goby and tilapia found in 4 sampling locations indicate that those species have broad living niches. These species play a significant role in using available food, have good adaptation in feed availability fluctuations, and have a substantial reproductive capability [27]. Both fishes can adapt and have a wide tolerance range to live and regenerate in various aquatic habitats.

Marble goby is dominant in Bayur and Linggai, where the bottom substrate is gravel to sandy mud, and there is also water hyacinth. This habitat description is in line with another study about marble goby’s eco-biology, which states that its habitat is calm currents, a slightly muddy substrate such as swamps, lakes, or river/stream mouths, and covered by aquatic plants [28]. Locations with many aquatic plants are also preferred by marble goby as a shelter and spawning.

Three-spotted cichlid was dominantly found in Galapung and Sigiran, areas with relatively deep, sandy, gravel to rocky, and the large rock substrate in the littoral. Moreover, in these two locations also found submerged aquatic plants Jariamon (*Elodea densa*). Three-spotted cichlids like hard substrate habitat, such as the rocky sand bottom, while fish with mature gonads inhabit the spawning area such waters with submerged aquatic plants [29].

### 3.3. Length-weight relationship and relative condition factor

A total of 117 *O. marmorata*, 100 *C. trimaculatum*, and 31 *O. niloticus* were measured and analyzed in this study. Length-weight relationships as a result of linear regression are shown by graphs (Figure 4).

![Graphs showing length-weight relationships for three fish species](image)

**Figure 4.** Length-weight relationship graph of three introduced fish species (a) *O. marmorata*, (b) *C. trimaculatum*, and (c) *O. niloticus*.

R² of the introduced fishes is close to 1.00, which means that the length-weight patterns predicted by the formula are good in value with the quadratic equation models. Therefore, these quadratic
equations are well operated in predicting the weight of each fish species. The constant of ‘b’ shows the growth pattern of fish species (Table 2). If b < 3, the growth pattern is negative allometric; b = 3 is isometric; and if b > 3, the growth pattern is positive allometric.

Table 2. Results of length-weight analysis and condition factors calculation of the marble goby, three-spotted cichlid, and tilapia in lake maninjau.

| Species          | O. marmorata | C. trimaculatum | O. niloticus |
|------------------|--------------|-----------------|--------------|
| N                | 117          | 100             | 31           |
| Total Length (cm)|              |                 |              |
| 13.42 ± 3.29     | 10.68 ± 3.59 | 14.13 ± 3.70    |
| TL min-max (cm)  |              |                 |              |
| 6.90 - 21.40     | 4.30 - 26.10 | 6.70 - 22.00    |
| W (g)            |              |                 |              |
| 34.19 ± 25.36    | 37.57 ± 43.74| 71.14 ± 51.50   |
| W min-max (g)    |              |                 |              |
| 4.40 - 116.20    | 2.20 - 326.80| 5.20 - 243.70   |
| W’ Equation      |              |                 |              |
| W’ = 0.012L^{2.992} | W’ = 0.022L^{3.012} | W’ = 0.016L^{3.108} |
| a                | 0.012        | 0.022           | 0.016        |
| b                | 2.992        | 3.012           | 3.108        |
| W’ (g)           |              |                 |              |
| 34.15 ± 25.05    | 37.32 ± 47.73| 71.26 ± 51.09   |
| W’ min-max (g)   |              |                 |              |
| 3.94 - 116.56    | 1.75 - 399.76| 5.77 - 232.15   |
| R^2              |              |                 |              |
| 0.987            | 0.955        | 0.993           |
| Growth Pattern   | (-) allometric| isometric       | (+) allometric |
| K_n              | 0.988 ± 0.08 | 1.024 ± 0.256   | 1.001 ± 0.073 |
| K_n min-max      | 0.739 - 1.261| 0.391 - 2.345   | 0.872 - 1.130 |

| N: Total sample; L: Length; W: Weight; W’: Predicted Weight; a and b: Regression Coefficient; R^2: Determination Coefficient; K_n: Relative Factor Condition. |

Marble Goby’s constant of ‘b’ is 2.992, which means that its growth pattern is negative allometric. With the same Goby species in Ulim River Aceh, a previous study calculated that the constant of ‘b’ was 2.68 and 2.75 [30]. That result is similar to this study, which showed that Marble Goby has a negative allometric growth pattern (with b < 3), where the length increases are faster than the weight gain. This condition is appropriate since the Marble Goby has an elongated body shape.

In contrast, the Three-spotted cichlid constant of ‘b’ is 3.012 (b = 3), which implies that this fish takes on an isometric growth pattern. The length-weight analysis of the cichlids in several Indonesia aquatic ecosystems has a wide variety as a result. This variation has been found in the same aquatic ecosystem at different times, such as the cichlids in Lake Matano. In April 2015, the cichlids constant of ‘b’ was 3.075, while in August, it was 3.143 [31]. Whereas, in 2016, the result of another study analysis was 2.952 [32]. The various constants of ‘b’ is caused by either difference in environmental conditions or the fish condition when caught. Even though several analyses have resulted in ‘b’ vary, the growth patterns of those are close to isometric patterns (b = 3) as occurs in this study.

Length-weight analysis of the tilapia in this field has resulted in a constant ‘b’ 3.108 (b > 3), implying that these fish specimens had a positive allometric growth pattern. That growth pattern is similar to the Tilapia in Lake Kerinci, which has a constant ‘b’> 3 [33].

The result of the length-weight analysis was varied even for the same fish species in the same place from the discussion above. Ideally, the results of length-weight relationship analysis can be compared more detail and precise with the complementary works below [34]:

- Separating the sexes might occupy some fish species which have different sizes in sex differ.
- Length classifying might occupy some fish species which have different growth among their juveniles and adults. Generally, the juvenile length is faster than its weight, while in adults, it is the weight one.
- Gonadal Maturity Analysis might occupy the mature fishes which have weight gain faster than the length. Generally, their weight will gain in line with the gonadal development (I to V).
- Seasonal fish sampling might occupy different growth patterns in different seasons.

Kn of the three introduced species in Lake Maninjau was varied, as shown in Table 2. In detail, cichlids have the broadest range of K_n, from 0.391 to 2.345. Simultaneously, the minimum and
maximum $K_n$ of gobies and tilapias were 0.739 to 1.261 and 0.872 to 1.130, respectively. On the other hand, the gobies have the lowest average in $K_n$; it was 0.988. While cichlids and tilapias have $K_n$ more than 1.00, there were 1.024 and 1.001, respectively. Generally, the three introduced fish species’ condition factors were close to 1.00, which means they are in good condition. Some introduced fish species can also live and grow in good conditions in other waters, such as Marble Goby in Ulim River Aceh [30] and Tilapia in Juanda Reservoir Jatiluhur [35].

All of the condition factor results in this study indicate that the habitat where the introduced fish live provides sufficient food for the fish population, and also, the predator density is still in balance [36]. According to a previous study, if the relative weight (which influences the condition factor) is below the standard, problems either lack prey availability or high predator density, or both occur [37]. On the other hand, if that value is above the standard, either the prey’s availability is high or low predator density occurs. Instead of food availability, other studies state that water qualities and fisheries management could also influence the condition factors [38, 39]. Another researcher added that stress could also affect fish condition factors [34] and it has proven that stress makes tilapia’s condition factor in Lake Turkana Kenya was very low [40].

3.4. Introduced fish management strategy in the inland water ecosystem

Several studies have shown that introduced fish species live in good condition in their new habitat. The existence of introduced fish species indicated that releasing introduced species into an aquatic ecosystem must be done carefully to give good biological and ecological impacts. In the implementation, releasing a new species in an aquatic ecosystem must be begun by in-depth research about potential impacts, especially in indigenous fish species in its ecosystem [41]. The abundance of the alien fish species directly impacts the indigenous fish’s existence due to food and territory competition. Moreover, gut analysis of the Marble Goby and Three-spotted cichlid fish, which found fishes in their digestive tract, have been proven that there is predation among them [42, 43, 44]. Thus, in-depth research shall examine the biology of the introduced fish about indigenous fish species, including competition (space, food, genetic) and predation [32]. In terms of regulation, releasing fish into an aquatic ecosystem must be restricted by environmental rehabilitation and stringent regulations on ornamental fish trades so they do not escape into open waters [45].

In addition to the preventive measures, fish-catching could overcome fish introduced species that already live in the water ecosystem. This effort works well on consumption fish, like tilapia, because fishers catch that kind of fish for their daily needs. In some regions in Indonesia, fishes are massively caught and held as a fish catching competition. As a tradition, this event also works as a natural local culture for introduced fish species restriction. Unfortunately, not all of the introduced fish are edible because some fish are not fish consumption or are not very likable to eat. To solve this and as the last option to overcome the introduced fish species problems, eradication or extermination with advanced scientific study is necessary [46].

In line with the efforts to restrict and overcome the introduced fish species, conservation of indigenous fish species should be conducted by establishing the fish sanctuary as an area where it is appropriate for spawning, nursing, and growth areas. Besides, domestication could be an effort to conserve the indigenous fish species in an ex-situ way. Those efforts in conservation have a goal to make sustainable fisheries resources in an aquatic ecosystem.

4. Conclusion and Suggestion

Results and discussion in this study conclude that the introduced fish species in Lake Maninjau are spread in several locations. Those fish species are in good condition and growth supported by the water quality of Lake Maninjau as an introduced fish species habitat. The existence of introduced fish species in a water ecosystem could threaten the indigenous fish population because of competition and predation. On the other hand, introduced fish species that become a fish consumption, like tilapia, would increase local people’s income as a fish-catching or
aquaculture. Therefore the existence of introduced fish species has to be well-monitored and overcome.

In completing the information and support the introduction of fish research in Lake Maninjau, several studies need to be conducted, such as:

- Gut content analysis to ensure whether the introduced fish species are competitors or predators of indigenous fish, and
- Introduced/alien fish species risk analysis in Lake Maninjau to determine the impact of introduced/alien fish species in the particular aquatic ecosystem.

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