Population dynamic of bungo fish (*Glossogobius giuris*) in three integrated lakes (Danau Tempe, Danau Sidenreng, and Danau Lampokka) South Sulawesi during rainy season

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The rapid growth and production of bungo fish without management efforts will threaten the sustainability of endemic fish in the three lakes (Tempe Lake, Sidenreng Lake and Lapompakka Lake) which are located in the central part of the South Sulawesi region. In order to manage Bungo fish resources, information on population dynamics is needed. This research aims to save the Bungo fish species which are endemic to Tempe, Sidenreng, and Lapompakka Lakes, and other lakes in South Sulawesi from the threat of extinction. Bungo fish samples (*Glossogobius giuris*) were collected from fishermen's catch during July - September 2020 in three lakes, namely the waters of Tempe Lake, Sidenreng Lake, and Lapompakka Lake. Sample measurements were carried out at the Laboratory of Fish Biology, Faculty of Marine and Fisheries Sciences, Hasanuddin University. The results showed that Lake Sidenreng had more age groups of bungo fish compared to Lake Tempe and Lake Lapompakka. The lengths found in Lake Tempe were longer than those found in Lake Sidenreng and Lake Lapompakka, and the smallest length of bungo fish was found in Lake Lapompakka. Bungo fish found in Sidenreng Lake and Lapompakka Lake are classified as fast growth because the K value is greater than 0.5, while in Lake Tempe it is classified as slow because it is smaller than 0.5. The natural mortality rate of bungo fish was more prevalent in bungo fish aged around 1 and 2 years and this was found in all three waters. Mortality that occurred at the three locations was due to natural mortality because the M value was greater than the F value.

1. Introduction

South Sulawesi have high potential in fisheries, in marine and freshwater. Research mostly done for marine, but inland also have potential to be manage. Inland water research still low and it is mostly done by foreign researcher and LIPI. Sulawesi, as in Wallace Region store many potentials [1, 2, 3, 4], including the lakes, such as Tempe Lakes, Sidenreng Lakes, Matano Lakes, Mahalona Lakes, Towuti Lakes, Wawantoa Lakes, Masapi Lakes, Lamompakka Lakes, etc. These lakes have very high genetic and species diversity, with very high endemicity.

Tempe Lakes is one of the biggest lakes from big lakes located in central area of South Sulawesi. There are two lakes at north part of Tempe Lake: Sidenreng Lake and Lapompakka Lake (Crocodiles Lake). Tempe lake has an area about 13,000 are. It has freshwater fishes that rarely found in other area. Geographically it is located between 1190 53’ and 1200 4’ BT and between 40 3’ and 40 9’ LS. The three lakes are separated during dry season and integrated during rainy season [5].

One of fish species that is endemic to lakes in Sulawesi is Bungo Fish (*Glossogobius giuris*). This fish could be found in the Tempe lake system. It has high economic value because it is a consumption fish with a distinctive taste with a high price ranging from IDR 50,000 to IDR 80,000 per kilogram. Bungo fish can be consumed fresh or dry. Compared to other fish species with high economic value, such as goldfish, bungo fish have not received much attention, both from researchers and local
governments, so that efforts have not yet been made to conserve or protect their population and habitat. On the other hand, Bungo fish has experienced a decline in population due to high levels of exploitation and changes in environmental conditions, especially sedimentation and water pollution which causes habitat fragmentation. As a result, this fish population is already very threatened [6]. If this condition is continuing, the existence of this Bungo fish population as an endemic germplasm of Lake Tempe will continue to be degraded and one day it will potentially experience extinction. Therefore, efforts to save this fish species must be carried out immediately, among others, by implementing appropriate and wise management strategies for the Bungo fish resources in the waters of Lake Tempe and its surroundings (Lake Sidenreng and Lake Lapompakka).

Bungo fish resource management strategy requires basic data, including population genetic data through a comprehensive series of studies on genetic diversity and population dynamics throughout the year, namely in the rainy season with the hypothesis that the waters of the three lakes are integrated or not isolated between lakes and dry season with the hypothesis that the three lakes are separate or isolated between lakes.

The research was carried out in the rainy season in the form of population dynamics of Bungo fish in the waters of Lake Tempe, Lake Sidenreng, Lake Lapompakka as a unitary ecosystem during the rainy season when the waters between the three lakes unite. The results of this research can be used as basic data for integrated management of Bungo fish based on population genetics in the Lake Tempe ecosystem area and its surroundings. This research is expected to be useful for the development of cultivation technology and conservation of Bungo fish in the waters of the Tempe Lake system (Tempe, Sidenreng, and Lapompakka) so that the endemic germplasm of South Sulawesi can be preserved.

2. **Materials and Method**

2.1. *Time and location*
Research has been done during Mei-July 2020. Sampling was done on Tempe Lake, Sidenreng Lake and Lapompakka Lake, which include in Tempe Lake ecosystem (Figure 1).

2.2. *Source of bungo fish (Glossogobius giuris)*
Fish used in this research is Bungo fish (*Glossogobius giuris*), collected from fishermen catch from Tempe Lake, Sidenreng Lake and Lappompakka Lake. Research was done in the middle of rainy season (May-July 2020), for three months. Indicator for this is the three lakes are in integrated condition. Samples measurement was done in Fisheries Biology laboratory, Faculty of Marine Science and Fisheries, Universitas Hasanuddin

2.3. *Data analysis*
Measurement tabulated into a frequency distribution table with an interval of 0.5 cm using the Excel 2010 program, then the data were analysed using the FISAT program with the Elefan I sub-program to estimate the length of infinity (*L*∞) and growth coefficient (K), according to the formula put forward by Von Bertalanffy [7] with the mathematical equation is:

\[ L_t = L \infty \left(1 - e^{-K(t - to)}\right) \]

**Note:**
- \( L_t \) = Length Bungo Fish (cm) at \( t \) year old (year)
- \( L \infty \) = Asimptot length of Bungo Fish (cm)
- \( K \) = Growth Coefisien (per year)
- \( to \) = The theoretical lifespan of the bungo fish at length is equal to zero (year)
- \( t \) = Age of Bungo Fish (year)
Figure 1. Map of sampling site

Figure 2. Bungo Fish (*Glossogobius giuris*, Hamilton-Buchanan 1822)

Estimation of theoretical age when the length of the Bungo Fish is zero (to) according to Pauly's empirical formula in [7], namely

\[ \log(-\text{to}) = -0.3922 - 0.2752 \log L_\infty - 1.308 \log K \]
to is the theoretical lifespan of the bungo fish when its length is zero (years). Total mortality (Z) was estimated using the curve converted to length method. This curve method has been incorporated in the FISAT-II program [8]. The natural mortality rate (M) was estimated using an empirical relationship [9]:

\[
\text{Log } M = 0.0066 - 0.279 \text{ Log } L_\infty + 0.6543 \text{ Log } K + 0.4634 \text{ Log } T
\]

\( L_\infty \) = growth parameter (cm) and \( T \) = mean annual water environmental temperature (° C). Capture mortality (F) is determined by subtracting M against Z and exploitation rate (E) is determined from \( F / Z \) and size of first caught (Lc) is calculated with the help of the FISAT-II program package [8]. Yield Per Recruitment and relative biomass per recruit (B / R ') as a function of E were determined from estimated growth parameters and catch probability [10] using the FISAT-II program tool.

3. Result and Discussion

3.1. Fish sampling

Sampling of fresh bungo fish was carried out in May - July 2020 in three lakes, namely Lake Sidenreng (Figure 3), Lake Tempe (Figure 4), and Lake Lapompakka (Figure 5) during the peak of the rainy season when the three lake waters unite or connect.

Figure 3. Bungo fish (*Glossogobius giuris*, Hamilton-Buchanan 1822) catch in Lake Sidenreng
3.2. Population dynamic of bungo fish in rainy season

3.2.1. Age group. The number of bungo fish samples obtained during the study at Lake Tempe was 293, ranging in size from 144.00 to 275.00 mm with an average length of 182.80 mm. Based on the results of the analysis of the age group of the Bhattacharya method contained in FISAT II Software, using 2 cm long class intervals obtained 3 age groups, namely age group 1 with a length of 187.12 mm, age group 2 with a length of 201.32 mm, and age group 3 with length 262.64 mm. The age group of Bungo fish that showed the most fish caught was 187.12 mm in length with 271 tails (Figure 6).
Figure 6. Histogram of total length frequency and normal curve of Bungo fish (Glossogobius giuris) (male and female) caught in the waters of Lake Tempe, South Sulawesi.

The number of bungo fish samples obtained during the study at Lake Sidenreng was 193 individuals. Size ranges from 10.00 - 275.75 mm with an average length of 175.62 mm. Based on the results of the analysis of the age group of the Bhattacharya method contained in FISAT II software, using 2 cm long class intervals obtained 4 age groups, namely age group 1 with a length of 137.05 mm, age group 2 with a length of 159.99 mm, age group 3 with a length of 185.53 mm, and age group 4 with a length of 220.77 mm. Bungo fish that showed the most fish caught were in the age group 3 at a length of 185.53 mm, as many as 98 fish (Figure 7).

Figure 7. Histogram of total length frequency and normal curve of Bungo fish (Glossogobius giuris) (male and female) caught in the waters of Sidenreng Lake, South Sulawesi.

The number of Bungo fish samples obtained during the study at Lapompakka Lake was 197 individuals. The size ranges from 90.70 to 217.00 mm with an average length of 145.61 mm. Based on the results of the analysis of the age group of the Bhattacharya method contained in FISAT II Software, using 2 cm long class intervals obtained 3 age groups, namely age group 1 with a length of 135.09 mm, age group 2 with a length of 159.00 mm, and age group 3 with a length of 197.30 mm. The age group of Bungo fish that showed the most fish caught was in the age group 2 at a length of 159.00 mm as many as 89 individuals (Figure 8).

The catch on Lake Sidenreng has a length ranging from 100.00 - 275.75 mm with an average of 175.62 mm. At Lake Lapompakka, the length ranges from 90.70 to 217.00 mm with an average of 145.61 mm. Lake Tempe has a length ranging from 144.00 - 275.00 mm with an average length of 182.80 mm. The length found in Lake Tempe is longer than that found in Lake Sidenreng and Lake Lapompakka, and the smallest length of bungo fish is found in Lake Lapompakka.
Figure 8. Histogram of total length frequency and normal curve of Bungo fish (*Glossogobius giuris*) (male and female) caught in the waters of Lapompakka Lake, South Sulawesi.

Samples for this research were taken from all the catch of fishermen landed during the research time (May to July, 2020), so that each Bungo Fish has the same opportunity to be sampled and at the same time the bias can be reduced. This method is based on [11] says that the samples taken are based on the same time interval. The species samples collected were used to determine growth parameters by single sample analysis with the Ford-Walford plot method. [12] state that sampling is used to determine the characteristics of an individual group without having to identify as a whole to individual group members.

[13] states that a population of marine resources can be divided into several age classes or size classes (cohorts) for the purposes of analysis. The results of the mode grouping analysis of the total length of the bungo fish combined (male and female), male and female, found two types of age groups for each fishing operation, namely one and two groups of length life sizes of the Bungo fish.

The difference in the number of catch cohorts in the three waters, namely Lake Tempe, Lake Sidenreng, and Lake Lampompakka is more due to the occurrence of recruits (entry) of new individuals from the spawning of bungo fish that occurred in the previous months so that the following month. The mode shift of each group of the total body length of the Bungo fish generally occurs in young Bungo fish. This is because the growth of young bungo fish is generally faster than old bungo fish. Young bungo fish generally have a faster growth rate when compared to older bungo fish, old bungo fish continue to grow but progress slowly until approaching the asymptotic length [14] and the body size increases (age old) then the growth rate is small [15].

Factors that influence growth differences are internal factors including genetics [13], gender, age and disease [16, 17] and external factors in the form of environmental factors water [17] and food [18; 19]. Generally, in a population, small bungo fish are usually more numerous than large bungo fish, this is naturally caused by the mortality process that occurs in large bungo fish in a population [11].

Based on the Bhatacharya analysis model which is based on total length data during the study of Bungo fishing operations, it is obtained an illustration that there are 3 cohorts in Tempe Lake. This shows that it is suspected that the fishing gear used to catch Bungo fish at the three research locations, catches all age groups so that it has a low level of selection and it is feared that Bungo fish that have not had time to regenerate will also be caught. [20, 21] stated that uncontrolled fishing factors have changed the relative abundance of individuals or species in aquatic communities which directly negatively impacts aquatic fertility, ecosystem, biomass, age, first maturity of gonads or food chain dynamics, and [22] stated that the need for fishing activities that prioritize the caution factor of fishing that is selective to size and usually this is done for biological and economic reasons. Based on the results of research that has been done previously, the cohort obtained is less.
3.2.2. Growth. The results of the analysis of the estimated growth parameters of the lake Tempe, Sidenreng, and Lampopakka flower fish using the ELEFEN I method contained in the FISAT II program are presented in Table 1.

**Table 1.** Estimation of growth parameters of bungo fish, *Glossogobius giuris* (Hamilton Buchanan, 1822) combined (male and female) in the waters of Lake Tempe, Sidenreng and Lampopakka

| Sampling Sites   | n (ind.) | L∞    | k     | t₀     | L₁     |
|------------------|---------|-------|-------|--------|--------|
| Lake Tempe       | 293     | 331.95| 0.19  | 0.1    | 331.95 (1 - e⁻⁰.¹⁹(t⁻₀.₁⁰)) |
| Lake Sidenreng   | 193     | 286.25| 0.55  | 0.1    | 286.25 (1 - e⁻⁰.⁵⁵(t⁻₀.¹⁷)) |
| Lake Lapompakka  | 197     | 224.85| 0.64  | 0.1    | 224.85(1 - e⁻⁰.⁶⁴(t⁻₀.¹⁷)) |

The data obtained from the three sampling waters, processed using the ELEFAN I method found in FISAT, obtained the form of the Bungo fish equation is the waters of Lake Tempe $L_t = 331.95 (1 - e^{-0.19(t - 0.10)})$, Lake Sidenreng $L_t = 286.25 (1 - e^{-0.55(t - 0.17)})$, and Lake Lompakka $L_t = 224.85 (1 - e^{-0.64(t - 0.17)})$. Based on analysis results of the average size value obtained from the results of the separation of long frequency data into groups of length measurements, the growth parameters were obtained with the asymptote length ($L$) of 331.95 mm (Lake Tempe), 286.25 mm (Lake Sidenreng), and 224.85 mm (Lake Lompakka); where at this length the fish reach their maximum body length. The increase in fish length will decrease as the fish age increases. This is supported by the statement put forward by [23] in accordance with the concept of autocatalytic growth, that growth will run slowly then it will run fast, then it will run slowly until it reaches a certain length, so the growth will run constantly.

Based on the k value obtained, the bungo fish found in Lake Sidenreng and Lake Lapompakka are classified as fast growth because the k value is greater than 0.5, while the growth of bungo fish in Lake Tempe is classified as slow because it is smaller than 0.5. According to [24], if the K value is> 0.5, the growth is relatively fast.

3.2.3. Mortality. The results of the mortality analysis and exploitation rate of Bungo fish in Tempe, Sidenreng, and Lampopakka lakes can be seen in Table 2.

**Table 2.** Mortality and rate of exploitation of Bungo fish, *Glossogobius giuris* (Hamilton Buchanan, 1822) combined (male and female) in the waters of Lake Tempe, Sidenreng and Lampopakka

| Sampling Sites   | n (ind.) | Z  | M   | F  | E  |
|------------------|---------|----|-----|---|---|
| Lake Tempe       | 293     | 0.32| 0.19| 0.13| 0.41|
| Lake Sidenreng   | 193     | 0.67| 0.56| 0.11| 0.19|
| Lake Lapompakka  | 197     | 1.00| 0.79| 0.22| 0.22|

Mortality rate is a measure of mortality at certain time intervals. Estimation of the total mortality rate (Z) of bungo fish is done by estimating the catch curve which is converted into a length (Length-converted catch curve) through the FISAT II software version 1.2.2 then entering the L∞ and k values. The mortality of Bungo Fish many occur in bungo fish aged about 1 and 2 years and this is found in all three waters. It is estimated that this can occur because the young bungo fish have not been able to adapt to environmental conditions which cause high cannibalism from other predatory fish. The mortality that occurs in the three locations is due to natural mortality because the M value is greater...
than the F value. However, we need to pay attention to the total mortality number in Lake Sidenreng and Lake Lampopakka which is higher compare to the Lake Tempe. It is need further study to recognise the cause of natural mortality in these two lakes. Also, since invasive fish is possible in the three lakes, precautions are important. The high natural mortality number in the three lakes also need to be considered for the sustainability of this endemic species.

3.2.4. Yield per recruitment relative. The results of the Yield per Recruitment Relative analysis were obtained in Lake Tempe at 0.0435, Lake Sidenreng at 0.0078, Lake Lapompakka at 0.0273. Estimation of $Y / R'$ was analysed using the Beverton and Holt method [12] by entering the values obtained. The exploitation rate shows in (E), in Table 2. The rate of exploitation of bungo fish is obtained with an E value on Lake Tempe, Lake Sidenreng and Lake Lapompakka below 0.5. The exploitation number greater than 0.5 indicates overfishing, and lower than 0.5 indicates not overfishing yet. The number was count based on Yield Per Recruitment and relative biomass per recruit (B / R'), as a function of E were determined from estimated growth parameters and catch probability [10].

4. Conclusion
Lake Sidenreng has more age groups of bungo fish compared to Lake Tempe and Lake Lapompakka. The lengths found in Lake Tempe are longer than those found in Lake Sidenreng and Lake Lapompakka, and the smallest length of bungo fish is found in Lake Lapompakka. found in Lake Sidenreng and Lake Lapompakka are classified as fast growth because the k value is greater than 0.5, while in Lake Tempe it is classified as slow because it is smaller than 0.5. The natural mortality rate of bungo fish was more common in bungo fish aged around 1 and 2 years and this was found in all three waters. Mortality that occurred at the three locations was due to natural mortality because the M value was greater than the F value. Nonetheless, it is important, to keep our eyes on the recruitment number, since the possibility of invasive fish could endanger this endemic fish.

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