Gillnets selectivity and effectivity for controlling invasive fish species in Lake Matano, South Sulawesi

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Abstract. Lake Matano is one of the ancient lakes in East Luwu Regency, South Sulawesi, which has uniqueness and high endemicity for freshwater fishes. The presence of invasive alien fishes there can threaten the existence of endemic fishes. This study aimed to investigate the selectivity and effectiveness of the use of gillnets on several mesh sizes for controlling the population of invasive alien fishes in Lake Matano, South Sulawesi. Sampling was conducted in May, October, November 2015 and February, July, November 2016 using monofilament experimental gillnets with various mesh sizes (0.75, 1.0, 1.5, 2.0, 2.5, 3.0 inches) and yarn thickness (D = 0.15, 0.20, 0.25 mm). The mesh size of 1.5, 2.0, and 2.5 inches could catch flowerhorn cichlid as the dominant and invasive alien fish with little chance to catch native fishes in Lake Matano. The selectivity factor (SF) for the mesh size of 1.5, 2.0, and 2.5 inches was 3.02. The average catch size of flowerhorn cichlid captured by the mesh size of 1.5. 2.0, and 2.5 inches were 11.5, 15.3, and 19.2 cm, respectively. The yarn diameter did not significantly affect flowerhorn cichlid capture ($P < 0.05$). However, the mesh size of 1.5 inches was significantly different ($P > 0.05$) to other mesh sizes. For effectiveness, gillnet was better to operate in littoral areas of lakes, especially in the location associated with the sand substrate with macrophytes. The operation of the gillnet in Lake Matano needs to be regulated in terms of location and setting time to minimize the capture of fish species other than flowerhorn cichlid.

Keywords: flowerhorn cichlid, gillnet selectivity, invasive species, Lake Matano, Louhan

1. Introduction

Malili Lakes Complex is an ancient lake complex located in East Luwu regency, South Sulawesi, consisting of several lakes such as Lake Matano, Mahalona, Towuti, Wawontoa/Lantoa, and Masapi [1,2]. Lake Matano has an area of 164 km^2 with a maximum depth of 590 m and an altitude of 382 m above the sea level [3,4]. Lake Matano has a very high conservation value because it has much endemic fish and other aquatic species [5,6].

One of the problems found in Lake Matano that threaten fish biodiversity is the introduced invasive species. According to Herder *et al.* [7], fourteen species were found in Lake Matano during the research on 2000-2012. The occurrence of flowerhorn cichlid, locally known as *louhan*, is increased, and the fish tend to be invasive. Almost 35% of freshwater fishes extinction is caused by habitat changes or loss, 30% by alien fishes introduction, 4% due to excessive exploitation, and by other

factors such as pollution, water use competition, and global warming. The introduction of alien fish species into freshwater ecosystems can have profound consequences, including loss of species diversity, extinction of endemic species, distortion of food web function, and changes to ecosystem productivity [8–15].

Lake Matano has 18 endemic fishes species that are generally dominated by family Telmatherinidae and Gobiidae [16,17]. The occurrence of alien fishes in Lake Matano has widely reported, and the invasive alien fishes are expected to have a negative impact because it will threaten the existence of native or endemic fishes [5,18,19]. Therefore, it is necessary for controlling invasive alien fishes, especially for flowerhorn cichlid in order to maintain biodiversity and endemicity of fishes in Lake Matano. Donaldson and Cooke [20] reported that capture technique is one of the methods for controlling invasive fish based on the selectivity of fishing gear. Next, this study aims to analyze the selectivity and effectiveness of the use of gillnets on several mesh sizes for controlling the population of invasive alien fishes, especially the flowerhorn cichlid in Lake Matano, South Sulawesi.

2. Methods

The research was conducted in May, October, November (2015) and February, July, November (2016) in Lake Matano, East Luwu Regency, South Sulawesi. Data were collected at 17 stratified random sampling stations [21] (figure 1).

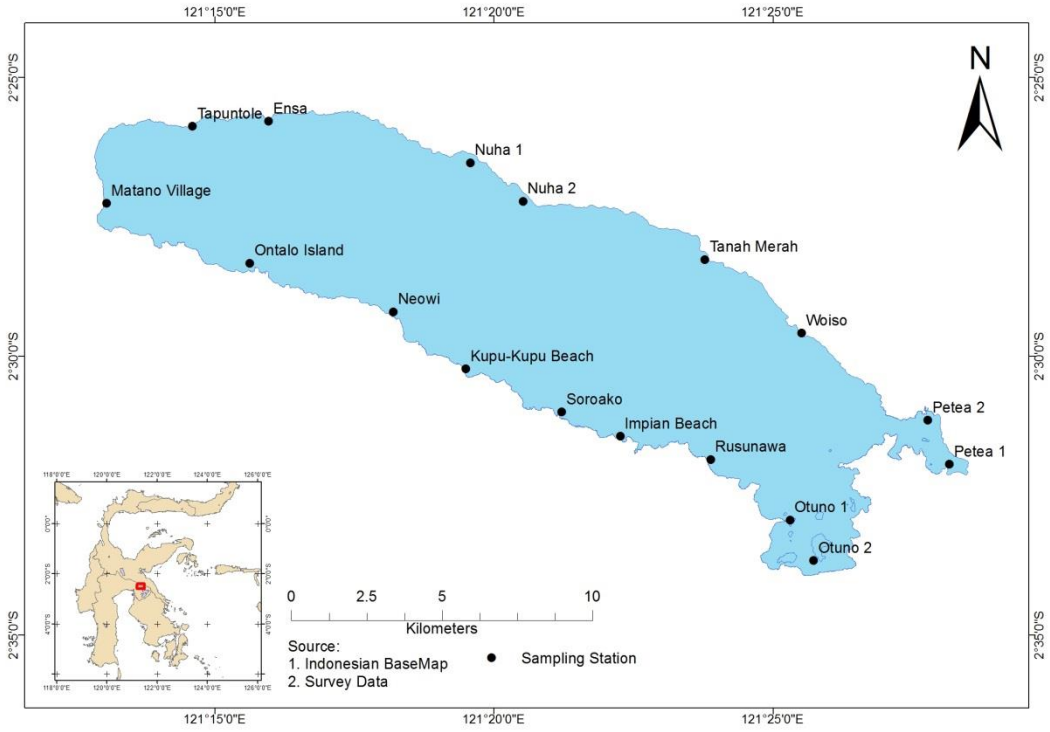

Figure 1. Sampling station in Lake Matano.

Fishing experiments were conducted by installing experimental gillnets for four hours during the day in the littoral zone (<100 m towards the shore). The gillnets used were made from monofilaments with specific mesh size, i.e. 0.75; 1.0; 1.5; 2.0; 2.5; 3.0 and 3.5 inches. Experimental fishing was also conducted in the limnetic area (depth >20 m) to determine the distribution patterns of flowerhorn cichlid horizontally and vertically. The yarn diameter size (D) was also used with certain variations, i.e., 0.15; 0.20; and 0.25 mm to analyze the effectiveness of flowerhorn cichlid fishing as an invasive fish in Lake Matano. Identification of flowerhorn cichlid referred to Herder *et al*. [7], Hildebrand [22],

Kullander [23], and the Fishbase [24]. The total length (TL) of fish samples were measured using a measuring board with a precision of 0.1 cm.

The analysis for controlling invasive alien species (IAS) was conducted based on a gear selectivity approach using gillnets. Estimation of gillnet selectivity was conducted using the logistic model (Holt model) by the normally distributed for capture selection curve [25]. The assumptions for this model are:

a. Fish caught *gilled* (fish caught just behind the operculum) and *wedged* (fish caught around the body as far as the dorsal fin).
b. The optimum length of fish caught from the selection curve is proportional to the mesh size.
c. Both the selection curves of two mesh sizes have the same standard deviation.
d. Both mesh size has the same fishing power.
e. The formula for this model is:

$$S_L = \exp\left[\frac{(L - Lm)^2}{2 * s^2}\right] \quad (1)$$

$$Lm_i = SF * m_i \quad (2)$$

where:
SL = points of the selection curve
L = the median of the fish length
Lm = the optimum length of the fish that can be caught
S = standard deviation
SF = selection factor
m = number of fish caught at L_i

The effectiveness of gillnets was analyzed using a *Randomized Block Design* [26]. The group approaches analyzed was a certain group of mesh sizes (1.5, 2.0, and 2.5 inches) and difference of yarn thickness (D) (0.15 mm, 0.20 mm and 0.25 mm) with 12 times repetition. The hypothesis tested was the effect of treatment of difference of mesh size and yarn diameter to the catch as follows:
$H_0 : \mu_1 = \mu_2 = \mu_n$ (treatment has no effect on flowerhorn cichlid catch)
$H_1 : \mu_1 \neq \mu_2 \neq \mu_n$ (at least one treatment where $\mu_n \neq 0$

The F test (*ANOVA: Two-Factor Without Replication*) was used following *Least Significant Difference* (LSD) test to determine the significance of the controlling treatment for flowerhorn cichlid by the formula:

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$$LSD = (t_{0.05/2,dfw})\sqrt{\frac{2MSw}{n}} \quad \text{..... ..... (2)}$$

where,
LSD = *Least Significant Difference*
$t_{0.05}$ = critical value from the t-distribution table ($\alpha = 0.05$)
df_w = degree of freedom
MSw = mean square within, obtained from the results of the ANOVA test
n = number of replication

3. Results

3.1. Distribution of the Flowerhorn Cichlid as Invasive Alien Fishes

The *flowerhorn cichlid* caught in Lake Matano had a total length ranging from 4.2 to 22.4 cm. The fish was caught on particular mesh sizes (1.0; 1.5 and 2.0 inches) and the yarn thickness. The 0.75-inch mesh size caught a high amount of native fish species, especially for *Telmatherina* spp. (*Opudi*),

while the mesh size > 2.5 inches had a deficient number of catches. The sufficient mesh size for capturing flowerhorn cichlid but low for native fishes was 1.5, 2.0 and 2.5 inches, while mesh size of ≤ 1.0 inches was poorly used for flowerhorn cichlid control because it profoundly caught the native fishes (figure 2).

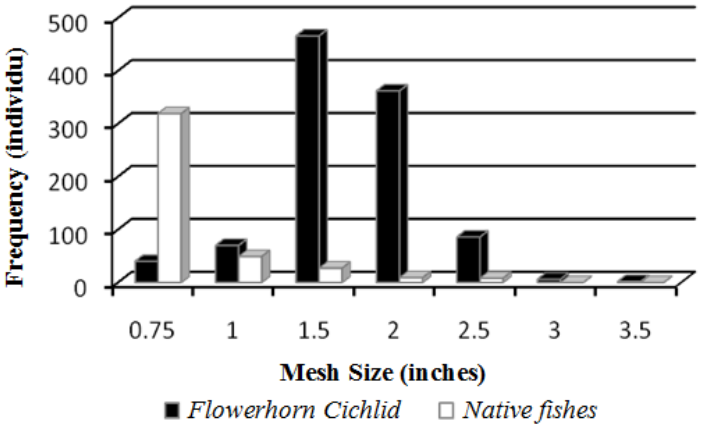

Figure 2. Catch distribution of flowerhorn cichlid based on mesh size in Lake Matano.

The observed research stations were divided into the dominant bottom characteristics of the waters, i.e., rocks, sand, mud, and aquatic plants (dominant species of submerged water plants). Based on the substrate characteristics, the division of each type of substrate was divided into 4. The sand substrate that was overgrown with submerged water plants consists of Matano Village, Ontalo Island, Petea, Kupu-Kupu Beach; the rock-sand substrates consist of Soroako, Rusunawa, Nuha, Impian Beach; the sandstone substrate consists of Otuno, Woiso, Ensa, Tapuntole, Neowi; and the sandy mud substrate consists of Tanah Merah.

The horizontal distribution of flowerhorn cichlid was very high (> 60%) in Matano Village, Ontalo Island, Kupu-Kupu Beach, Soroako, Impian Beach, and Petea 2 (figure 3). However, in Petea 1 and Otuno region adjacent to the outlet area had a relatively low abundance of flowerhorn cichlid (<30%). An attempt by experimental fishing for investigating vertical distribution of flowerhorn cichlid showed decreasing of total catch with increasing depth [27] (figure 4). However, the flowerhorn cichlid with bigger body size was found at > 15 m depth.

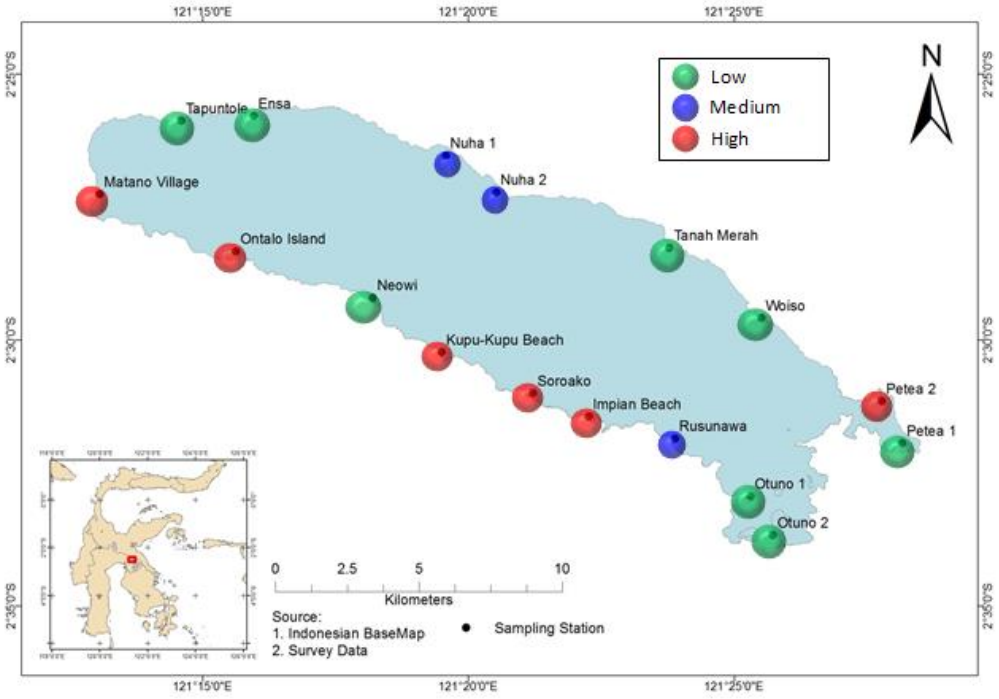

Figure 3. Horizontal distribution of flowerhorn cichlid in Lake Matano

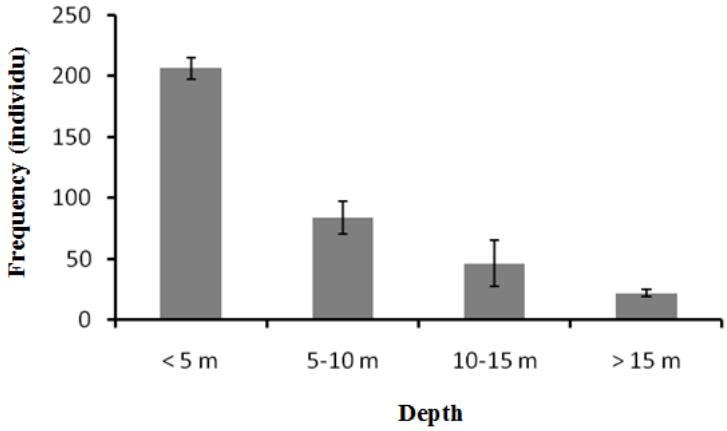

Figure 4. Vertical distribution of flowerhorn cichlid in Lake Matano [27].

3.2. Selectivity and effectiveness of gillnets

The flowerhorn cichlid controlling as invasive alien fish in Lake Matano was effectively carried out using the fishing method. A fishing gear that had the capability of capturing flowerhorn cichlid in large quantities and selectively without the risk and the great opportunity for native fishes was gillnets. The gillnets selectivity was analyzed for mesh size of 1.5, 2.0, and 2.5 inches.

The selectivity factor (SF) for the three mesh sizes was 3.02. The 1.5-inch mesh size had an optimal for flowerhorn cichlid captured at 11.5 cm TL, 2.0 inches for 15.3 cm TL, and 2.5 inches for 19.2 cm TL (figure 5). A significant mesh size that could catch a lot of flowerhorn cichlid but a few for native fishes and captured flowerhorn cichlid before mature or spawn (Lm) was 1.5 inches mesh size. The length at maturity (L_m) for female and male flowerhorn cichlid was 12 cm and 14.2 cm, respectively.

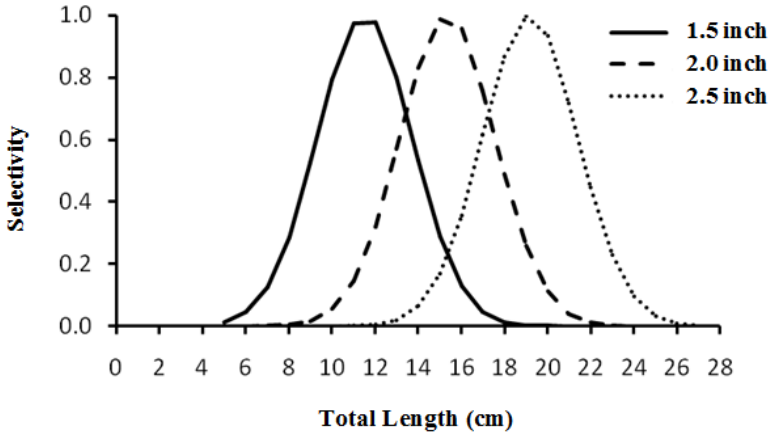

Figure 5. Gillnets selectivity for flowerhorn cichlid in Lake Matano.

The study of fishing effectiveness with different yarn diameter (D = 0.15, 0.20, 0.25 mm) and various mesh size using ANOVA & LSD test showed that the yarn diameter did not significantly affect the flowerhorn cichlid fishing ($P<0.05$). However, the mesh size of 1.5 inches was significantly different ($P>0.05$) to other mesh sizes.

4. Discussion

The flowerhorn cichlid had spread and could be caught in all the waters of Lake Matano, especially in the littoral area. This result showed the distribution data and the adaptation level of the flowerhorn cichlid in Lake Matano. However, in Petea which is the region adjacent to the outlet area had a relatively low abundance, similar to Herder *et al*. [7]. The flowerhorn cichlid was able to be adapt in all types of habitat characteristics and various types of substrates, especially it on the sand bottom substrate and overgrown with submerged water plants where the fish abundantly found [7,27,28].

The efforts to prevent and control invasive alien fish species (IAS) require the involvement of various parties in synergy through strong cross-sectoral coordination at the national level. Government supported the research and development related to IAS impacts, such as impact mitigation methods, is also needed. Therefore, it was necessary to build the complete system information for IAS distribution and circulation, threat detection and attacks as well as for controlling and eradicating the IAS.

Complete system information is needed to build basic data on the spread and distribution, threat detection, and the negative impact of IAS. The basis of prevention and IAS control has been stated in the Regulation of the Minister of Marine Affairs and Fisheries Number: PER.17/MEN/2009 concerning Prohibition of Import of Several Fish Species from Overseas into the Territory of the Republic of Indonesia. On the other hand, comprehensive prevention and control measures against the IAS have not been visible, either by governments, universities, private institutions, NGOs or the communities themselves. The level of public understanding of the dangers and threats of IAS needs to be improved.

Based on our studies conducted in 2015-2016, we propose some concepts, techniques of management, and control for the IAS population in the Lake Malili Complex, especially in Lake Matano, to be utilized by the relevant stakeholders. The efforts needed for managing fisheries, especially related to the IAS, are as follows:

1. There is a need for synergy between the Center for Conservation of Natural Resources of South Sulawesi Province, Ministry of Environment and Forestry, as the management authority of Lake Matano, and the Office of Marine and Fisheries of East Luwu Regency, as the supervisor and the

surrounding community as the lake water users, to control flowerhorn cichlid population by capture continuously.
2. The flowerhorn cichlid can be caught and controlled using gillnets. The gillnet specifications used are made from monofilament yarn with 1.5-inch as an optimal mesh size for capturing them. The yarn thickness can be adjusted because it did not affect the catch significantly.
3. An intensive fishing effort can be conducted, especially in the flowerhorn cichlid spawn season, at the beginning of the rainy season.
4. The flowerhorn cichlid fishing shall be done in areas with sand substrate and overgrown with aquatic plants and high anthropogenic activity.
5. The capture shall be done in the littoral area (<100 m to the lake), done during the day because the endemic crabs would be highly caught in the night.

The prevention efforts for reducing IAS in Lake Matano must be a concern for some point as follows:
1. Fish cultivation at the surrounding of Lake Matano needs to be supervised to prevent the unintentional release of introduced culture fishes such as carp fish, tilapia, and catfish to Lake Matano as those fishes can proliferate and potential to be an invasive alien species.
2. We need to educate the community about the importance of species biodiversity and endemicity in Lake Matano and the negative impact of IAS.
3. In order to stimulate flowerhorn cichlid fishing activities, the local governments (i.e., Provincial or District Government, The Office of Marine and Fisheries, and other relevant agencies) need to hold a massively flowerhorn cichlid fishing activity as it was done in 2014.
4. The local government and relevant stakeholders issue some regulations in prevention efforts by prohibiting the introduction of alien fish species and providing the rule of law and punishment. Socialization to the people needs to be intensified for the effectiveness of the regulations that have been made.
5. It is necessary to determine a conservation area for the native fishes species from Lake Matano. Areas that can be proposed as conservation areas are Woiso, Neowi, Tapuntole, Enda and Otuno based on criteria low abundance of IAS from this research.

5. Conclusion

An effective mesh size gillnet for controlling flowerhorn cichlid in Lake Matano is 1.5 inches. The thickness of the yarn did not significantly affect for flowerhorn cichlid fishing. For effectiveness, gillnets are better to operate in littoral areas of lakes, mainly associated with the sand substrate with macrophytes and more anthropogenic activities. The operation of the gillnet in Lake Matano needs to be regulated in terms of location and setting time to minimize the capture of fish species other than flowerhorn cichlid.

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