Reproductive Biology of the Goby *Sicyopterus longifilis* from the Matama River, West Sulawesi, Indonesia

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Abstract

Sustainable fisheries management depends heavily on the reproductive biology of amphidromous fishes, yet little is known about *the reproductive traits of Sicyopterus longifilis*. In this study, *we determined gonad development stages in S. longifilis from the Matama River in West Sulawesi, Indonesia, macroscopically, following Effendie (1979), and calculated GMI* **from gonad weight and total body weight.** From July to December 2023, we sampled fish monthly using an electric shocker. We measured egg diameter with an ocular micrometer under a compound microscope, evaluated fecundity using the gravimetric method, determined gonad development stages macroscopically according to Effendie (1979), and computed GSI from gonad and body weight. A total of 758 specimens, comprising 281 male and 477 females, were examined. Throughout the investigation, we found five gonad maturity stages (I-V), indicating ongoing reproductive growth. The peak reproductive activity occurred in July, and female GMI increased with gonadal development, reaching its highest value at GMS IV. Egg diameter varied from 0.20 to 0.44 mm, and fecundity varied from 43 to 7,887 eggs, with an average of 1,702 ± 2,551 eggs. *S. longifilis* appears to have a complete spawning strategy based on the unimodal distribution of egg diameter. The relationships between fecundity and total length, body weight, and gonad weight were relatively weak, indicating that reproductive output is influenced not only by fish size but also by environmental conditions and physiological status. These findings provide the first comprehensive information on the reproductive biology of *S. longifilis* in the Matama River and contribute essential baseline data for the conservation and sustainable management of amphidromous goby populations in West Sulawesi.

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Keywords: amphidromous goby, egg diameter, fecundity, gonad maturity stage, gonadosomatic index

Introduction

Diadromous fish have a unique life cycle; they spawn in freshwater, larvae migrate to the sea after hatching, and young fish return to rivers to grow until they reach maturity. Consequently, future climate warming is expected to alter recruitment dynamics and population persistence in amphidromous fishes. However, the life cycle of amphidromous fish depends heavily on connectivity between rivers and the sea, making this group highly sensitive to habitat fragmentation, hydrological changes, water quality degradation, dam construction, and climate change. As a result, amphidromous fish are widely used as indicators of tropical river ecosystem health. They are also an important group for freshwater biodiversity conservation and fisheries management

(McDowall, 2007; Keith *et al.*, 2011; FishBase, 2016).

Studies of amphidromous species also show that oceanographic conditions during the larval phase greatly influence population dynamics. Teichert *et al*. (2021) demonstrated that water temperature strongly influences the early development and survival of Sicyopterus lagocephalus larvae. Increasing water temperature significantly reduced larval survival and affected critical developmental processes, highlighting this amphidromous species' sensitivity to thermal conditions during early life stages. Larvae developing at higher sea temperatures have faster growth rates, shorter pelagic durations, and smaller sizes at recruitment; thus, climate change is expected to increase. *S. longifilis* is one of the amphidromous species that has significant ecological and economic value in Indonesia. In West Sulawesi, this species is called goby fish, or "penja," in the postlarval phase and is a highly profitable seasonal fishery commodity for coastal communities and those along river flows. In addition to generating income, this species has ecological benefits as an important part of the fast-flowing river fish community. Tikawati *et al.* (2024) found that the physicochemical characteristics of the water suitable for growth are still present in the habitat of *S. longifilis* in the Ummiding River and Matama River. However, increased fishing activities, land-use changes, and habitat disturbances can affect the population structure and sustainability of fish resources, so managing *S. longifilis* requires more comprehensive biological information.

Reproduction is one of the most important biological parameters in fish resource management because it indicates the population's ability to maintain stock sustainability in nature and produce offspring. Gonad Maturity Stages (GMS), Gonad Maturity Index (GMI), fecundity, and egg diameter can be used to determine spawning season, size at first gonadal maturity, reproductive energy investment strategy, and population recruitment potential. This data is used to formulate management policies, including minimum catch size, closed seasons, and spawning habitat protection (Kudsiah *et al*., 2024). Furthermore, West (1990) explains that although macroscopic observation and gonad indices suit surveys of very large populations, histological methods are most accurate for determining fish reproductive phases.

Brown-Peterson *et al.* (2011) proposed standardized terminology for fish reproductive phases that can be applied across various teleost groups, reflecting advances in fish reproductive biology research. They divide reproductive development into immature, developing, spawning-capable, regressing, and regenerating phases. This classification allows for more consistent comparisons of research results between species. This standardization is very important because several previous studies used different gonad classification systems, making the interpretation and synthesis of research findings difficult.

Studies on the reproduction of Gobiidei fish have developed very rapidly. Cole and Parenti (2022) describe the reproductive morphology of Rhyacichthys aspro, a basal gobiid. They describe typical gobioid reproductive characteristics, such as asynchronous spawner-type ovaries and reproductive tract structures crucial for spawning success. This study provides an important foundation for understanding the evolution of goby fish reproduction, but it has not yet addressed quantitative reproductive elements such as fecundity and gonadal maturation dynamics in amphidromous species utilized by the community.

Studies on goby reproduction remain very limited in Indonesia. Kudsiah *et al.* (2024) found that Glossogobius giuris in Lake Sidenreng has four stages of ovarian maturity. In addition, females have a higher ovarian maturity index than males, and the size at first ovarian maturity differs between the sexes. This study provides a foundation for managing goby reproduction in the freshwater waters of South Sulawesi. However, the research findings cannot be directly applied to *S. longifilis* because the two species have different habitats, lifestyles, and migration patterns.

Previous research shows that most studies focus on reproductive morphology, standardization of gonadal development classification, or reproductive aspects of non-swimming goby species. Currently, little data exist on the reproductive biology of *S. longifilis*, particularly gonadal maturity levels, gonadal maturity indices, fecundity, and egg diameter in its natural population in West Sulawesi. Nevertheless, this information is crucial for understanding the reproductive strategies of this species, determining the spawning season, estimating the potential population increase, and formulating fisheries management policies based on scientific data. Accordingly, to support the management and conservation of amphidromous species in the Matama River, West Sulawesi, this study aims to analyze the reproductive aspects of *S. longifilis,* including gonadal maturity levels, gonadal maturity indices, fecundity, and egg diameter.

Materials and Methods

The study was conducted from July to December 2023 in the Matama River, Polewali Mandar Regency, West Sulawesi Province. Sampling was conducted periodically at several stations representing the main habitat of *S. Longifilis*

Fish reproduction analysis was conducted at the Biology Laboratory, West Sulawesi University. Figure 1 shows the study locations. Fish samples were collected monthly using an electric shocker set to 12 volts and 9 A. The operator used the electric shocker to capture fish by following a zig-zag pattern against the river current (moving upstream). The capture was conducted over 200 meters at 30-minute intervals. We then

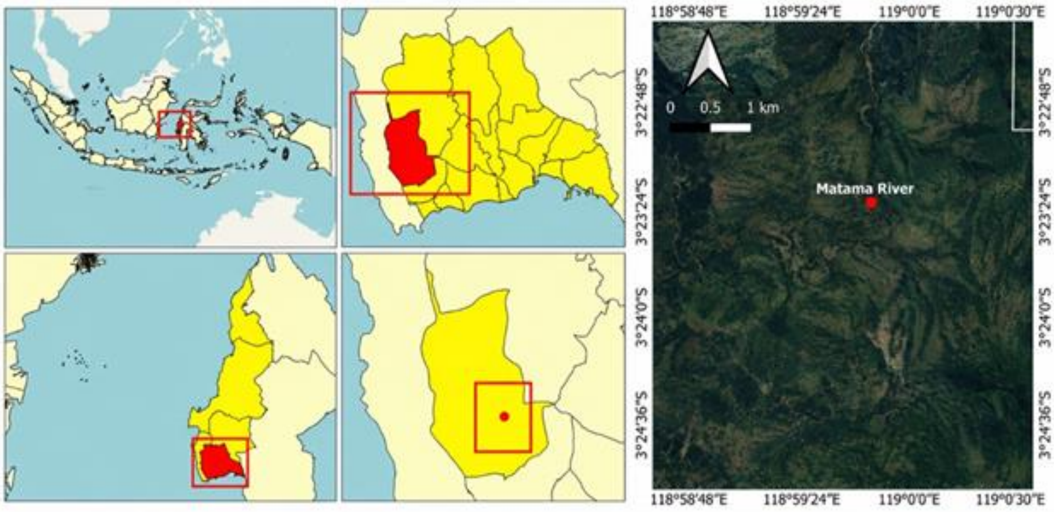

Figure 1. Research Map of the Matama River *Sampling collection*

separated the fish caught in the Matama River by species and counted them. We preserved the separated fish in 1000 ml sample bottles containing 10% formalin, labeled with the location and collection date. After 2-3 hours, the fish were washed thoroughly with running water and transferred to a container containing 70% alcohol for laboratory analysis.

Data Analysis

Gonad Maturity Stages (GMS) is analyzed by grouping data based on the proportion of fish that have not and have matured gonads. The Classification of Gonad Maturity Stages (GMS) *S. longifilis* refers to Effendie (1979) as shown in Table 1.

Table 1. Classification of fish gonadal maturity levels (Effendie, 1979)

GMS	Male	Female
I	Testes are thread-like, shorter (limited in length), and their tips are visible in the body cavity. They are clear in color.	The ovaries are thread-like and extend to the front of the body cavity. They are clear in color and have a smooth surface.
II	The testes are larger, with a milky white color. Their shape is more distinct than in gonadal maturity stage I.	The ovaries are larger and have a darker, yellowish color. The eggs are not yet clearly visible to the naked eye.
III	The surface of the testes appears serrated; the color becomes whiter, and the testes grow larger. When pressed, they break easily.	The ovaries are yellow. Morphologically, the eggs begin to appear as visible granules to the naked eye.
IV	As in gonadal maturity stage III, the features are more clearly visible. The testes become increasingly firm.	The ovaries are getting larger; the eggs are yellow and can be easily separated. Oil droplets do not appear to fill ¼–? of the abdominal cavity, and the intestines are displaced.
V	The posterior part of the testes is deflated, while the part near the ejaculatory duct is still filled.	The ovaries are wrinkled, with thick walls; residual eggs are present near the oviduct opening, and there are many eggs similar to gonadal maturity stage II.

Gonadal Maturity Index

The gonadal maturity index (GMI) is calcul-ated using the following formula (Effendie, 2002):

$$IKG = \frac{Bg}{Bi}100\%$$

Explanation:

GMI = gonadal maturity index (%),
Bg = gonad weight (g),
Bi = fish weight (g).

Fencudity

Observations of fecundity and egg diameter were determined from fish samples with GMI stages III, IV, and V. Total fecundity was calculated using the gravi-metric method (Andy Omar, 2013) with the following formula:

$$F = \frac{G\ x\ f}{g}$$

Explanation:

F = Total number of eggs in the gonads (fecundity, eggs)
G = Gonad weight (g)
g = Weight of a portion of the gonads (subsample, g)
f = Number of eggs from the gonad subsample (eggs)

Next, the relationship between fecun-dity and total fish length was calculated using the following formula (Effendie, 2002):

$$F = aL^b$$

Explanation:
F = Fecundity (eggs)
L = Total fish length (mm)
a dan b = Constants

The relationship between fecundity and fish body weight was calculated using the following formula (Effendie, 2002):

$$F = a + bW$$

Explanation:
F = Fecundity (eggs)
L = Total fish weight (g)
a dan b = Constants

The relationship between fecundity and fish gonad weight is calculated using the formula (Effendie, 2002) as follows:

$$F = a + bG$$

Explanation:
F = Fecundity (eggs)
G = Gonad weight (g)
a dan b = Constants

Egg Diameter

Egg diameter measurements were performed using an ocular microscope equipped with an ocular micrometer. Egg diameter was calculated using the following equation Andy Omar, 2010):

$$Ds = \sqrt{Dh \times dv}$$

Explanation:
Ds = Actual egg diameter (mm);
Dh = Horizontal egg diameter (mm);
Dv = Vertical egg diameter (mm).

The data on gonadal maturity levels are presented in graphs and descriptive tables. The analysis of fecundity, gonadal maturity index, and egg diameter is conducted using descriptive statistics, which include mini-mum, maximum, average, and standard deviation values. Simple linear regression analysis was also used to examine the relationship between fecundity and total length and body weight. Statistical software IBM SPSS version 26 and Microsoft Excel 2021 were used to perform the statistical analysis. To show the reproductive charac-teristics of *S. longifilis* in the Matama River, the analysis results are presented in the form of descriptions, tables, and graphs.

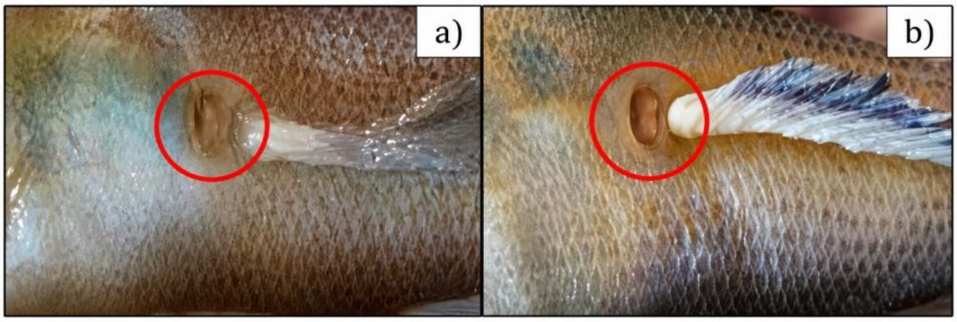

Figure 2. Sexual dimorphism in the goby fish *S. longifilis*. Description: a) Papilla in male goby fish, b) Papilla in female goby fish

Results

Gonadal Maturity Stage (GMS)

The gonadal maturity Stage (GMS) is the stage of fish gonad development from before, during, to after spawning. The goby fish (*S. longifilis*) in the Matama River exhibit sexual dimorphism that can be distinguished based on the shape of the urogenital papilla. Male fish have a triangular and somewhat pointed papilla, while female fish have a round and bifurcated papilla (Figure 2).

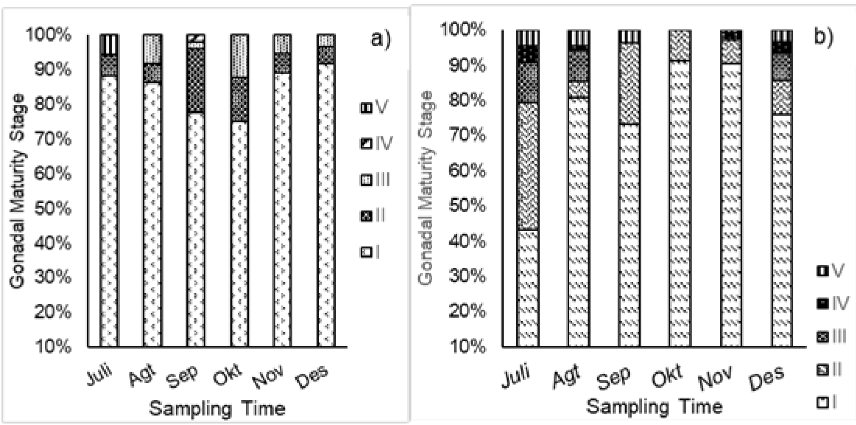

Figure 3. Frequency (%) of gonadal maturity levels of *S. longifilis* goby fish observed based on the sampling time in the Matama River

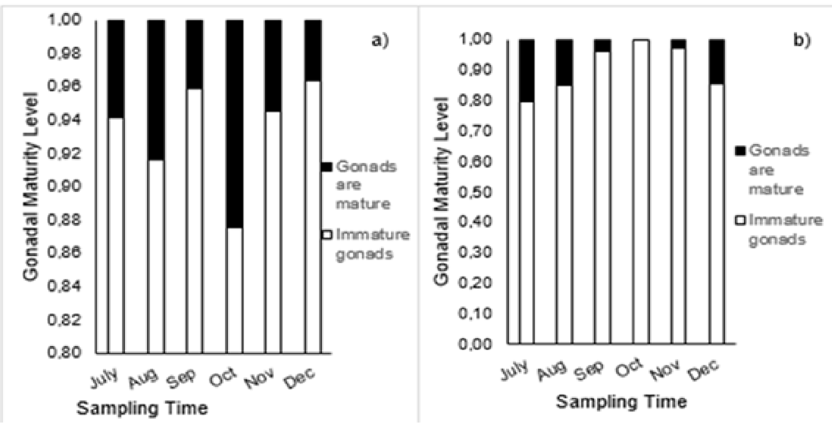

Figure 4. Frequency (%) of Gonad maturity stage of *S. longifilis* Goby Fish Observed Based on Fish with Matured and Immature Gonads at Each Sampling Time in the Matama River: a) Male, b) Female

Table 2. Distribution of gonadal maturity stages of *S. longifilis* in the Matama River

Gonadal Maturity Stage	Male		n (Individuals)	Female		n (Individuals)
	Range	Mean±SD		Range	Mean±SD	
I	24,01-95,28	55,7936 ± 15,0997	246	0,049-9,656	52,9608 ± 52,9660	370
II	41,7-89,99	64,6757± 13, 7180	23	47,2-108,63	64,1921 ± 13,3890	62
III	67,42-91,86	79,0983 ± 6,6805	12	49,6118,9	73,6326 ± 16,4002	23
IV	0	0	0	44,7-88,61	77,6762 ± 15,5499	8
V	0	0	0	54,3-127,49	90,5857 ± 23,5087	14
Total			281			477

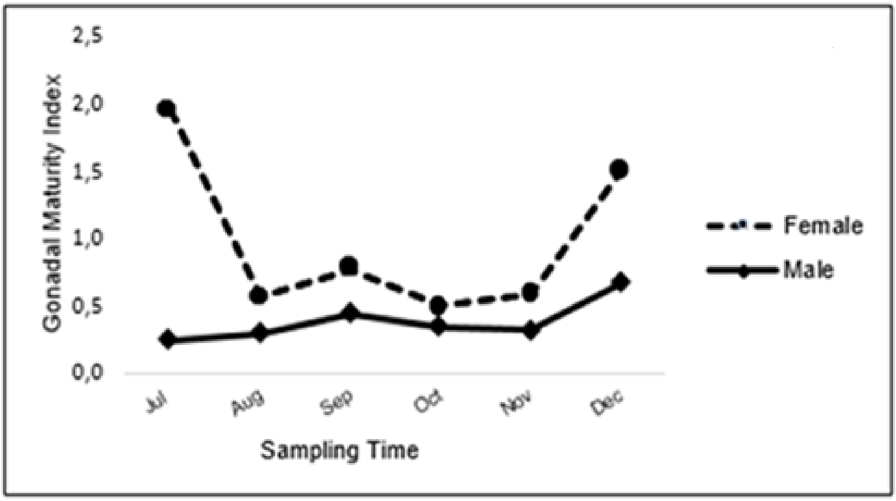

Figure 5. Gonad maturity index (GMI) of *S. longifilis* goby fish in the Matama River

The differences in urogenital papilla morphology provide a clear external characteristic for distinguishing the sex of *S. longifilis*. This sexual dimorphism is particularly useful for assessing gonadal maturity because it allows identification of males and females before detailed examination of gonadal development.

Gonadal Maturity Index (GMI)

The gonadal maturity index (GMI) of goby fish (*S. longifilis*) in the Matama River shows a pattern of change over the Observation period (Figure 4). The GMI varied by gonadal maturity stage and sampling month, reflecting changes in gonadal development throughout the reproductive cycle. In female fish, the GMI increases and peaks in July, then gradually decreases from August to December. The distribution of gonadal maturity index values based on the level of gonadal maturity can be seen (Figure 4), while the distribution of the gonadal maturity index can be seen in Table 3.

Table 3. Gonadal maturity index of the goby fish *S. longifilis* based on gonadal maturity stages in the Matama River

Gonadal maturity index	Male		n (Individuals)	Female		n (Individuals)
	Range	Mean±SD		Range	Mean±SD	
I	0.0111-2.8571	0.15084±0.2833	246	0.0041-2.1739	0.1132±0.1883	370
II	0.01467-2.3178	0.8079±0.6064	23	0.0678-4.7692	0.8136±0.8216	62
III	0.3021-3.1854	1.6917±0.8431	12	0.0189-7.8461	2.8075±2.0677	23
IV	0	0	0	0.0109-11.3636	6.8034±3.5579	8
V	0	0	0	0.2202-7.2043	2.3809±2.0330	14
Total			281			477

Table 4. Range and average fecundity of the goby fish *S. longifilis* based on the sampling time in the Matama River

Sampling time	Range of total body length (mm)	Body weight range (g)	Fekundity range (Eggs)	Mean ±SD
July	49.60-118.90	1.300-22.700	558-3,766	2.488±1.191
August	58.66-122.51	3.123-23.990	43-7,887	1.702±2.551
September	111.09-119.41	20.735-25.755	33-34	33.5 ±0.707
October	0	0	0	0
November	78.94-90.25	6.666-9.109	1,285-3,144	11.620±1.717
December	68.41-88.64	4.733-9.188	594-1,648	3.144±3.620

The highest GMI value was obtained in female individuals with GMS IV, while the lowest value was found in GMS I. The increase in GMI value indicates a higher proportion of gonad weight to body weight during the gonad maturation process.

Fecundity

The fecundity of goby fish (*S. longifilis*) in the Matama River was analyzed in 39 female fish with gonadal maturity levels (GML) III, IV, and V. The research results showed that the fecundity of goby fish in the Matama River varied, with the number of eggs ranging from 43 to 7,887 at total lengths of 58.66 to 122.51 mm, with an average value of 1,702 ± 2,551 eggs (Table 4).

August had the highest fecundity. The relationship between fecundity and total length, body weight, and gonad weight showed a low correlation (Figure 5), indicating that fecundity varies not only with body size but also with environmental factors and the fish's reproductive condition. Table 5. Fecundity of *S. longifilis* in the Matama River. The relationship between fecundity and total length and body weight shows a positive trend: larger individuals produce more eggs.

Egg Diameter

The diameter of goby fish eggs (*S. longifilis*) in the Matama River ranges from 0.20-0.44 mm during GMS III, IV, and V (Figure 7).

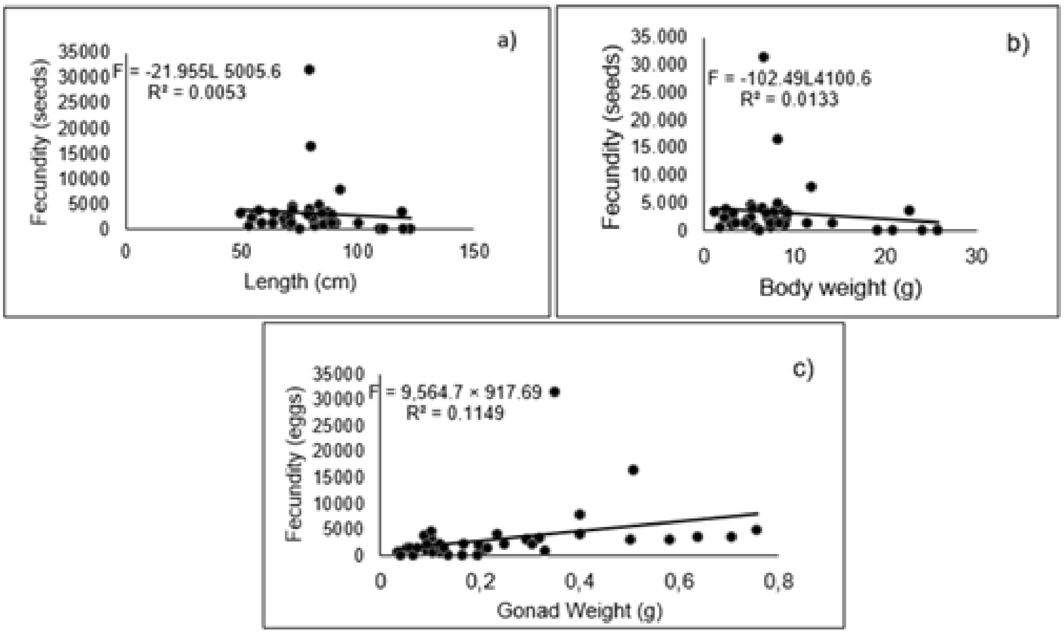

Figure 6. Relationship between fecundity and total body length (a) between fecundity and body weight (b), and between fecundity and gonad weight (c) of Matama River Gobies

Table 5. Range and average gonadal maturity stage of the goby fish based on the sampling time in the Matama River

Gonadal Maturity Stage	N	Total body range (mm)	Body weight range (g)	Fecundity range (seeds)	Mean ±SD
III	19	49.60-118.90	1300-22700	558-31448	4,570±7490
IV	7	64.41-88.61	3300-9188	973-4,777	3042±4777
V	13	54.30-122.51	2300-25755	33-3976	1472±1357

The variation in egg diameter indicates differences in the developmental stages of oocytes during the gonad maturation process. Differences in egg diameter can occur within the same species or between different species, influenced by environmental factors, particularly the availability of food sources that support gonad development. The distribution of goby fish egg diameters in the Matama River shows a single highest modal value at each stage of gonadal maturity, indicating that *S. longifilis* has a total spawner spawning pattern.

Table 6. Distribution of egg diameter of *S. longifilis*.

Discussion

Gonad Maturity Stage

The gonadal maturity Stage (GMS) is a stage of gonadal development before and after spawning that describes the sexual maturity level of fish. In this phase, most of the fish's metabolic output is utilized for gonad development (Iskandar, 2024). GMS can be observed morphologically through changes in gonad shape, size, color, and texture

Table 6. Spawning Seasons of Several Goby Fish Species

Spesies	Spawning Season	Location	References
Neogobius caspius	April and May	Noor Beach	Mahdipour *et al.*, 2020
Glossogobius matanensis	March-April and October-December	Towuti, South Sulawesi	Sulistiono *et al.*, 2007
Glossogobius giuris	July though August	Ujung Pangkah Waters	Sulistiono 2012
Glossogobius giuris	September through November	Tempe Lake	Eragradhini, 2014
Syciopterus lagocephalus	May	River Cibareno	Ambarwati *et al.*, 2023
Sicyopterus lagocephalus	November though May	Reunion	Bielsa *et al.*, 2003
Sicyopterus japonicus	September though October	Shuang-Chi River, Taiwan	Shen and Tzeng 2002
Glossogobius matanensis	October and March	Towuti Lake	Mamangkey and Nasution, 2012

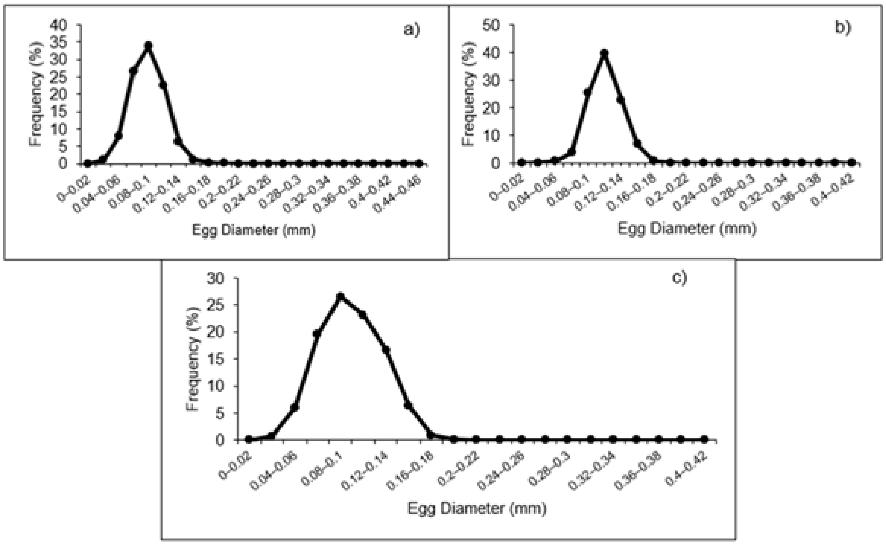

Figure 7. Distribution of the diameter of *S. longifilis* goby fish eggs observed at each stage of gonadal maturity during the study in the Matama River. Note: a) (GSI III), b) (GSI IV), and c) (GSI V).

Macroscopic observations of the goby fish (*S. longifilis*) in the Matama River show that the gonads develop into two reproductive organs, namely testes in male fish and ovaries in female fish (Figure 2). According to Sulistiono et al. (2007), the level of gonadal maturity can be used to estimate the reproductive status of fish, the size and age at which gonads first mature, the proportion of the fish stock that has matured reproductively, and to provide information on the reproductive cycle of a population. In addition, GMI can be used to estimate a species' spawning period.

The determination of the gonadal maturity stages (GMS) of the goby fish (S. longifilis) in the Matama River was conducted thru macroscopic observation based on the modification of Salvanes *et al.* (2018), which divides gonadal development into five stages: GMS I (not developed), GMS II (early developing), GMS III (developing), GMS IV (mature), and GMS V (post-spawning). The research results show that all stages of gonadal maturity (GMS I-V) were found in the goby fish population in the Matama River during the study period.

Gobies that have not yet matured their gonads (GMS I and II) were found in every month of observation, from July to December, in both male and female fish. This indicates that recruitment occurs continuously, resulting in a population dominated by individuals in the early stages of gonad development. Meanwhile, goby fish with mature gonads (GMS III, IV, and V) were found in July, August, September, November, and December. The absence of fish in GMS III, IV, and V in October indicates that during that month, most of the population is in the reproductive rest phase or has completed the previous spawning process (Figure 4 and Table 2).

The presence of individuals in GMS V (post-spawning) indicates that spawning occurred in the Matama River. Based on the distribution of gonadal maturity levels during the study, it is suspected that the spawning activity of the goby fish (*S. longifilis*) in the Matama River took place in July (Figure 5). This assumption is reinforced by the discovery of post-spawning individuals after that period, indicating that gamete release has occurred. According to Lelono *et al.* (2023), food availability and environmental conditions strongly influence gonad development. Under normal conditions, the weight of the female fish's gonads can reach 10–25% of their body weight, while for male fish it ranges from 5–10% of their body weight during the gonadal maturation phase.

The presence of all levels of gonadal maturity (Gonadal Maturity Stages I-V) in the Matama River indicates that the habitat supports the continuity of the goby fish (*S. longifilis*) reproductive cycle. Information on the distribution of these gonadal maturity levels is crucial for understanding reproductive patterns, determining spawning seasons, and formulating sustainable management and conservation strategies for goby fish resources in the Matama River (Sulistiono *et al*., 2007; Iskandar, 2024; Lelono *et al*., 2023).

Gonad Maturity Index

The gonad maturity index (GMI) of *S. longifilis* increased with increasing gonadal maturity and reached its highest value at GMS IV, followed by a decline at GMS V. This pattern reflects the increase in gonad weight during gonadal development and its subsequent reduction following spawning. Based on the research results in the Matama River, the gonad maturity index of female goby fish (*S. longifilis*) peaks in July, then begins to decline from August to December (Figure 6). This pattern indicates that gonad development reaches maturity in July, followed by spawning, which causes a decrease in gonad weight. This is consistent with the spawning season of the goby fish Glossogobius giuris in the waters of Ujung Pangkah as reported by Sulistiono *et al.* (2007).

The gonadal maturity index of female goby fish in the Matama River is higher compared to male goby fish. This differen-ce indicates that female gonadal develop-ment is more intensive due to yolk forma-tion and accumulation (vitellogenesis) in the ovaries. Barbieri *et al.* (2023) reported that GMI values increase over time as long as the gonads are still developing. The dec-rease in GMI value occurs when the gonad weight rapidly decreases during the spawn-ing process until the end of spawning (Asriyana and Halili, 2021). The increase in GMI value is directly proportional to time, which is suspected to be due to ongoing gonad development.

The increase in gonad weight during reproductive development occurs as a result of the accumulation of yolk precursors in the ovaries. Hara *et al.* (2016) mentioned that the increase in gonad weight is the result of the accumulation of yolk deposition during the gonad development process. This causes female gonad weight to be greater than that of male fish, resulting in higher GMI values. According to Gustomi *et al.* (2016), the average gonadal maturity index value of female fish is greater than that of male fish because the gonad weight of female fish is larger than that of male fish.

The pattern of changes in the Gonad Maturity (GMI) of goby fish in the Matama River, which increased in July and then decreased from August to December, indicates that reproductive and spawning activities occur during that period. Tropical freshwater fish generally exhibit.

High GMI values indicate that the gonads are in the mature phase, whereas a subsequent decrease in GMI may indicate spawning and post-spawning conditions.. Thus, the gonadal maturity index can be used as an indicator to determine the breeding season of the goby fish (*S. longifilis*) in the Matama River, as explained by Sulistiono *et al.* (2007) that the GMI is one of the effective parameters in estimating the spawning season of fish.

Fecundity is the total number of eggs present in the ovaries and the potential to be released during spawning. Fecundity in goby fish can vary even among individuals of the same species because of environ-mental factors and the availability of food nutrients (Jan & Jan, 2017). Fecundity analysis was conducted to estimate the reproductive potential of the goby fish *S. longifilis* in the Matama River. Fecundity calculations were performed on female goby fish at gonadal maturity stages (GMS) III, IV, and V. According to Winemiller *et al.* (2008), fecundity values and egg sizes vary.

The research results show that the fecundity of goby fish in the Matama River ranges from 43 to 7,887 eggs with a total length of 58.66-122.51 mm, while the average fecundity value reaches 1,702 ±

2,551 eggs. August had the highest fecundity (Table 4). Variation in egg production indicates differences in reproductive capacity among individuals, likely related to body size, gonadal maturity, and aquatic environmental conditions.

Different environmental conditions can cause differences in egg numbers among fish populations (Langroudi & Sabet, 2016). In addition, variations in fecundity are also influenced by the size composition of the captured fish (Jan, 2017). Intrinsic factors, such as body size, age, and parental physiological condition, along with environmental factors such as temperature, food availability, and habitat conditions, can influence variation in fish fecundity. Reproductive success (Lowerre-Barbieri *et al*., 2023; Alix *et al*., 2020; Bhat *et al*., 2025). Another factor that also influences is the geographical location and the timing of sample collection (Wagle, 2014). Puspaningdiah *et al*. (2014) also explain that fecundity is closely related to age, body weight, body length, and food availability. The better the fish's growth, the higher its reproductive capacity, resulting in more eggs produced.

The fecundity value of goby fish in the Matama River is still within the range of tropical freshwater fish fecundity, which is generally lower compared to marine fish or migratory fish. Yonvitner *et al*. (2018) reported that the fecundity of freshwater fish is generally lower compared to the fecundity of marine fish or migratory fish. In addition, Jega *et al.* (2018) stated that food availability, fish size, salinity, temperature, and genetic factors influence variations in fecundity and reproductive potential.

The relationship between fecundity and the total length of female goby fish with mature gonads in the IV and V stages of maturity in the Matama River follows the equation F= -21.95L+5005.6 (Figure 6). The equation shows a relationship between total fish length and egg production, indicating that body size is one factor affecting fecundity. In general, fish with larger body sizes have higher reproductive capacity because they are able to produce a greater number of eggs, as reported in various other fish species. The com-

Egg Diameter

An egg is the final product of gametogenesis after the oocyte undergoes a growth phase influenced by hormonal activity (Mylones *et al.,* 2010). Larger eggs generally contain more yolk, resulting in larvae with a larger initial size and higher energy reserves. Larvae use yolk reserves as a nutritional source during early life before they can obtain food from the environment. Thus, egg diameter is a reproductive strategy that increases the chances of larval survival under fluctuating environmental conditions.

Based on the observations, the diameter of goby fish eggs (*S. longifilis*) in the Matama River ranges from 0.20-0.44 mm (Figure 7). The variation in egg diameter indicates that the observed oocytes are at different stages of development, ranging from early vitellogenesis to near maturity. The larger the diameter of the egg, the higher the level of oocyte development and the closer it is to spawning time.

The results of this study are consistent with Iskandar (2024), who stated that egg diameter can affect larval growth and development in the early stages of life. The diameter of the egg is also an indicator of the amount of nutrients stored within the egg, so the larger the diameter of the egg, the greater the reserve of nutrients available to support the growth of the embryo and larva after hatching.

The increase in egg diameter occurs due to the accumulation of yolk during the oocyte development process. Suhenda *et al.* (2016) explain that the increase in egg diameter is caused by the formation of yolk deposits and the distribution of yolk granules, which are used as an energy source during embryo development.

The process occurs thru the stages of vitellogenesis, which is the process of synthesis, transport, and absorption of vitellogenin into the developing oocyte (Hara et al., 2016). According to Song et al. (2020), vitellogenin is the main phospholipid-glycoprotein component of the yolk that continues to accumulate in the oocyte, leading to an increase in egg dia-meter until reaching the gonadal maturity stage.

The success of the vitellogenesis process is influenced by various factors, both internal and external. Cleveland et al. (2019) reported that vitellogenin synthesis is influenced by the physiological condition of the female, while Marzuqi et al. (2015) stated that nutritional adequacy is one of the important factors determining the success of yolk formation. Therefore, the variation in egg diameter found in goby fish in the Matama River is suspected to be influenced not only by the level of gonadal maturity but also by the aquatic environmental conditions and the availability of food that support the reproductive process.

Table 7. Fecundity in several freshwater fish species

Spesies	Fecundity (eggs)	Location	Reference
Neogobius caspius	400-1800	Noor Beach	Mahdipour et al., 2020
Glossogobius giuris	10640-150639	Ujung Pangkah Waters	Sulistiono, 2012
Glossogobius giuris	14505-181981	Lake Tempe	Eragradhini, 2014
Sicyopterus lagocephalus	24320-73810	Cibareno River	Ambarwati et al., 2023
Sicyopterus lagocephalus	14304-232475	River Marsouins, Reunion Island	Teichert et al., 2014
Sicyopterus japonicus	11000-18000	Shung-Chi River, Taiwan	Shen and Tzeng 2008
Glossogobius matanensis	20667-178133	Towuti Lake, South Sulawesi	Sulistiono et al., 2007
Boleophthalmus dussumieri	15223-37963		Ridho et al., 2021
Periophthalmodon schlosseri	13693-25863		
Glossogobius matanensis	25447-56907	Lake Towuti	Mamangkey and Nasution, 2012

Table 8. Egg Diameter of Freshwater Goby Fish

Spesies	Egg Diameter (mm)	Spawning Pattern	Location	Reference
Glossogobius matanensis	0.04-0.65	-	Towuti Lake, South Sulawesi	Sulistiono et al., 2007
Sicyopterus lagocephalus	0.20-0.22 mm	*Total spawner*	Cibareno River, Sukabumi, West Java	Ambarwati et al., 2023
Glossogobius giuris	49-372 µm	-	Ujung Pangkah, Waters	Sulistiono 2012
Glossogobius giuris	49-372 µm 32-150	- -		Eragradhini, 2014
Sicyopterus japonicus	72-103		Shuang-Chi River, Taiwan	Shen & Tzeng 2008
P. chrysospilos	0.051-0.069	-	Musi River Estuary	Ridho et al., 2021
B. dussumieri	0.034-0.04			
P. chrysospilos	0.051-0.069	-		

Information regarding the diameter of goby fish eggs (*S. longifilis*) in the Matama River provides an overview of the reproductive strategy of this species in producing offspring capable of surviving the early stages of their life. Comparison of egg diameters among several species of goby fish is presented in Table 8.

Conclusions

The reproductive biology of *S. longifilis* in the Matama River, West Sulawesi, revealed five gonadal maturity stages (GMS I–V) in both males and females, with July showing the highest reproductive activity. Egg diameter ranged from 0.20 to 0.44 mm, while fecundity ranged from 43 to 7,887 eggs. The unimodal distribution of egg diameter suggests that *S. longifilis* exhibits a total spawning pattern. These findings provide baseline information to support sustainable conservation and fisheries management of amphidromous gobies in tropical river ecosystems and contribute to a better understanding of the reproductive strategy of *S. longifilis*.

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