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Gonadal Maturity Level and Index of Goby Tank Fish (*Glossogobius Giuris*) in the Waters of Lake Sidenreng, South Sulawesi

Hadiratul Kudsiah[1,*], Suwarni[1], Basse Siang Parawansa[1], Sri Wahyuni Rahim[1], Muhammad Ahsin Rifa'i[2], Andi Aliah Hidayani[3], Ita Wisma[1]

[1]Department of Fisheries, Faculty of Fisheries and Marine Science, Hasanuddin University, Indonesia
[2]Department of Marine Science, Faculty of Fisheries and Marine Science, Lambung Mangkurat University, Indonesia
[3]Aquaculture Study Program, Faculty of Fisheries and Marine Science, Hasanuddin University, Indonesia

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Abstract Bungo fish is a valuable freshwater species with significant economic worth. The villagers consume the fish either fresh or dry. This study aims to look into the reproductive biology of *Glossogobius giuris* bungo fish (Buchanan, 1882) in Sidenreng Lake, Sidenreng Rappang Regency, South Sulawesi. It comprises the sex ratio, gonadal maturity level (GML), gonadal maturity index (GKI), and the first mature gonad size. The research effort was carried out over the months of September, October, and November in the year 2022. Five sites that represented reservoir waters provided fish samples. The catches of nearby fishermen were also collected. Fish samples were described at Makassar's Fisheries Biology Laboratory, Department of Fisheries, Faculty of Marine and Fisheries Sciences, Hasanuddin University. It included 235 fish samples in all, 163 of which were male and 72 of which were female. The study's findings indicate that there is a 2.59:1 sex ratio between male and female fish. The continuity between male and female fish is depicted by this ratio. Male and female bungo fish have four gonadal maturity levels (GMLs): GML I, II, III, and IV. The value of the gonad maturity index was 12.59% greater in female fish (3.63%) than in male fish. Male gonads mature at 327.07 mm, while female bungo fish mature at 227.36 mm. This reveals that male fish mature faster than females.

Keywords Gonadal Maturity Level, Gonadal Maturity Index, Goby Tank Fish (*Glossogobius Giuris*), Sex Ratio, Sidenreng Lake

1. Introduction

Sidenreng Lake is one of South Sulawesi's freshwater habitats [1, 2]. Lake Sidenreng, with an area of ± 4,753.3 ha, provides freshwater fish for fishermen to meet their protein demands and enhance household income [3, 4]. However, research suggests that Sidenreng Lake covers around 3,000 hectares during the dry season and 35,000 hectares during the rainy season, and crosses boundaries with Tempe Lake and Buaya Lake [4, 8]. Sidenreng Rappang Lake is home to various fish species [5], including Tawes fish (*Puntius goniatus*), nilem fish (*Osteochilus vittatus*), betok fish (*Anabas testudineus*), gabus fish (*Ophiocephalus streatus*), and bungo fish (*Glossogobius giuris*).

Various types of fish may become extinct in Lake

Sidenreng due to fishing and community activities [6, 7]. Some destructive activities include non-selective fishing gear, using poisons and explosives, using electric current (Strom), silting, and dumping household and agricultural waste. Another factor influencing the extinction of fish in lakes is a lack of public knowledge and poor local government supervision of this problem [5, 8].

Bungo fish (*Glossogobius giuris*), also known as the goby tank or gudgeon tank, is a freshwater fish in Southeast Asia [9]. This fish belongs to the Gobiidae family, is small and long, has unique behavior, and can adapt to various aquatic environments [10]. Bungo fish are defined as fish with a flat body shape and a condition factor that fluctuates between 0.36-42.27 for males and 0.54-2.58 for females [4]. *Glossogobius giuris* fish live in rivers, streams, and even ponds. This demonstrates its adaptability to shifting water conditions [11, 12]. *Glossogobius giuris* fish in the Mekong River are accustomed to fast-moving water and rocky surfaces. They live in canals, ditches, and ponds, and can adapt to various environments, but these fish are known to be aggressive towards other fish species, especially during the reproductive season [12, 14].

Glossogobius giuris fish have varying reproductive biology based on their maturity, spawning season, and fecundity level [14, 15]. Maturity is critical for understanding fish populations' reproductive capacity, and size at maturity is a significant influence [16, 17]. The spawning season is determined by changes in the gonadal-somatic index and the proportion of adult fish [18, 19]. Fecundity is assumed to give reproductive capacity and varies according to species and environmental conditions [13, 20, 21, 22, 23]. Most of the research that has been conducted on this fish still focuses on the life cycle and feeding experiments [24, 25]. Therefore, we need to study the natural environment of this *Glossogobius giuris* species to gain a more comprehensive understanding of its behaviour, reproductive strategies, and population dynamics. Furthermore, examining fish in their natural habitat allows us to see interactions with other species, predator-prey relationships, and how environmental conditions influence their behavior [26]. Studying fish reproductive biology in both controlled and natural settings provides a thorough grasp of their reproductive patterns.

Ten years ago (2014), Eragradhini [27] did study in Lake Tempe on the reproductive biology of bungo fish, specifically the level and maturity index of their gonads. Drawing on the above backdrop, the goal of this study is to ascertain the current reproductive biology of bungo fish in the waters Lake. This research is designed to educate relevant stakeholders on the management of bungo fish resources in Lake Sidenreng.

2. Materials and Methods

2.1. Study Area

This study occurred from September-November 2022 at Lake Sidenreng, Sidenreng Rappang Regency, South Sulawesi (Figure 1). Bungo fish samples were examined at Hasanuddin University's Fisheries Biology Laboratory in Makassar.

2.2. Procedures

We collected 3000 fish samples from five stations representing Lake Sidenreng's waters. Additionally, we gather samples from the catches of local fishermen. We collect samples once per month for three months. Fishermen use a trap with a net measuring 1.5 cm, arrest by boat. We next put the caught fish in a refrigerated box with ice cubes to keep them fresh until they arrive at the laboratory. When we arrive at the laboratory, we remove the fish samples from the coolbox, clean them with water, place them on a longboard, and label them with label paper. The entire body length of the fish sample was then measured using a ruler with a precision of 1 mm, beginning at the leading edge of the mouth and terminating at the rear tip of the tail. The total body weight of the sample was determined using an electric scale with an accuracy of 0.01 g, and the gonads were dissected and examined to determine the sex and level of gonad maturity [13, 28, 29, 30, 31, 32]. Suryandari and Krismono [33] identified the sex and gonad development levels of bungo fish in Wisma [34]

2.3. Data Analysis

Sex Ratio. The gender split is derived by comparing the number of male and female fish using the following formula:

$$SR = \frac{\sum M}{\sum F} \quad (1)$$

Note: SR = sex ratio, ΣM = number of male fish (tails), ΣF = number of female fish (tails).

To ascertain if the gonadal maturity level (GML) was equivalent to a 1:1 ratio pattern and the sex ratio between male and female fish at each sampling interval, chi-square analysis was performed using SPSS software.

Gonad Maturity Level (GML). The GML is determined by the color, shape, and size of the fish gonads. The gonad observations in this study are based on Suryandari and Krismono's [33] classification in Wisma [34], which distinguishes gonad maturity into four stages, namely GML I, II, III, and IV, as illustrated in Table 1.

Gonad Maturity Index (GMI). The GMI is computed by multiplying the fish's body weight by 100% and dividing the gonad weight by that amount. The following formula is used to calculate the GMI:

$$GMI = \frac{Gw}{Gb} \text{ x } 100\% \quad (2)$$

Note: GMI = gonad maturity index, Gw = gonad weight (grams), Gb = gonad body weight (grams).

Size of the first mature gonads. The Spearman-Karber method is used to analyze fish size at the time of gonad maturation. The following is the formula:

$$M = X_K + \frac{x}{2} - \{ X\sum P_i \} \quad (3)$$

Note: pi is the percentage of gonadal mature fish in the i-length class with the number of fish length intervals; xk is the log of the middle value of the last length class the fish has gone gonadally matured; x is the log of the length increase at the mean; and M is the length of the first gonadal.

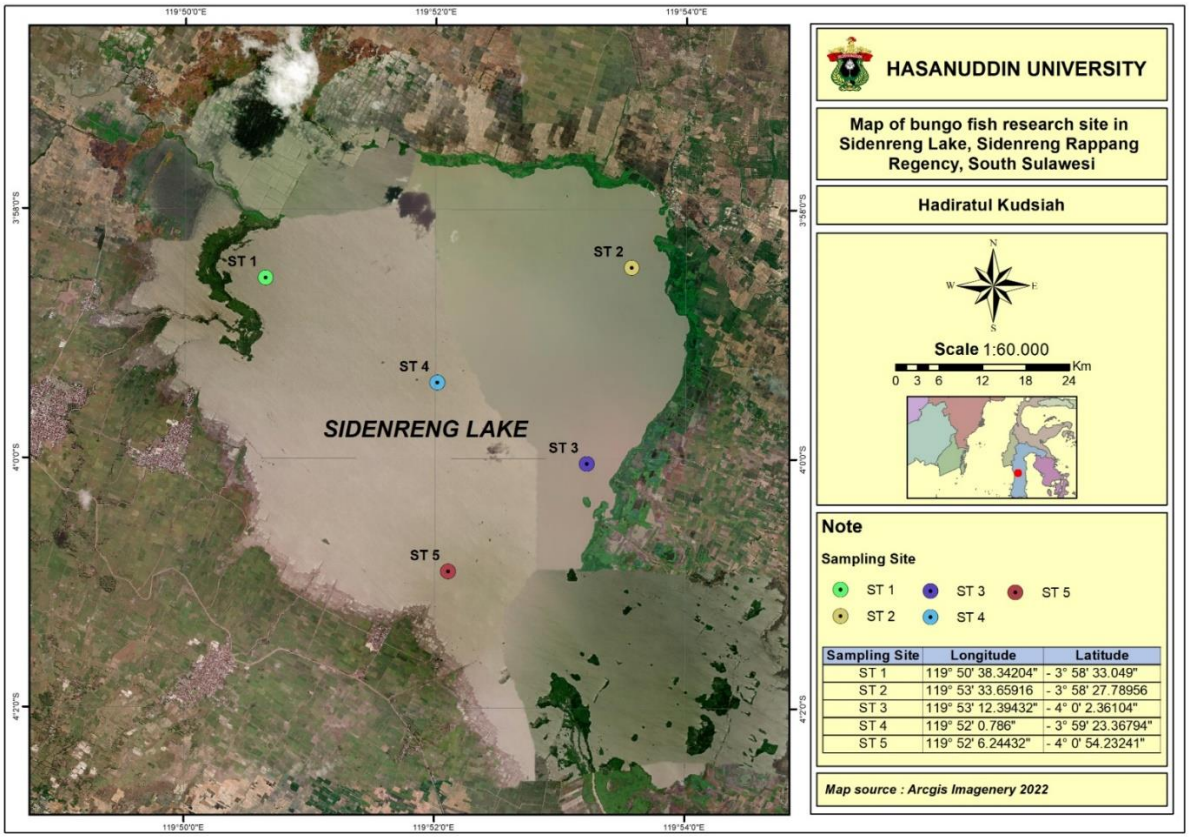

Figure 1. Research location in the waters of Lake Sedenreng, Sidenreng Rappang Regency, South Sulawesi Province

Table 1. Classification of gonadal maturity level of *Glossogobius giuris* (Buchanan 1822) [33, 34]

GML	Female	Male
I	The ovaries are like threads, with a yellowish white color and a few red lines.	The testes are like thin threads with a clear white color that is slightly reddish.
II	The size of the ovaries is larger with a clearer yellow color but the egg granules are clearly visible. At this level the granules appear oily.	The shape is clearer at level I with a larger size and milky white color.
III	The ovaries are larger than the gonad maturity II level, have a yellow hue, and have visible but not very dense egg granules.	The testes are clearly visible, getting bigger in size with a thick white color, and are starting to appear to fill the abdominal cavity.
IV	Each egg is very easy to remove from the ovaries, which are protruding, dark yellow, and extremely dense. The abdominal cavity is not filled by the ovaries.	As in level III it appears larger with a thick white color resembling a layer of fat.

Note: GML = Gonadal maturity level

3. Results

3.1. Sex Ratio of Bungo Fish, *Glossogobius Giuris*

There were 235 bungo fish collected for the study, including 163 males and 72 females. Table 2 displays the findings of the sex ratio study based on sampling time. The chi-square test results (Xhit) were greater than Xtab, with Xhit 400.7886 > Xtab 5.9915, as shown in Table 2, which also shows the sex ratio at sampling time. There are more male fish than female fish, according to the ratio of 2.26:1. Furthermore, the results of the sex ratio investigation are shown by gonad development level in Table 3. According to Table 3, the chi-square test indicates a higher sex ratio in the bungo fish's gonad development level, with Xhit measuring 673.9115 and Xtab measuring 7.8147. The most prevalent GML is GML II, which indicates that there are more male fish than female fish, resulting in a 2.26:1 GML.

3.2. Gonad Maturity Level (GML) of Bungo Fish, *Glossogobius Giuris*

We assessed the gonad maturity level of bungo fish, GML I-IIV, using observations of male and female gonads (Figure 2).

Figure 3 presents the findings of a frequency analysis of the gonadal maturity levels of male and female bungo fish throughout time.

Figure 3 shows that the frequency of gonadal maturity levels for male bungo fish exhibited the highest frequency at GML II (73.68%) in October and lowest in GML IV (2.86%) in September, while for female bungo fish, the highest was GML I (38.89%) in November and the lowest was GML I (11.76%) in September. Figure 4 presents the results of the frequency analysis of gonadal maturity levels with immature and mature gonads.

Based on Figure 4, it is found that the frequency of immature gonads in male bungo fish is highest in October (94.74%) and lowest in September (71.43%), while the frequency of mature gonads is highest in September (28.57%) and lowest in October (5.26%). For female bungo fish whose gonads have not yet matured, the highest is in November (55.56%), and the lowest is in September and October (50.00%), while those with mature gonads are highest in September and October (50.00%), and the lowest (44.44%) in November.

Table 2. Bungo fish sex ratio, *Glossogobius giuris* (Buchanan 1822), depending on sample time

Sampling time	Number (tails)		Sex ratio	
	Male	Female	Male	Female
September	70	34	2.06	1.00
October	57	20	2.85	1.00
November	36	18	2.00	1.00
Total	163	72	2.26	1.00

Table 3. Sex ratio of bungo fish, *Glossogobius giuris* (Buchanan 1822), determined using GML

GML	Number (tails)		Sex ratio	
	Male	Female	Male	Female
I	42	15	2.80	1.00
II	93	22	4.23	1.00
III	22	17	1.29	1.00
IV	6	18	0.33	1.00
Total	163	72	2.26	1.00

Note: GML = Gonadal maturity level

GML	Male		Famale	
I		The testes are like thin threads with a clear white color that is slightly reddish		The ovaries are threadlike, with a yellowish white color and a slight red line
II		The shape is clearer at level I with a larger size and milky white color		The size of the ovaries is larger with a clearer yellow color, but the egg granules are clearly visible. At this granular level oil appears
III		The testes are clearly visible, getting bigger in size with a thick white color, and are starting to appear to fill the abdominal cavity		The size of the ovaries is greater than the level of gonad maturity II, the color is yellow and the egg granules are clearly visible but not very dense
IV		As in level III it appears larger with a thick white color resembling a layer of fat		The ovaries are bulging, dark yellow in color, very dense with each egg being very easy to separate. The ovaries appear to fill the abdominal cavity

Figure 2. Gonad maturity level (GML) of male and female bungo fish, *Glassogobius giuris* (Buchanan 1822)

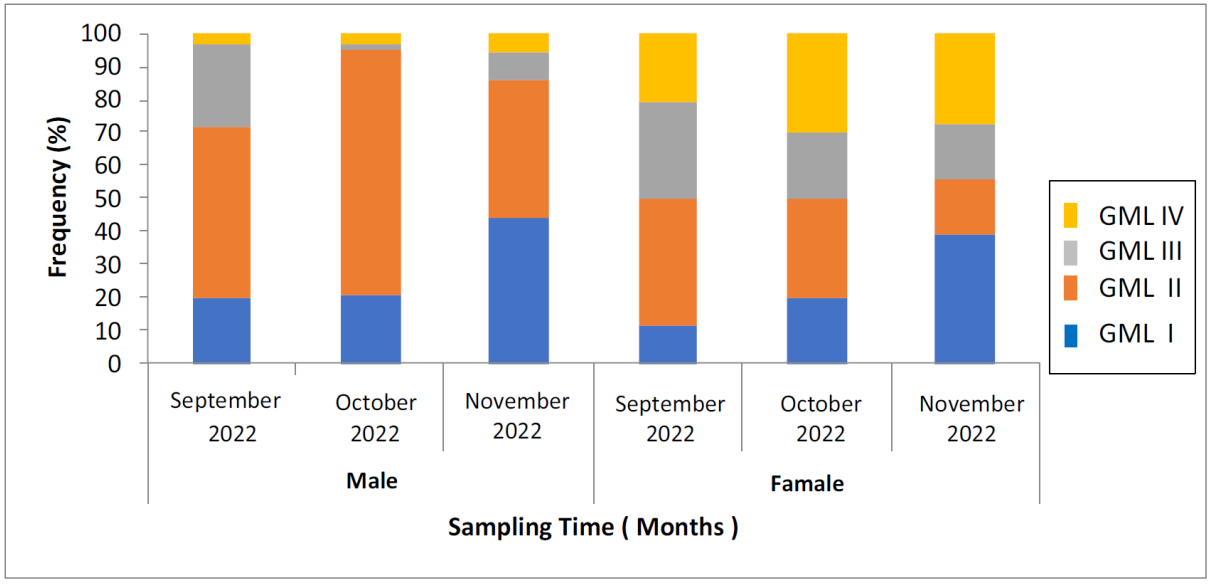

Figure 3. The number of male and female bungo fish (*Glossogobius giuris* Buchanan 1822) in Lake Sidenreng, Sidenreng Rappang Regency, South Sulawesi, is displayed based on their gonad maturity at each sampling interval. A percentage of the numbers is displayed

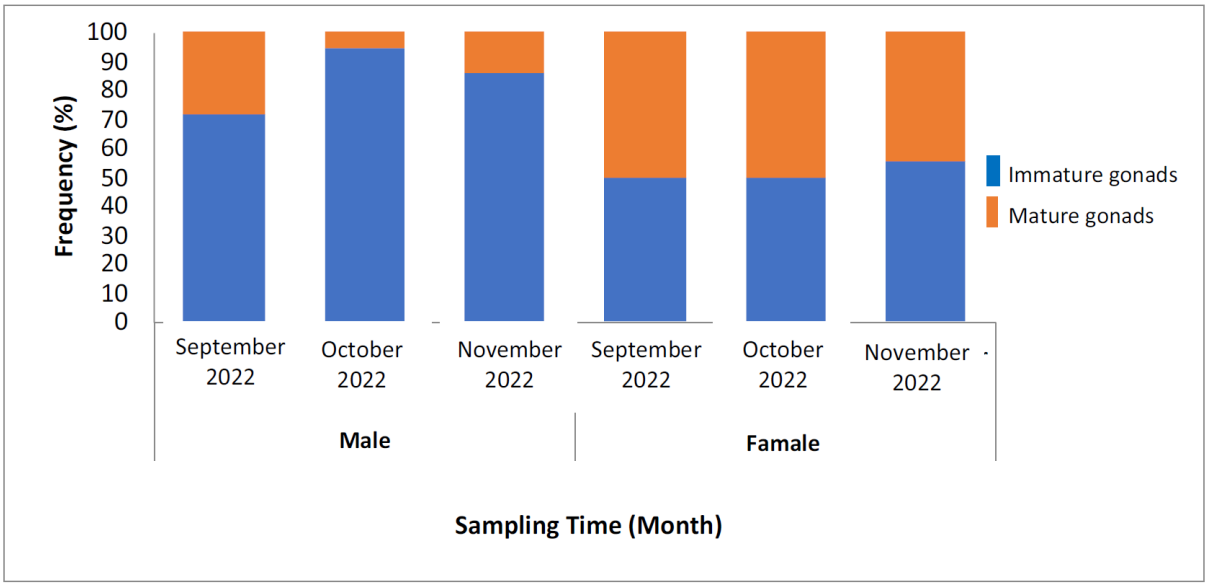

Figure 4. Based on sampling time, the frequency (%) of male and female bungo fish, *Glossogobius giuris* (Buchanan 1822), with immature and developed gonads was determined in the waters of Lake Sidenreng

3.3. Gonadal Maturity Index (GMI) of Bungo Fish, *Glossogobius Giuris*

3.3.1. Gender

Table 4 displays the range of mean values of the gonadal maturity index based on gender in the waters of Lake Sidenreng.

Table 4. Range of values and average GMI (%) of *Glossogobius giuris* bungo fish (Buchanan 1822) based on sex in the waters of Lake Sidenreng

Sex	n (tails)	Gonadal Maturity Index (%)	
		Range	Average
Male	163	2.93 – 3.65	1.97 ±2.99
Female	72	5.44 – 11.77	4.25 ±11.40

Table 4 reveals that the average gonadal maturity index for female bungo fish ranges from 1.97 to 2.99, whereas the average value for male fish is between 4.25 and 11.40. The GMI statistical test yielded no significant differences ($P > 0.05$). This demonstrates that female bungo fish have a higher gonadal maturity index than males.

Sampling time. Figure 5 displays the range of values and average gonadal maturity index based on sampling time.

Figure 5 shows that the average gonadal maturity index for male bungo fish is lowest in November (2.93%) and highest in October (3.63%), while the index for female bungo fish is highest in October (12.59%) and lowest in September (5.44%). Furthermore, Table 5 displays the average value of the gonadal maturity index based on the level of gonad maturity.

Based on Table 5, the male bungo fish with the highest gonadal maturity index value (mean value 10.15 ± 3.71) was found in GML IV. In GML IV, female bungo fish had the highest mean value (19.98 ± 8.80). The statistical test findings for the gonadal maturity index based on sample time revealed no significant differences ($P > 0.05$). This demonstrates that as time passes, the GMI will increase.

3.3.2. First Mature Gonad Size (FMGS)

The first mature gonads of the male Bungo fish measured 327.07 mm and ranged in length from 100 to 385 mm, while those of the female Bungo fish measured 227.36 mm and ranged in length from 120 to 360 mm, and female Bungo fish's first mature gonads measured 227.36 mm with a length range of 120–360 mm.

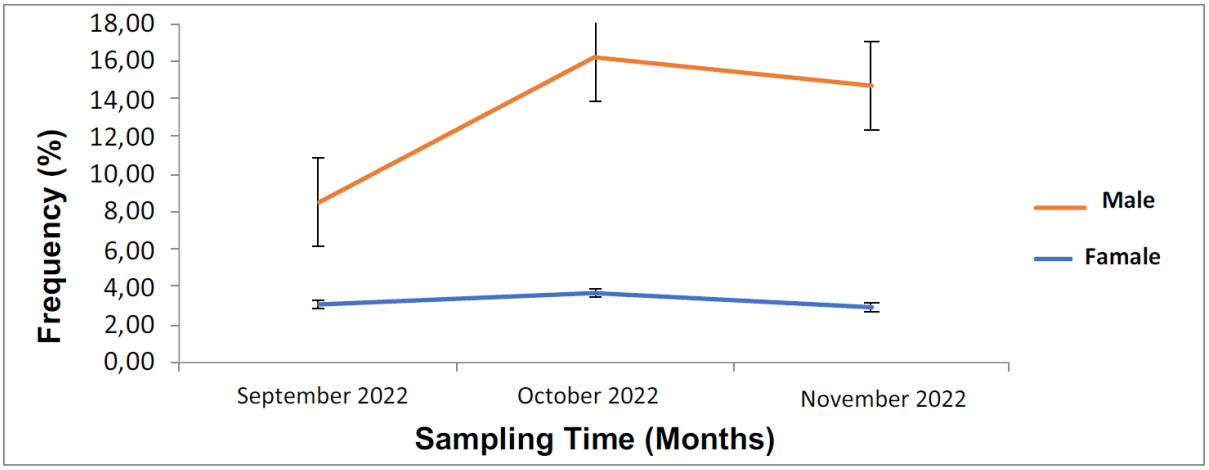

Figure 5. Average gonadal maturity index of male and female bungo fish, *Glossogobius giuris* (Buchanan 1822)

Table 5. Range of values and average gonadal maturity index (%) of *Glossogobius giuris* bungo fish (Buchanan 1822) based on the gonadal maturity level in Sidenreng waters

GML	Male		n (tails)	Female		n (tails)
	Range	Avr ± SE		Range	Avr ± SE	
I	0.25 – 6.67	1.79 ±1,27	42	0.29 – 2.35	1.05 ±0.58	12
II	0.74 – 10.00	2.77 ±1,74	92	1.03 – 5.33	2.73 ±1.25	22
III	3.11 – 10.37	6.22 ±2,07	22	5.69 – 40.00	12.14 ±8.68	22
IV	6.15 – 16.00	10.15 ±3,71	6	8.94 – 40.00	19.98 ±8.80	18

4. Discussion

Bungo fish have mature gonads and a sex ratio of 2.26:1. Male and female fish are unequally distributed in the population, with a sex ratio of 1:1. Fish have comparable behaviors. Male bungo fish outnumber females in this species. The sex ratio of bungo fish in Lake Tempe was 1.47:1, according to research [27]. In contrast, Male fish had a greater sex ratio in Ujung Pangka waters than female fish (Sulistiono et al. 2011 [35] in Wisma, 2022 [34]); the ratio was 1.3:1.

Male fish predominate in terms of distribution, both male and female. According to Wisma [34], male and female fish catch rates fluctuate due to unequal distribution. This is because fish behave differently depending on whether they are male or female, with females generally being less energetic than males. Overfishing is more likely when there is an uneven distribution of fish due to the capture of more male fish. If male and female fish have distinct schooling behaviors, development patterns, death rates, and environmental conditions, the 1:1 ratio might be balanced. Fish typically have a sex ratio of about 1:1 in the wild. This indicates that the amount of male fish harvested is roughly equivalent to the quantity of female fish captured. El-Halfawy et al. [36] state that the growth techniques employed for fish reproductive success are directly influenced by the male to female fish ratio.

The study found that male and female bungo fish have varied levels of gonad development, specifically GML I, II, III, and IV. Similar findings were made in Lake Tempe [30], as well as in the waters of Ujung Pangkah [35]. The distribution of various GML indicates that both immature and adult gonads were present during the research. We found male bungo fish with immature gonads (GML I and II) at 57.45%, mature gonads (GML III and IV) at 16.60%, and female bungo fish with immature gonads (GML I and II) at 15.74% and mature gonads (GML II and IV) at 14.89%. The varying levels of gonad maturity suggest that bungo fish spawn throughout the year. Aswady et al. [37] assert that the high percentage of immature gonad GML (GML I and II) suggests a high recruitment rate in the population, implying that spawning has likely taken place in the previous months.

According to Pinem et al. [38], fish who get GML IV every month do not have a breeding season. Prior to spawning, fish acquire increasingly mature gonads as part of the reproductive process. Throughout this step, fish devote the majority of their metabolic energy to gonad development. The main factors that influence the maturity of fish gonads are temperature and food. Gonad maturity occurs in line with increasing water temperature, and if the temperature is low, it will have an impact on slowing gonad maturity [39].

Male and female bungo fish had the highest GMI values (3.65% and 12.59%) in October and the lowest GMI values (2.94% and 5.44%, respectively) in November during the

study. The highest GMI values for male and female bungo fish were 10.15% and 19.98%, respectively. The maturation index values of both male and female bungo fish increased from GML I to GML IV. Eragradhini et al. [27] analyzed the gonadal maturity index of male and female bungo fish in Lake Tempe, and they found a similar occurrence. In particular, they found that female bungo fish had a maximum GMI value of 24.62% during the study, while male fish had a maximum GMI value of 16.26%. For fish both male and female, the lowest GMI values were found in August, at 8.35% and 9.48%, respectively. This suggests that female bungo fish had a higher GMI than males. This is because female fish have heavier gonads than male fish.

It seems that the fish's body weight, gonad weight, and degree of gonad maturity (GML) all affect the GML and GMI values. A fish's GMI rating rises with the weight of its body and gonads. In (Kudsiah, 2021) [5], Tamsil [40] states that fish gonads will continue to expand and reach their maximum size at GML IV. In (Kudsiah et al. 2021) [5], Anene states that fish with a GMI of less than 20% are capable of reproducing more than once a year. Studies on bungo fish in Lake Sidenreng have revealed that the GMI value of both male and female fish is less than 20%, implying that the fish can reproduce numerous times each year.

In line with the research findings, the first fully grown gonads in male bungo fish measure 327.07 mm, while female fish measure 227.36 mm. The male bungo fish's first mature gonads measured 221 mm, while their body length was 209 mm, according to studies conducted in Lake Tempe [27]. These findings suggest that compared to male fish, female bungo fish have smaller gonads. According to Wisma [34], Craig et al. [41] discovered that female fish generally attain gonad maturity earlier than male fish. Variations affect the maturity of fish gonads in different species, as well as age, size, food, temperature, currents, spawning, and individual physiological traits (Lagler et al., 1991 [42] in Kudsiah, 2022) [5].

Each fish has a distinct size when its gonads first develop, according to Wisma [34]; even the same species in various habitats may have gonads that grow at different sizes. Growth, along with the effects of growth and reproductive strategy, determines the size at which the gonads first mature. In this instance, fish that are under more fishing pressure tend to grow to be smaller. Setyohadi & Wiadnya [43] state that fish sizes vary by species and even within species when the gonads initially develop. It is possible for fish of different ages or lengths to have different gonad maturity sizes.

The sex ratio was 2.26:1, showing an imbalance between male and female fish due to sample length and gonad development. We used GML I, II, III, and IV to determine the gonadal maturity levels of male and female bungo fish. Female fish have a higher gonad maturity index (12.59%) than male fish (3.63%). We consider it to be more often than once a year, as the obtained GMI is less than 20%. A male bungo fish's first completely grown gonad measures 327.07 mm in length, whereas a female's is 227.36 mm. We suggest carrying out additional research on the reproduction of bungo fish at various times in order to ascertain the spawning season.

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