Spatial-temporal analysis of catch fish communities structure with gillnet technology in Lake Mahalona, East Luwu District, Indonesia

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Abstract. Lake Mahalona is a tectonic ecosystem area with clear and relatively calm water. The lake has a depth of approximately 73 m, and an area of 2377.5 ha. It is a center of community capture fisheries activities. The study aims to analyze the structure of catch fish communities by using spatio-temporal gillnet technology data. This research was carried out in Lake Mahalona, East Luwu Regency, from March to November 2019. The research was done by using an experimental fishing method in six research stations surrounding the lake, namely by using gillnets as fishing gear. The results showed that the Shannon-Wiener (H') diversity index was relatively moderate. ANOSIM indicated that the abundance of caught fish between stations or habitats was not significantly different (R=-0.139; p=0.09), while the abundance of caught fish by seasons was significantly different (R=0.342; p=0.081). SIMPER analysis showed that louhan fish (*Amphilophus trimaculatus*) was the main species (marker species) found, based on habitat and season. Louhan contribution is relatively high in the Tandu Mata (TM) habitat, which is 49.72%.
Key Words: gillnet, lake Mahalona, louhan (*Amphilophus trimaculatus*), moderate.

Introduction. Lake Mahalona is one of 3 tectonic lake clusters in the Malili complex. It is located in the northern part of South Sulawesi Province, directly bordered by Moroali Regency, Central Sulawesi Province. Lake Mahalona is an area that represents the lake ecosystem with beautiful natural scenery, with clear water and calm water flow. According to Whitten et al (2002), Lake Mahalona has a depth of up to 73 m with an area of 2337.5 ha. The lake is thought to have formed from folds of hills or wide rivers. Lake Mahalona is the center of capture fisheries activities for people who live around the lake. This lake has some endemic fish, namely buttini (*Glossogobius matanensis*) and botoboto (*Glossogobius* sp.), as well as some local fish. It can be said that the lake has a high biodiversity (Hadiaty & Wirjoatmodjo 2002). The lake's endemic fish have a delicious taste. Fishermen on the lake do not use selective and environmentally friendly fishing gear. According to Sulistiyarto et al (2007), buttini has meat that tastes good, being very popular and widely consumed by residents around the lake.

Lake Mahalona’s endemic fish are endangered due to several factors: 1) the use of fishing gear that is not environmentally friendly (for example guiding barrier fishing gear powered by electricity); 2) the intensity of fishing that can cause overfishing and overexploitation; commonly used fishing gear technologies are gillnets, guiding barriers, bottom traps, and rod and lines; 3) the presence of introduced fish, like Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*Oreochromis niloticus*) and louhan (*Amphilophus trimaculatus*). The introduced fish have become dominant and invasive. This happened because of the high reproduction and growth rate, influenced by the good quality of the environment (Sulistiyarto et al 2007). However, the introduced fish have become preferred by the local community, because they have better economic value. If not handled quickly, these problems can cause the extinction of the endemic fish. Lake

Mahalona's local endemic fish is divided into 2 groups, namely: the main endemic fish, buttini and botoboto, and other local fish such as snakeskin gourami (*Trichogaster* sp.), climbing perch (*Anabas* sp.), carp (*Cyprinus* sp.), and others.

Research about the distribution of introduced fish and local fish based on habitat and season is needed for better management (Prianto et al 2016), so the sustainability of endemic fish can be maintained and the movement of introduced fish restricted. This study aimed to analyze the structure of fish communities (fish species, abundance, diversity index, and dominance), clustering, and main species caught using gillnets in Lake Mahalona, East Luwu Regency, Indonesia.

Material and Method. The research was carried out on Lake Mahalona, in 3 villages: Tole Village, Mahalona Village, and Buangin Village. The location of the lake is in Towuti District, East Luwu Regency (Figure 1). The research took place from March to November 2019. The samples were collected during 3 seasons: the transition season March-May (TS), the rainy season (RS) in June-August, and the dry season (DS) in September-November.

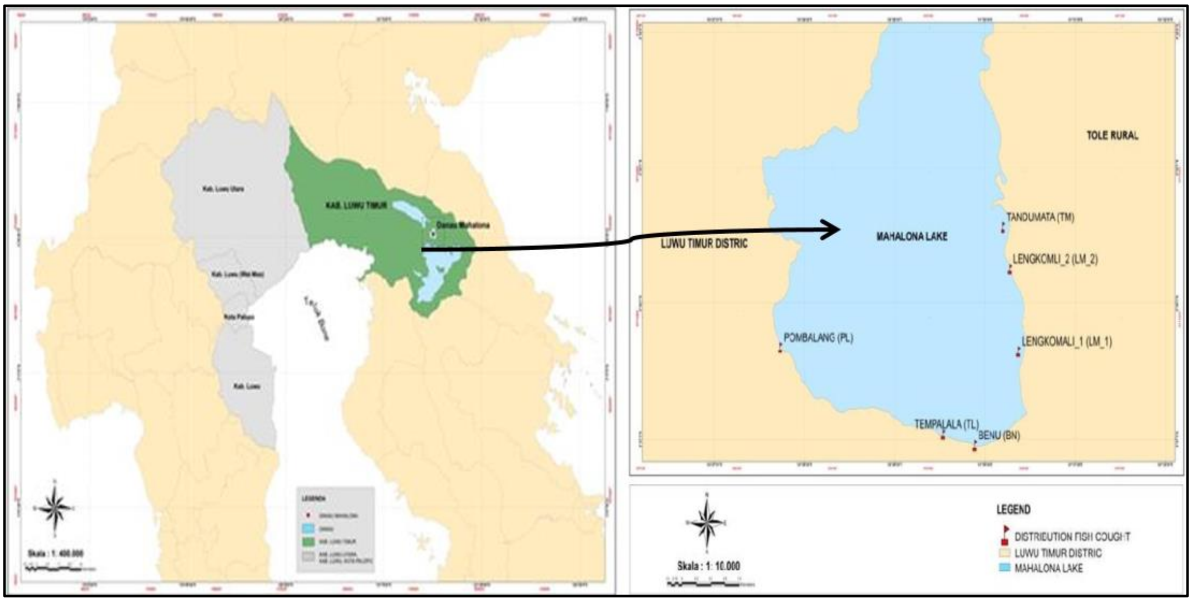

Figure 1. Research map in Lake Mahalona.

Research design. 6 research stations were established based on habitat. The stations were determined using the zoning (segmentation) method. Determination of the research stations as the location of the gillnet fishing gear operations was based on the assumptions that: (1) the fish samples will represent the spatial and temporal distribution of fish, (2) the habitat is different according to the fish distribution, and (3) differences of physico-chemical and biological parameters of the water. Thus, 6 stations (habitats) were determined. The coordinates of each station were recorded using the Global Positioning System (GPS) (Table 1).

The gillnet used in this study is a surface gillnet that uses a head rope and foot rope and is equipped with a buoy and sinker. The net body has a height of 2 m and a length of 50 m. The material used in the gillnet technology is presented in Table 2. The gillnet construction is presented in Figure 2. The dominant fishing gear used by fishermen in the Malili Lake is the gillnet (Samuel et al 2009).

Table 1

Characteristic of the research location divided into 6 fish sampling stations

Habitats (Stations)	*Coordinates*	*Description*
Lengko Mali -1 (LM-1)	2°36'23.68"S 121°30'56.67"E	Shore are overgrown with vegetation; there are water plants, plantations and rice fields. Depth of water of 1-3 m, water brightness 80-90%. Dominant substrate is muddy, slightly sandy.
Lengko Mali-2 (LM-2)	02° 35′ 46.6″S 121°30′ 50.9″E	Depth of water 1-3 m, water brightness 80-90%. Dominant substrate muddy, slightly sandy. Shore are overgrown with vegetation; there are water plants, plantations and rice fields.
Tandu Mata (TM)	2°35'27.82"S 121°30'46.30"E	Depth of water of 1-4 m; water brightness of 90%. Rocky, muddy, and slightly gritty substrate. Shore is overgrown with trees, and little vegetation is spreading, overgrown by aquatic plants.
Benu (BN)	02° 37′ 05.8″S 121° 30′ 27.2″E	Water depth of 0.5–3 m. Brightness level of 90-100%. The beach is sloping with a slightly muddy sandy substrate.
Tompalala (TL)	02° 37′ 00.9″S 121° 30′ 05.7″E	The shore is overgrown by trees, with the changes being a community garden. The beach is steep, with a water depth of 1-5 m, sand substrate, with water plants with high density.
Pembalaang (PL)	02°36'21.6"S 121°28'15.72"E	The shore is overgrown by trees, with the changes being a community garden. There are springs from the hills. The beach is steep, with a water depth of 1-5 m. Sand substrate with water plants with high density.

Table 2

Materials used in gillnet construction

Component	*Material*	*Size*	
Sign floats	Styrofoam	20 g	2 units
Gillnet float	Styrofoam	5 g	100 units
Headrope/Footrope	Nylon	no. 6	120 m
Upper/Lower selvedge line	Nylon	no. 4	100 m
Net body	Monofilament	no. 0.35	100 m^2
Sinker	Black tin	10 g	150 seeds
Sinker line	Nylon	no. 4	120 m

The determination of the gillnet placement point in each station took into consideration habitat characteristics: 1) the water depth at the lowest recede of at least 2.5 m; 2) safe from the traffic of fishing boats; and 3) the brightness of the water. The gillnet was positioned in the water column in line with the coastal levels of the lake (horizontal). The distance from the head rope to the water surface was 30 cm.

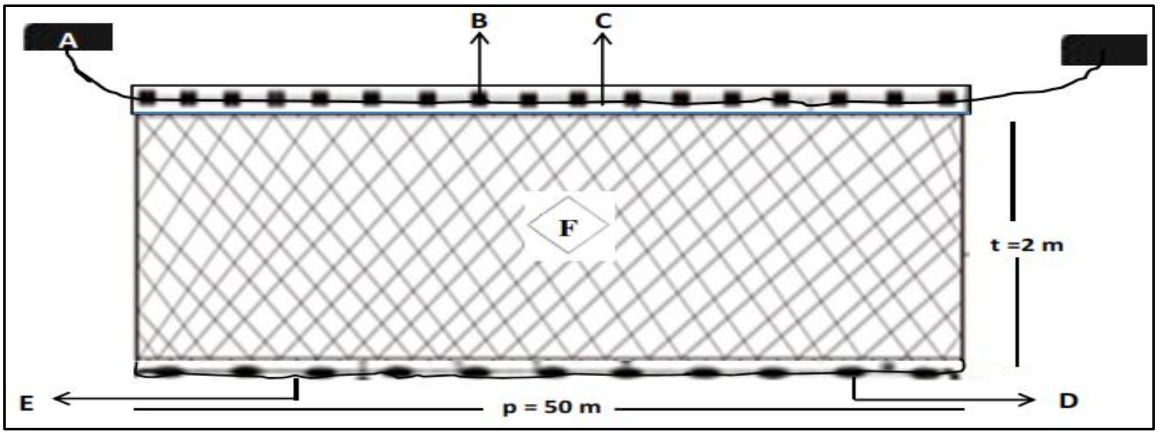

Figure 2. Gillnet used for sampling fish in Lake Mahalona; A - float signs; B - gillnet float; C - headrope; D - sinker; E - footrope; F - mesh size.

Data collection. The gillnet was installed in the morning at the designated station using a boat. The gillnet installation begun by lowering the float signs, then lowering the net body, while rowing the boat on the shoreline. After completing the gillnet installation, the gillnet was immersed for 5 h. The gillnet was pulled at midday and it was operated by 3 people with different tasks. The gillnet catch from each station was collected in plastic containers. Fish sampling was done 3 times in one season.

Data analysis. Determining the fish community structure by gillnet catch was done by grouping the catch spatially (based on habitat) and temporally (by month/season). Fish catch data were analyzed, obtaining the number of species, abundance, and diversity index. To study diversity parameters, the correlation between the parameters, characteristics of species and similarities, multivariate statistics were performed using PRIMER (Plymouth Routines in Multivariates Ecological Research) software version 5.2 (Clarke & Gorley 2001; Taurusman 2007).

Abundance analysis (A). Fish abundance was based on families and species. The results of the grouping were analyzed by comparing the average abundance of fish per habitat and season. The abundance of organisms in water is expressed as a single number per area (Odum 1975), calculated by the equation:

$$A = \frac{Xi}{Ni}$$

Where: A - abundance of individuals (ind m^{-2}); Xi - number of individuals of species i; ni - the total number of species quadrant.

Diversity index. We determined the Diversity index (H') using the Krebs (1989) formulation. This analysis consists of the number of types (s) of individual numbers (N), the Margalef's Species Richness (D), the independence of Pielou's evenness (J'), and Shannon-Wiener's Diversity index (H'). The diversity index was determined with the following equation:

$$H' = -\sum_{i=1}^{s} P_i \, Log_2 P_i$$

$$H' = -\sum_{i=1}^{s} \left(\frac{ni}{N}\right) Log_2 \left(\frac{ni}{N}\right)$$

Where: H' - the Shannon-Wiener Diversity Index; s - number of taxa; Pi - n/N; ni - individual number of types to I; N - total number of individuals. H' will be maximum if all species or genera are spread homogeneously.

Cluster analysis. Cluster analysis was conducted to determine the structure relation of fish catches spatially and temporally. The Bray-Curtis similarity index was used to create the value of the similarity between the data of the catches based on habitat and season. In the initial step, data was standardized using four root transformations (4h root transformed). Furthermore, the cluster analysis was split into dendrogram form and statistical testing.

Analysis of similarities (ANOSIM). Analysis of the similarity was used to test the real difference in the abundance of fish from gillnet catch spatially and temporally. ANOSIM is a non-parametric analysis carried out based on the rank of values in the matrix similarity (Quinn & Keough 2002; Taurusman 2011; Suardi et al 2019). Taurusman (2011) recommends using ANOSIM to test different hypotheses between groups in multivariate statistics. The relationship of similarity is based on the changes in R values according to the following equation:

$$R = \frac{aver.\ rb - aver\ .rw}{M\ 2}$$

$$M = \frac{n(n-1)}{2}$$

Where: *aver. rb* - average ranking of data similarity between groups; *aver. rw* - average ranking of data similarity within a group or in a particular habitat, month/season.

The interpretation of the R-value (Clarke's R) describes the level of difference between groups, with a scale from 0, where differences do not exist, to 1, where all data in the group are less similar than the similarity of data between groups.

Similarity percentage (SIMPER). This analysis was used to identify the key species that determine the characteristics of a data group (in this case, habitat and season), usually determined by the value of an individual or weighted spread similarities.

Results and Discussion. The catches using gillnet technology at Lake Mahalona within 9 months are grouped into 3 seasons and 6 stations. The composition of fish catches in Lake Mahalona consists of 6 species, grouped in two categories, namely local endemic fish groups and introduced fish groups. There are three species of local endemic fish: snakeskin gourami, climbing perch, and buttini, while the introduced fish were Mozambique tilapia, Nile tilapia, and louhan. The composition of fish catches is presented in Table 3.

Table 3

The type of catch by using gillnet fishing gear technology in Lake Mahalona

Fish type and naming		
Local name	*Indonesian name*	*Scientific name*
Bale Janggo'	Sepat siam	*Trichogaster pectoralis*
Kosang	Betok	*Anabas testudineus*
Mujair	Majair	*Oreochromis mossambicus*
Buttini	Buttini	*Glossogobius metanensis*
Nila	Nila	*Oreochromis niloticus*
Louhan	Louhan	*Amphilophus trimaculatus*

Table 3 showed that 6 species were found in Lake Mahalona captured by using gillnet technology. The number of species that were caught with a gillnet in Lake Mahalona was less than the number of species caught in Lake Burung and Lake Hanjalutung, which was 18 species for each (Fauziah et al 2017; Sweking et al 2019). 14 species were found in Lake Rokan Hilir and 17 fish species in the waters of Lebak Jungkal, Ogan Kerin Ilir Sipogas. The difference in the number of gillnet catch species occurred presumably because the gillnet used in this study had a 5.08 cm mesh size, so small fish or very large fish could not be entangled. The gillnet mesh size of 6.4 cm effectively captures surface fish, especially tilapia in the Cacaban reservoir (Miftahurrohman et al 2016).

The number of gillnet caught species based on the habitat (station) was highest in Lengko Mali-1 (LM-1) habitat (Table 3), with 182 ind m^{-2} and the lowest was in PL, with 56 ind m^{-2}. The high catch of fish in the LM-1 habitat occurred presumably because this habitat has a muddy substrate and a small amount of sandy aquatic plants that grow entirely in the water column. In addition, parts of the littoral area are widely covered with vegetation and various ecological niches are able to develop. These conditions support the survival of various fish and other organisms, especially the introduced fish (Mozambique tilapia, Nile tilapia, and louhan). The presence of Mozambique tilapia, Nile tilapia, and louhan in Lake Batur illustrates that the introduced fish have been able to live and adapt well to the environment (Sentosa & Wijaya 2013).

The diversity index (*H´*) of fish captured with gillnet technology among habitats (stations) in Lake Mahalona was relatively moderate or tended to be high, with the value of 1.852-2.645 (Table 4) compared to the results of Binur (2008) in Lake Tes Bengkulu, who obtained a H′ value between 0.7-1.27. The moderate or high spatial fish catch in Lake Mahalona could have occurred due to several factors, described next. Firstly, the number of fishermen conducting fishing operations in Lake Mahalona was less than 5. According to Samuel et al (2009), in Lake Towuti, the number of fishermen operating was around 25-30, so the diversity index of captured fish in our study tended to be lower. According to Michael (1994), high species diversity in a community shows the stability of the community and vice versa. Secondly, there were fewer variations of fishing gear operated by fishermen in Lake Mahalona, namely 4 types of fishing gear. Weri & Sucahyo (2017) found that eight types of fishing gear from the net group were used in the Rawa Pening Reservoir.

Table 4

The diversity indices of fish captured by gillnet based on habitat (station)

Habitat/Station	*Species no.*	*N (ind m^{-2})*	*J′*	*H' (log)*	*H' (log2)*	*D*
LM-1	6	182	0.902	1.756	2.533	0.802
LM-2	6	141	0.942	1.834	2.645	0.829
TM	6	67	0.773	1.505	2.171	0.723
BN	6	169	0.818	1.594	2.299	0.755
TL	6	119	0.810	1.576	2.274	0.770
PL	5	56	0.797	1.283	1.852	0.705

Note: LM-1 - Lengko Mali-1; LM-2 - Lengko Mali-2; TM - Tandu Mata; BN - Benu; TL - Tompalala; PL - Pembalaang.

Furthermore, the diversity index (H') of fish catch in Lake Mahalona based on the season was relatively high with an average value of 2.32. The relatively high diversity index value indicates that the structure of the fish community in Lake Mahalona was in a stable condition in each season. Brower et al (1990) stated that a community has a high diversity of species, if there are many species with the number of individuals relatively evenly distributed, and low diversity when species are few, and the number of individuals is uneven. Simanjuntak (2012) obtained a diversity index in the rainy and dry seasons in Lebak Jungkal waters lower when compared to the results of our study. Ridho et al (2019) found the highest species diversity index in the dry season.

Table 5

Index of fish diversity for gillnet captured fish by season

Seasons	*Species no.*	*N (ind m*$^{-2}$*)*	*J'*	*H' (log2)*	*H' (log10)*	*D*
MP	6	18	0.91	2.56	0.77	0.81
MH	6	125	0.86	2. 42	0.73	0.78
MK	6	95	0.68	1.92	0.58	0.69

Note: MP - transitional season; MH - rainy season; MK - dry season.

Clusters of fish catch. The grouping of fish catch by gillnet aims to determine the similarity of the abundance of fish catch based on location and season, to help improve further fishing activities in the area.

Grouping of observations stations was done with the Bray Curtis similarity index. The sample habitats (stations) were divided into three groups: the first group combining Tompalala (TL) station with Benu (BN) station, the second group includes Lengko Mali-2 (LM-2) and Lengko Mali-1 (LM-1) and the third group is Pembalaan (PL) with Tandu Mata (TM) (Figure 3). ANOSIM results show that there was no significant differences in the abundance of fish catch in each station on Lake Mahalona, with Global R=-0.139 and p=0.09.

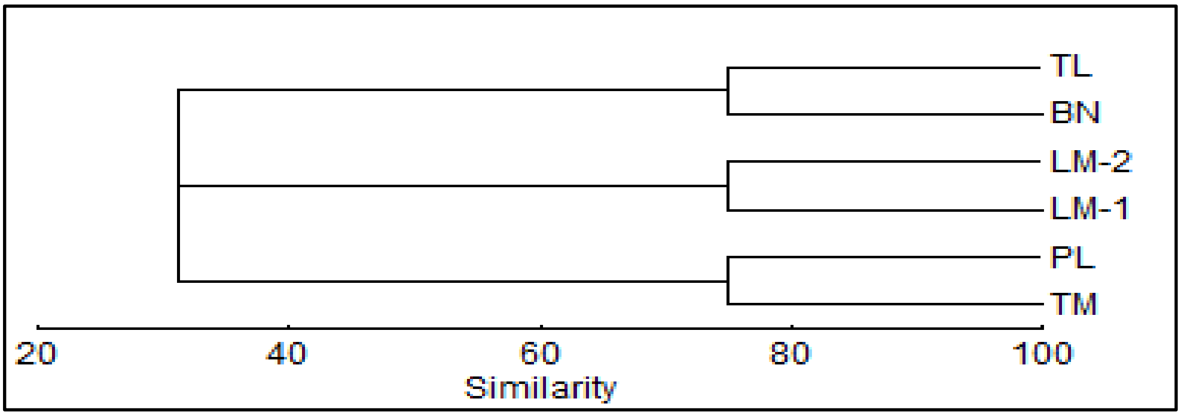

Figure 3. Dendrogram of fish caught by station; LM-1 - Lengko Mali -1; LM-2 - Lengko Mali -2; TM - Tandu Mata; BN - Benu; TL - Tompalala; PL - Pembalaan.

Clustering of fish catch abundance temporally using gillnet technology was analyzed using the Bray Curtis similarity index. Based on the analysis regarding the grouping of seasons, the sampling was divided in two groups (Figure 4). The first group was represented by the dry season (MK) and transition season (MP), and the second group was represented by the rainy season (MH).

The results of the similarity analysis (ANOSIM) showed that, in general, there were no significant differences in the abundance of fish catch in each season in Lake Mahalona (Global R=0.342 and p=0.90). The abundance was similar is the transitional season (MP) and the rainy season (MH) (R=0.002; p=0.37). Furthermore, there was a difference in catch abundance between the rainy season (MH) and the dry season (MK) (R=0.35; p=1.5). The relationship between the level of the fish catches in the transitional season (MP) and the rainy season (MH), which was quite high, was thought to occur because the lake waters have similar physical properties in these two seasons. The distribution of fish in lake waters is influenced by abiotic factors (water quality and habitat) and biotic factors (natural food and aquatic plants) (Nasution et al 2007). Sulistiyarto et al (2007) found that fish abundance tends to be higher in the shallow or dry season (DS) than in the rainy season (RS). Changes in water quality and depth cause fish migration.

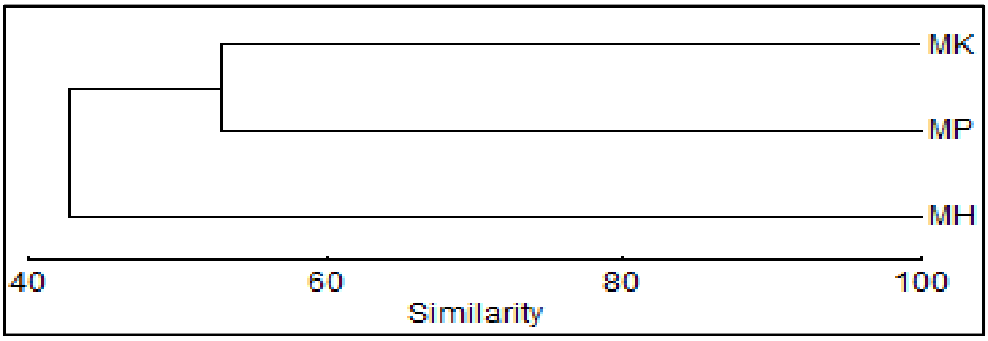

Figure 4. Dendrogram abundance of fish catches by season; MP - transition season; MH - rainy season; MK - dry season.

Identifying captured fish. SIMPER aims to determine the type of fish or main species captured by gillnet spatially and temporally. The main species caught are presented in Tables 6 and 7.

Table 6

Characteristics of fish catch and their contribution spatially (habitat)

Taxa	*Habitat and contribution percentage (%)*						
	LM-1	*LM-2*	*TM*	*BN*	*TL*	*PL*	*Average*
Amphilophus trimaculatus	46.58	33.26	49.72	43.65	33.24	48.54	42.49
Glossogobius metanensis	8.64	8.62	13.81	31.02	27.26	33.64	20.19
Oreochromis niloticus	16.41	28.32	25.0	13.05	24.5	14.58	20.30
Oreochromis mossambicus	8.10	16.40	11.48	6.14	12.53	0.00	9.06
Anabas testudineus	10.38	0.00	0.00	0.00	0.00	0.00	1.73
Trichogaster pectoralis	0.00	4.93	0.00	0.00	0.00	0.00	0.82

Note: LM-1 - Lengko Mali -1; LM-2 - Lengko Mali -2; TM - Tandu Mata; BN - Benu; TL - Tompalala; PL - Pembalaan.

The SIMPER analysis results are presented in Table 7. The main species of gillnet catch with the highest percentage (spatially) in Lake Mahalona was louhan with 42.49%, and Nile tilapia, with 20.30%, both being introduced species.

Introduced fish have adapted to the conditions of the lake. Fish introduced in a freshwater ecosystem will have an impact on the structure of fish communities, sometimes becoming dominant species (Oktaviani 2008). Purnomo & Utomo (2013) mentioned that tilapia is also dominantly found in several reservoirs and sites in West and Central Java. Tilapia is one of the most successful species to live and develop in various areas of the mainland public waters in Indonesia (Wijaya et al 2011).

Table 7

Characteristics of fish catch and their contributions temporally (seasonally)

Fish species	*Season and contribution percentage*			
	MP	*MH*	*MK*	*Average*
Amphilophus trimaculatus	37.47	50.37	27.48	38. 44
Glossogobius metanensis	11.94	16.00	43.95	23.96
Oreochromis niloticus	24.54	14.45	19.90	19.63
Oreochromis mossambicus	13.27	6.35	0.00	6.54
Anabas testudineus	6.08	6.33	0.00	4.13
Trichogaster pectoralis	0.00	2.00	0.00	0.00

Note: MP - transition season; MH - rainy season; MK - dry season.

Based on Table 6, the highest percentage of captured fish temporally was louhan, with 38.44%. Syafei (2017) found that introduced fish can eliminate local fish because the local fish cannot compete with introduced fish in obtaining feed and occupying spawning area. Moreover, local fish can be preyed on by introduced fish.

Conclusions. Research in Lake Mahalona using gillnet technology during nine months in 6 stations (habitats) and 3 seasons found 6 species. The Shannon-Wiener (H') diversity index was relatively moderate for the catches grouped spatially and temporally. The highest abundance of fish catch based on habitat (station) was in the Lengko Mali-1 (LM-1) station, with 182 ind m^{-2}, and the lowest was in the Pembalaan (PL) station, with 56 ind m^{-2}. ANOSIM showed that fish catches among habitats were not significantly different, (R=-0.139; p=0.09), while the fish catches among seasons were significantly different (R=0.342; p=0.081). SIMPER analysis shows that louhan (*A. trimaculatus*) was the main species found based on habitat and season. The highest contribution of louhan was in the Tandu Mata (TM) station, with 49.72%.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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