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Sex Ratio and Gonadal Maturity of Marble Goby (*Oxyeleotris marmorata*) in Lake Tempe, Indonesia

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Abstract: Understanding the sex ratio and initial gonadal maturity size of fish populations is essential for effective conservation and sustainable fishery management. This study aims to analyze the comparison of sex ratio and initial gonadal maturity size of marble goby (*Oxyeleotris marmorata*) in Lake Tempe, Wajo Regency, South Sulawesi. The research was conducted over two months, from October to November 2023, with four sampling events, two during the dark moon phase and two during the bright moon phase. A total of 285 individuals were collected, consisting of 118 females and 167 males, using jabba or bubu fishing gear. Sex identification and gonadal maturity determination were conducted at the Fisheries Biology Laboratory, Faculty of Marine and Fisheries Sciences, Universitas Hasanuddin. The results showed that the overall sex ratio was 0.71:1.00 (female:male), with significant male dominance during the dark moon phase and at Station 1 (near agricultural land). Gonadal maturity levels (TKG) ranged from stage I to stage V, with first gonadal maturity sizes varying between moon phases and locations. The smallest first gonadal maturity size was recorded at 175.72 mm for females (Station 1) and 191.65 mm for males (Station 1). These findings provide essential data for supporting sustainable fishery management in Lake Tempe.

Introduction

Marble goby is a medium-sized freshwater fish belonging to the Eleotridae family. This fish can be distinguished from members of the Gobiidae family by its separated pelvic fins and six bony rays on its operculum (1). Also known as the lazy or sleeper fish, this species generally inhabits freshwater and estuarine waters. Its natural habitat includes shallow, muddy areas such as river estuaries, reservoirs, and lakes with calm water currents, where it tends to hide beneath aquatic vegetation (2).

Sex ratio compares the number of male and female individuals within a population. Understanding this ratio at different times and seasons is important for determining population dynamics and sex distribution, especially during spawning. According to Purdom (1993), sex ratio is an important parameter in estimating the productivity of a fish species (3). In freshwater habitats, a balanced sex ratio is generally 1:1 (4)

Lake Tempe is an important lake in South Sulawesi, located within Wajo, Soppeng, and Sidrap Regencies (5) This lake receives inflow from the Bila River and the Walennae River, and it holds great fisheries potential, serving as the main source of livelihood for local fishing communities (6). One of the fish species inhabiting Lake Tempe is the marble goby, locally known as “bale lappuso” (7). Marble goby is an indigenous freshwater species in Indonesia, favored by the community for its high economic value and health benefits (8). The body of this fish has a pattern resembling reddish marble, and its distribution covers the Southeast Asian region. Marble goby is a carnivorous, nocturnal species that preys on shrimp, insects, aquatic snails, and small fish (9).

Given its high economic value, intensive fishing poses risks of overexploitation and population imbalance. Sustainable management requires comprehensive biological data, particularly on the sex ratio and gonadal maturity level (GML), including the size at first gonadal maturity (GMI). These parameters are essential for determining reproductive potential, setting appropriate minimum size limits, and guiding conservation efforts. Although several studies have examined marble goby biology in other regions (10-12), esearch on the sex ratio and GMI/GML of this species in Lake Tempe remains limited. Additionally, the potential influence of environmental factors such as moon phases and fishing locations on reproductive patterns has received little attention. Addressing this gap is necessary to support sustainable utilization and conservation strategies for marble goby populations in Lake Tempe.

Metodology

Material

This study used a Jabba fishing gear as a trap measuring 9 m in length, 40 cm in width, and 40 cm in height, with a mesh

Figure 1. Bubu fishing gear used by local fishermen for catching fish in Lake Tempe.

size of 1 cm made from nylon rope and an iron frame (see **Figure 1**). Fishermen used this gear to catch marble goby at two locations around the Walennae River, near agricultural areas and in the middle of the lake, far from agricultural activities. The caught fish were stored in a cool box containing crushed ice and then transported to the laboratory for analysis.

In the laboratory, the total length of the fish was measured using a caliper with an accuracy of 0.01 mm. In contrast, body and gonad weights were measured using a digital scale with an accuracy of 0.01 g. Dissection was then performed using a dissecting set to determine the sex and gonadal maturity level (TKG) based on the Umage classification. Other supporting equipment included a dissecting board for sample placement, a camera for documentation, writing tools for data recording, and label paper to identify each sample. Crushed ice was used during transportation and storage to maintain the freshness and quality of the fish (13).

Sampling of Marble Goby

Marble goby samples were collected from October to November 2023, with a sampling frequency of four times. The samples were obtained from fishermen's catches at two different stations. Station 1 was located around the Walennae River, close to agricultural land, while Station 2 was situated in the middle of the lake, far from the influence of agricultural activities. Fish were caught using bubu or jabba fishing gear, specifications of 9 meters in length, 40 cm in width, 40 cm in height, and a mesh size of 1 cm, made from nylon rope and an iron frame. The collected fish samples were immediately stored in a cool box containing crushed ice to maintain their quality and then transported to the laboratory for further analysis. The total number of samples (285 individuals) was determined based on sampling feasibility during the research period, as well as reference to previous similar studies on marble goby population biology (14). While no formal power analysis was conducted, the number of samples was considered sufficient to provide robust descriptive and inferential statistical analysis for sex ratio and gonadal maturity assessment.

Sampling was conducted at two distinct locations during four independent sampling events (two during the dark moon phase and two during the bright moon phase), with each event treated as an independent replicate to account for temporal variation. Both sampling stations were sampled separately during each event to assess spatial differences.

Observation Procedures for Marble Goby Samples

Upon arrival at the laboratory, the marble goby samples were removed from the cool box, washed thoroughly, and arranged on a dissecting board. Each sample from each sampling period was placed sequentially on the work table. The total length of each fish was measured using a caliper with an accuracy of 0.01 mm, starting from the tip of the snout to the end of the caudal fin. Next, the total body weight was measured using a digital scale with an accuracy of 0.01 g. The fish's abdomen was then dissected using a scalpel to observe the gonads. Sex identification and gonadal maturity level (TKG) determination were carried out based on the criteria proposed by Umage *et al*. (2020), as listed in Table (13).

Data Analysis

Data analysis in this study was carried out using a combined approach between descriptive statistical analysis and inferential statistics.

Level of Gonadal Maturity (TKG)

Determination of the level of gonadal maturity is done morphologically based on the color, size, and shape of the fish gonads. TKG classification refers to the criteria described

Table 1. Classification of gonadal maturity levels in marble goby (13).

Level of gonadal maturity	Female	Male
I	The ovary is shaped like a long thread extending to the body cavity's front. Clear in color with a smooth surface.	The testes are threadlike, but shorter, and the tips are visible inside the body cavity. Clear color.
II	The ovaries are larger with a darker color, tending to yellowish. Eggs are not yet visible to the naked eye.	The testes are larger with a milky white color. They are more firmly shaped than grade I.
III	The ovaries are yellow, and the egg grains are morphologically visible.	The surface of the testicle appears jagged, the color gets whiter, the size increases, and the testicle becomes brittle when preserved.
IV	The ovaries are getting bigger, the eggs are yellow and easy to separate. Oil granules are not visible, and the ovaries fill about ½ to ⅔ of the abdominal cavity, so that the intestines are pushed.	These features are similar to those of stage III but more pronounced. The testes are denser and more solid.
V	The ovary appears wrinkled with thickened walls. Egg remnants are visible near the discharge area, with many eggs resembling grade II characteristics.	The back of the testicle shrinks (collapses), but the part near the release duct is still full.

by Umage (10) (see **Table 1**). TKG levels I and II are categorized as immature gonads, while levels III, IV, and V are categorized as mature gonads.

Sex Ratio

Sex ratio was determined based on the number of male and female individuals obtained during the study period. Sex ratio calculations were made using **Equation 1** (15).

$$\mathrm{NK} = \frac{\Sigma\,\mathrm{J}}{\Sigma\,\mathrm{B}}$$

Equation 1 | NK is sex ratio, *ΣJ* is the number of male marble goby, and *ΣB* is the number of female marble goby.

$$\mathrm{x^2} = \sum_{\mathrm{i=1}}^{\mathrm{k}} \frac{(\mathrm{O_{ij}} - \mathrm{E_{ij}})^2}{\mathrm{E_{ij}}}$$

Equation 2 | O_{ij} is alues appear as observations of both male shrimp and female fish and E_{ij} = Expected values for both male and female prawns.

$$\mathrm{Ei} = \frac{\mathrm{n_i} \times \mathrm{n_j}}{\mathrm{n}}$$

Equation 3 | Ei is theoretical frequency expected to occur, n_i is the number of observations in the i-th row, n_j is the number of shrimps in the j-th column, and *n* is the sum of the frequencies obtained from the values of the observations.

$$\mathrm{x^2_{hit}} = \Sigma\,\frac{(|\mathrm{x_i} - \mathrm{x'}| - 0.5)^2}{\mathrm{x'}}$$

Equation 4 | X^2_{hit} is the chi-square value calculated using the Yates continuity correction, x_i is the observed frequency in category i, x' is the expected frequency in category i if the hypothesis is null.

To test whether the overall sex ratio was significantly different from the 1:1 ratio, the chi-square test (x^2) was used according to the method of Sudjana (1992) that can be seen in **Equation 2**. To determine the sex ratio based on the sampling time and TKG equal to 1:1 or not, a chi-square test is needed, arranged in the form of a contingency table (see **Equation 3**) (16). To determine whether the sex ratio between male and female fish at each sampling time and each level of gonadal maturity was significantly different from the 1:1 ratio, a chi-square test with Yates continuity correction was used (see **Equation 4**) (17).

Initial Body Size Gonadal Maturity

The determination of the number of classes and width of intervals in the calculation of the size of the first maturing gonads is based on Sturges' Rule, which is the most commonly used method for determining the number of classes in a frequency distribution (14), using **Equation 5**.

$$\mathrm{k} = 1 + 3.3\log \mathrm{n}$$

Equation 5 | *k* is the number of classes and *n* is the number of samples.

$$\log \mathrm{m} = \mathrm{X_k} + \frac{\mathrm{X}}{2} - \mathrm{X}\Sigma\,\mathrm{pi}$$

Equation 6 | *m* is the logarithm of length of fish at first gonadal maturity, X_k is the logarithm of the mean value at first gonad maturity 100%, *X* is the difference in the logarithm of the mean value, and *pi* is number of gonadally mature fish in the i-th class/number of gonadally mature fish in the i-th class, *qi* = 1-*pi*.

$$\mathrm{M} = \mathrm{antilog}\,[\mathrm{m} \pm 1.96\sqrt{\mathrm{x^2}\Sigma}\,(\frac{\mathrm{pi}\,-\,\mathrm{qi}}{\mathrm{ni}\,-\,1})\,]$$

Equation 7 | *M* is contingency interval of size at first gonadal maturity.

The size of the first mature gonads was calculated using the Spearman-Karber method (18) that can be seen in **Equation 6**. If α = 0,05, then the 95% confidence limits of m can be calculated as in **Equation 7**.

Results

Gonadal Maturity Levels of Marble Goby

The marble goby caught in the waters of Lake Tempe (see **Figure 2**) exhibits distinctive morphological characteristics, including a pointed head resembling a snout, a wide and thick mouth equipped with small, sharp teeth. The surface of the fish's body is covered with fine scales that extend from the back of the head to near the base of the tail. Dark brown and black spots are found on certain body parts and fins. Meanwhile, the ventral part of the body is brownish-white with black spots, and the fins are light brown (9).

The morphological differences between male and female individuals are quite noticeable. Males tend to have a slimmer abdomen compared to females, a lighter body color, and a head shape that appears more blunt. The most obvious difference lies in the genital papilla; females have a reddish-colored papilla, while males have a white one (19).

Sex identification of the marble goby can be carried out through dissection to observe the gonadal structure. Observations showed that the gonadal maturity level (TKG) can be determined morphologically.

The gonadal development in marble goby, both male and

Figure 2. Marble goby (Oxyeleotris marmorata) caught in the waters of Lake Tempe.

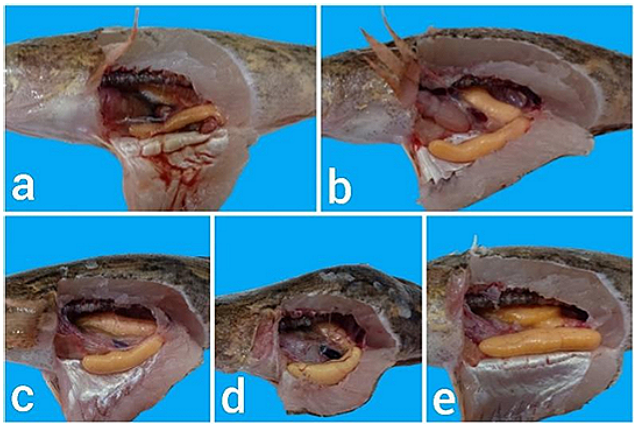

Figure 3. Male gonads of marble goby. Note: (a) TKG 1, (b) TKG 2, (c) TKG 3, (d) TKG 4, and (e) TKG 5.

Figure 4. Female gonads of marble goby (Oxyeleotris marmorata). Note: (a) TKG 1, (b) TKG 2, (c) TKG 3, (d) TKG 4, and (e) TKG 5.

Table 2. Morphological characteristics of male and female gonads of marble goby based on gonadal maturity levels in the waters of Lake Tempe.

Gonadal Maturity Level (TKG)	Female	Male
TKG I	Ovaries are small, do not yet show egg formation, and are clear yellowish.	The testes are small, shaped like fine threads, and appear clear.
TKG II	Ovaries begin to enlarge, dark yellowish, but eggs are not yet visible to the naked eye.	The testes begin to enlarge, milky white, with a more defined shape than in the previous stage.
TKG III	Ovaries are yellow, and eggs appear, although they are still attached, making it difficult to separate.	The testes appear larger, the surface shows a jagged texture, and the color becomes whiter.
TKG IV	Ovaries are significantly enlarged with eggs filling ½ to ⅔ of the abdominal cavity, reddish yellow, and can be separated.	The testes are milky white, the surface looks jagged, and they feel firm.
TKG V	The ovaries are shriveled, reddish-yellow with thickened walls, and still contain residual eggs around the release ducts.	The back of the testicle looks deflated, but the area near the discharge canal still contains sperm.

Table 3. Sex ratio of marble goby based on sampling time in Lake Tempe.

Sampling Time	Number of Fish (tail)		Sex Ratio	X^2_{hit}	Description
	Female	Male			
October	65	92	0,71:1,00	4,65	Significantly different
November	53	75	0,71:1,00	3,79	Not significantly different

female, can be distinguished based on morphology, including the shape and color of the gonads (see **Table 2**). In males, an increase in gonad weight occurs along with advancing maturity levels. Another distinctive feature is the appearance of a serrated gonad surface starting at TKG III, which becomes more pronounced by TKG V. Meanwhile, in females, gonad weight increases at each maturity stage. Color changes occur gradually in both sexes: in males, the gonads change from translucent to pale white, while in females, they develop from translucent yellowish to reddish-yellow (see **Figures 3** and **4**).

Sex Ratio of Marble Goby

Based on Sampling Time

During the research conducted at Lake Tempe, 157 marble goby were caught in October, consisting of 65 females and 92 males (see **Table 3**). The sex ratio between females and males was recorded at 0.71:1.00, indicating that the number of male fish was higher than that of females. The results of the analysis using the chi-square test ($\alpha = 0.05$; χ^2 calculated = 4.65; χ^2 table = 3.8415; df = 1) showed that the calculated χ^2 value exceeded the table value. Therefore, it can be concluded that the sex ratio between female and male marble goby differed significantly or was not balanced (not 1:1) (**Supplemental Table 1**).

In November, 128 marble goby were caught, consisting of 53 females and 75 males. The sex ratio between females and males was also 0.71:1.00, indicating that the male population was still higher than the female population. However, the result of the chi-square test ($\alpha = 0.05$; χ^2 calculated = 3.79; χ^2 table = 3.8415; df = 1) showed that the calculated χ^2 value was lower than the table value. Therefore, the difference in sex ratio was not significant, and it was considered balanced (1:1).

Based on the Moon Phase

During the research period in Tempe Lake, 149 marble goby were obtained during the Dark moon phase, consisting of 54 females and 95 males. The sex ratio between female and male fish was 0.57:1.00, indicating the dominance of males over females (see **Table 4**). The results of analysis using the chi-square test ($\alpha = 0.05$; χ^2 count = 11.29; χ^2 table =

Table 4. Sex ratio of marble goby by moon phase in Lake Tempe.

Moon Phase	Number of Fish (Tail)		Sex Ratio	X^2_{hit}	Description
	Female	Male			
Dark	54	95	0.57:1.00	11.29	Significantly different
Light	64	72	0.89:1.00	0.48	Not significantly different

Table 5. Sex ratio of marble goby based on sampling locations in Lake Tempe.

Sampling location	Number of Fish (tail)		Sex Ratio	X^2_{hit}	Description
	Female	Male			
Station 1	51	77	0.66:1.00	5.29	Significantly different
Station 2	67	90	0.74:1.00	3.38	Not significantly different

3.8415; db = 1) resulted in a χ^2 count value higher than the χ^2 table value. Thus, the sex ratio obtained showed a significant difference, or an imbalance towards the 1:1 ratio.

Meanwhile, 136 marble goby were caught during the Bright moon phase, consisting of 64 females and 72 males. The sex ratio between females and males was recorded at 0.89:1.00, which still showed more males. However, the chi-square test ($\alpha = 0.05$; χ^2 count = 0.48; χ^2 table = 3.8415; db = 1) showed that the χ^2 count value was lower than the χ^2 table value. This indicates that the sex ratio between female and male fish is not significantly different and is considered balanced with a ratio of 1:1 (**Supplemental Table 2**).

Sampel Based on Sampling Location

During the research period in Lake Tempe, a total of 128 marble goby specimens were obtained at Station 1, consisting of 51 females and 77 males. The sex ratio between females and males was recorded at 0.66:1.00, indicating a dominance of male individuals (see **Table 5**). The results of the chi-square test ($\alpha = 0.05$; χ^2 calculated = 5.29; χ^2 table = 3.8415; df = 1) showed that the calculated χ^2 value was higher than the table value. This indicates that the sex ratio between female and male fish differed significantly from the balanced ratio 1.00:1.00 (see **Supplemental Table 3**).

At Station 2, 157 marble goby specimens were collected, consisting of 67 females and 90 males. The sex ratio between females and males was 0.74:1.00, with the number of males still being higher. However, the results of the chi-square test ($\alpha = 0.05$; χ^2 calculated = 3.38; χ^2 table = 3.8415; df = 1) showed that the calculated χ^2 value was lower than the table value. Therefore, there was no significant difference in the sex ratio at this station, and it can be considered balanced or close to a 1.00:1.00 ratio.

First Gonad Maturity Size

The determination of the first gonad maturity size of marble goby was conducted using the Spearman-Karber method (15). Based on the sample collection in October, the female fish body length indicating the first gonad maturity was recorded at 219.27 mm, with a range of 203.80–235.92 mm (see **Table 6**). During the same period, the first gonad maturity size for male fish was 265.15 mm, with a range of 249.88–281.35 mm. Meanwhile, in November, the body length of female fish showing first gonad maturity was recorded at 190.02 mm (179.50–201.16 mm), while for male fish it was 197.30 mm (184.65–210.82 mm).

Based on the moon phase, during the dark period, female fish showed the first gonad maturity size at 230.46 mm (212.65–246.75 mm), while male fish showed the first gonad maturity size at 247.14 mm (228.45–267.35 mm). During the light period, the first gonad maturity size of female fish was recorded at 188.94 mm with a range of 209.60–236.34 mm, and for male fish it was 209.28 mm with a range of 192.99–226.95 mm.

In terms of the sampling location, at station 1, the first gonad maturity size for female fish was at a length of 175.72 mm (167.80–184.02 mm), while for male fish it was 191.65 mm (178.41–205.87 mm). At station 2, female fish had a first gonad maturity size of 198.41 mm (190.94–206.18 mm), and male fish had a first gonad maturity size of 256.88 mm (239.49–275.54 mm).

Regarding body weight, in October, female fish reached gonad maturity for the first time at an average weight of 179.65 g (149.00–216.60 g), while male fish reached it at 352.07 g (286.47–432.71 g). In November, female fish reached a weight of 86.13 g (76.54–96.98 g), while male fish reached maturity at 187.64 g (156.40–225.13 g).

Based on the moon phase, during the dark period, female fish reached first gonad maturity at a weight of 72.53 g (65.26–80.62 g), while male fish reached maturity at 119.80 g (98.51–145.69 g). During the light period, the first gonad maturity weight for females was 178.73 g (149.84–206.80 g), and for males it was 347.34 g (285.18–423.04 g).

Based on the location, at station 1, female fish reached gonad maturity for the first time at a weight of 175.47 g (148.89–206.80 g), while male fish reached it at 382.18 g (312.44–467.48 g). At station 2, the first gonad maturity weight for females was recorded at 93.80 g (75.13–117.12 g), and for males, it was 110.40 g (98.75–123.42 g).

Discussion

In the observation of the gonads of male and female marble goby during the study, significant morphological changes were found at each level of gonad maturity (TKG). These changes included size, color, volume, and texture of the gonads. This is in line with Omar's (2013) statement that histological, cytological, and morphological changes in the gonads serve as indicators of gonad development, which is also accompanied by an increase in weight and volume (20). Therefore, these morphological characteristics can serve as a basis for determining the gonad maturity level.

Table 6. Average range of first gonad maturity size of marble goby in Lake Tempe.

Observation		Sex Ratio	Parameters	Average	Range
Sampling time	October	Female	Total length (mm) Body weight (g)	219.27 179.65	203.80 – 235.92 149.00 – 216.60
		Male	Total length (mm) Body weight (g)	265.15 352.07	249.88 – 281.35 286.47 – 432.71
	November	Female	Total length (mm) Body weight (g)	190.02 86.13	179.50 – 201.16 76.54 – 96.98
		Male	Total length (mm) Body weight (g)	197.30 187.64	184.65 – 210.82 156.40 – 225.13
Moon Phase	Dark	Female	Total length (mm) Body weight (g)	230.46 72.53	212.65 – 246.75 65.26 – 80.62
		Male	Total length (mm) Body weight (g)	247.14 119.80	228.45 – 267.35 98.51 – 145.69
	Light	Female	Total length (mm) Body weight (g)	188.94 178.73	209.60 – 236.34 149.84 – 206.80
		Male	Total length (mm) Body weight (g)	209.28 347.34	192.99 – 226.95 285.18 – 423.04
Sampling location	Station 1	Female	Total length (mm) Body weight (g)	175.72 175.47	167.80 – 184.02 148.89 – 206.80
		Male	Total length (mm) Body weight (g)	191.65 382.18	178.41 – 205.87 312.44 – 467.48
	Station 2	Female	Total length (mm) Body weight (g)	198.41 93.80	190.94 – 206.18 75.13 – 117.12
		Male	Total length (mm) Body weight (g)	256.88 110.40	239.49 – 275.54 98.75 – 123.42

During the study in Lake Tempe, the marble goby captured showed five categories of gonad maturity levels, namely TKG I to TKG V. Referring to the classification by Kariyanti *et al*. (2018), TKG I indicates immature gonads, TKG II reflects the early stage of development, TKG III marks the maturity stage, TKG IV indicates the final development stage, and TKG V represents the spawning phase(21). According to Effendie (2002), the TKG analysis is useful for determining the level of maturity, timing and intensity of spawning, and the size or age when fish first reach gonad maturity (22).

In this study, most of the marble goby individuals captured were in TKG I and II, both male and female. At the same time, the lowest number was found in TKG V. This finding indicates that most of the captured fish population has not yet reached gonad maturity. This is suspected to be due to the sampling location not being a spawning habitat. According to Kordi (2013), marble goby form pairs and choose sheltered spawning sites, such as areas with hard substrates, rocks, or aquatic plants (23).

However, throughout the observation period (October–November), all stages of gonad maturity (TKG I–V) were still identified in both male and female marble goby, indicating the presence of spawning activity during the sampling period. This finding aligns with Widhawati's (2015) report, which stated that marble goby are capable of spawning throughout the year(24), with spawning intensity increasing during the rainy season(25).

Both internal and external factors influence the variation in gonad maturity levels. External factors include temperature, food availability, the presence of the opposite sex, water current conditions, and the suitability of substrates for spawning. On the other hand, internal factors include age, body size, species, and the physiological condition of each individual within a population (26). Additionally, Tang & Affandi (2001) indicated that hormonal regulation is key in determining differences in gonad maturity levels between individuals (27).

Furthermore, an analysis of the sex ratio of marble goby observed through the sampling time, moon phase, and capture location showed an overall ratio of 0.71:1.00 (female:male). The chi-square test results indicated that this sex ratio significantly differed from the balanced value (1.00:1.00), indicating an imbalance in the proportion of female and male fish across all observation categories. This phenomenon shows that the male marble goby population tends to dominate compared to the female population in Lake Tempe.

The inclusion of moon phases in this study was intended to explore whether lunar cycles might influence the reproductive behavior or capture probability of marble goby, as has been observed in other freshwater and estuarine fish species. Although the biological connection between moon phases and reproductive activity in marble goby has not been well documented, the significant imbalance in sex ratio observed during the dark moon phase may be related to changes in fish behavior or movement patterns associated with lunar cycles (28). Further studies focusing on behavioral observations and environmental interactions during different moon phases are recommended to clarify this relationship.

The variation in sex ratio observed from various parameters shows inconsistency across locations and times, but is dominated by male individuals. This imbalance is suspected to be related to the species' reproductive behaviour, where marble goby tend to form pairs only just before or during the spawning process, which is usually detected through gonads at maturity level IV (29).

Rahman *et al*. (2013) stated that in natural ecosystems, the sex ratio is not always balanced because various factors,

such as food availability, population density, and the stability of the food chain, influence it. If a population shows a balanced ratio or a female dominance, it is considered stable and capable of sustaining its continuity. On the other hand, excessive male dominance can decrease natural reproductive potential due to the limited number of females(30).

This study's findings are consistent with Sitepu *et al*.'s (2018) findings, which also documented an imbalanced sex ratio of marble goby in Lake Tempe, with a male dominance (7). Conversely, a study by Fatah and Adjie (2013) in Kedung Ombo Reservoir showed a higher proportion of female marble goby than males (16). According to Miazwir (2012), this imbalance in sex ratio could be caused by differences in behavior, growth patterns, and mortality rates between males and females (31).

Regarding the first gonad maturity size (UPMG) of marble goby in Lake Tempe, there was variation based on body length and weight, influenced by time, moon phase, and sampling location. In terms of body length, in October, female fish reached gonad maturity at 219.27 mm, while males reached it at 265.15 mm. In November, the UPMG decreased to 190.02 mm for females and 197.30 mm for males. During the dark moon phase, females reached maturity at 230.46 mm, while males reached it at 247.14 mm. On the other hand, during the light moon phase, females reached gonad maturity at 188.94 mm and males at 209.28 mm. Based on location, at station 1, females reached maturity at 175.72 mm and males at 191.65 mm; at station 2, females reached maturity at 198.41 mm and males at 256.88 mm.

In terms of body weight, in October, female marble goby reached UPMG at 179.65 g, while males reached 352.07 g. In November, females reached gonad maturity at 86.13 g and males at 187.64 g. During the dark moon phase, UPMG for females was 72.53 g and for males, 119.80 g. Meanwhile, females' UPMG was recorded at 178.73 g during the light moon phase and males' at 347.34 g. Based on location, UPMG for females at station 1 was 175.47 g and for males, 382.18 g; at station 2, females' UPMG was 93.80 g and males' was 110.40 g.

These findings suggest that female marble goby reach gonad maturity faster than males. This difference is due to variations in gonad growth rates between the sexes. According to Nikolsky (1963), differences in the first gonad maturity size within the same species can be influenced by environmental factors, food availability, and different habitat conditions (32).

A similar phenomenon was found in a study by Kariyanti (2014) on *Marosatherina ladigesi* in the Bantimurung River, South Sulawesi, where females matured at 48.10 mm and males at 54.25 mm (21). Other studies by Hedianto & Purnamaningtyas (2013) and Wahyuni *et al*. (2015) also support the idea that female fish generally reach gonad maturity earlier than males, which is associated with a larger energy allocation to the female gonads compared to body growth. As a result, males often have a larger body length at the same gonad maturity level ((33,34).

Each fish species exhibits variation in age and size when reaching sexual maturity, and even among individuals of similar length and age classes, not all will mature at the same size (35). Abubakar *et al*. (2019) further added that UPMG variability can be influenced by various factors such as environmental conditions, geographic location, abiotic factors, genetic variation in populations, water quality, and fishing pressure (36).

The findings of this study have important implications for the sustainable management of marble goby in Lake Tempe. The observed imbalance in sex ratio, with a dominance of male individuals, highlights the need for cautious harvesting practices to prevent a decline in female populations, which are crucial for maintaining reproductive output. Furthermore, the smaller initial gonadal maturity size in females suggests that implementing minimum size limits based on gonadal maturity could help ensure that individuals have the opportunity to reproduce before capture (breeding season protection). For potential restocking efforts, broodstock selection should prioritize balanced sex ratios and consider the documented size at first maturity to optimize reproductive success. Additionally, future management strategies should account for spatial variation and potential influences of lunar cycles on reproductive behavior to enhance the effectiveness of both harvesting regulations and restocking programs.

Study Limitation

This study focused primarily on analyzing the sex ratio and initial gonadal maturity size of marble goby in Lake Tempe based on temporal and spatial sampling. However, environmental variables such as water temperature, dissolved oxygen, pH, and habitat characteristics were not measured in this study, as they were beyond the main scope of the research. These factors may play a role in influencing reproductive patterns and sex ratios in fish populations. Future studies are recommended to incorporate environmental and habitat variables to provide a more comprehensive understanding of the ecological factors affecting the reproductive biology of marble goby in Lake Tempe.

Conclusion

This study revealed that marble goby in Lake Tempe exhibited continuous reproductive activity, with a sex ratio skewed toward males and females reaching gonadal maturity at smaller sizes than males. These findings highlight the need for sustainable harvesting strategies, including the protection of mature females and the application of minimum size limits based on gonadal maturity. Additionally, the results provide baseline data to support future restocking and breeding programs aimed at conserving marble goby populations in Lake Tempe.

Declarations

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The authors declare no conflicting interest.

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Additional Information

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