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“Analysis of Gonadal Maturity Stages in Ponyfish (*Leiognathus equula*) in the Waters off Takalar, South Sulawesi”

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Abstract

Gonadal maturity is an important indicator for understanding reproductive development and supporting fish resource management. This study aimed to analyze the gonadal maturity stages of ponyfish (*Leiognathus equula*) based on sex and observation time in the waters off Takalar, South Sulawesi. The study was conducted from April to September 2023 using 900 fish obtained from fishermen's catches and landed at the Beba Fish Landing Site. Gonadal maturity stages were determined macroscopically and classified into stages I–V. Data were analyzed descriptively based on the proportion of maturity stages by sex and observation month. The results showed that male fish were dominated by GMS II from April to July, while GMS III was dominant in August (53%). In September, GMS II, III, IV, and V accounted for 34%, 26%, 32%, and 7%, respectively. In female fish, GMS II dominated from April through August (73–89%), while in September, GMS III became dominant (41%), followed by GMS IV (22%) and GMS V (5%). The increase in the proportion of GMS III–V toward the end of the observation period indicates an increase in the reproductive development of the ponyfish. The results also showed that gonadal maturation in male fish.

Keywords: fish reproduction, gonad maturity stage, *leiognathus equula*, ponyfish

A. Introduction

Background The ponyfish (*Leiognathus equula* Forsskål, 1775) is a demersal fish of ecological and fisheries importance in coastal waters. This species belongs to the family Leiognathidae and is commonly found in coastal ecosystems that provide habitats for foraging and shelter. The presence of the ponyfish is also linked to the function of coastal ecosystems as habitats for various aquatic resources (Aw wali et al., 2024; Muslim et al., 2024a). Although *Leiognathus equula* has a global conservation status of Least Concern, the sustainability of its population remains affected by fishing pressure, habitat degradation, and changes in coastal environmental conditions (Klangnurak & True, 2022; Muslim et al., 2024b).

These pressures make information on reproductive capacity crucial for fisheries management. Reproductive characteristics, such as sex ratio, size at gonadal maturity, spawning time, and fecundity, determine reproductive potential and a population's ability to sustain itself (Lowerre-Barbieri et al., 2011; Lowerre-Barbieri et al., 2023). Reproductive information is also a key component in understanding population dynamics and supporting fisheries management based on the biological condition of the stock (Heino et al., 2019).

One important parameter for describing the reproductive status of fish is the gonadal maturity stages (GMS). GMS indicates the development of gonads toward maturity and can be used to identify the proportion of individuals that are capable of reproduction and to estimate the reproductive patterns of a population. Gonadal maturity data also serve as the basis for determining the maturity ogive and the first-maturity size, which are relevant for stock assessment and fisheries management (Heino et al., 2019; Lowerre-Barbieri et al., 2023). Macroscopic GMS observations

are relatively simple and efficient for field research, although they carry the potential for subjectivity, necessitating consistent observation procedures (Heins & Brown-Peterson, 2022).

Previous research has shown that the reproductive characteristics of *Leiognathus equula* can vary by location. In the waters off Palabuhanratu, the age at first gonadal maturity and spawning patterns exhibit specific characteristics related to local population conditions (Sitindaon et al., 2023). Meanwhile, a study along the Cilincing coast documented the development of male and female gonads to the mature stage, as well as indications of spawning during specific periods (Awwali et al., 2024). In the waters off Takalar, Haslina (2024) has examined the reproductive biology of *Leiognathus equula*, while Haslina et al. (2024) reported on the growth characteristics and environmental factors affecting the species. These findings highlight the importance of local biological characteristics in understanding the population dynamics of *Leiognathus equula*.

However, information on the age-class structure based on sex, body size, and maturity stage distribution remains important for clarifying the reproductive patterns of the population in the waters off Takalar. Such an analysis can provide more targeted information on the composition of immature and mature individuals, as well as potential reproductive periods. This information is needed to strengthen the biological basis for the management of *Leiognathus equula*, particularly in relation to the sustainable use of fishery resources in coastal areas.

Given these conditions, this study aims to analyze the gonadal maturity stages of ponyfish (*Leiognathus equula*) in the waters off Takalar, South Sulawesi, with a focus on the distribution of GMS by sex and fish size. The results of this study are expected to provide information on the reproductive status of the population and serve as a basis for the sustainable management of ponyfish resources.

B. Research Methods

Research Location

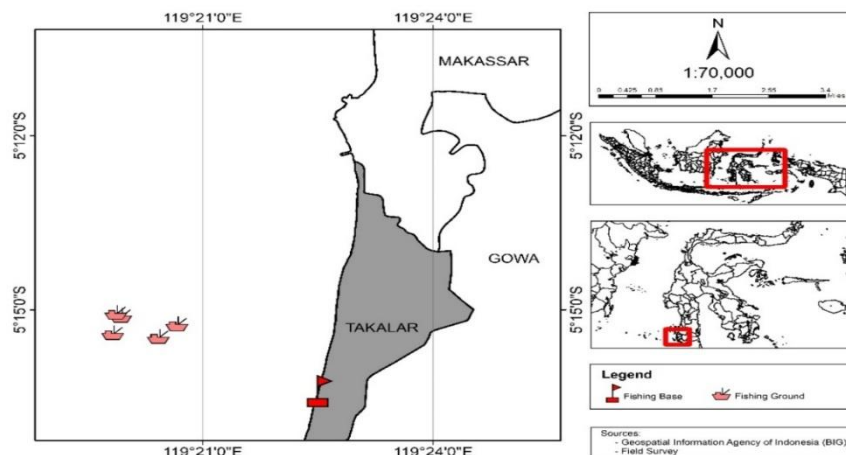


Figure 1. Map showing the sampling locations for *Leiognathus equula* in the waters off Takalar, South Sulawesi.

The study was conducted over a six-month period, from April to September 2023, in the waters off Takalar, South Sulawesi. Samples of ponyfish (*Leiognathus equula* Forsskal, 1775) were

obtained from fishermen's catches landed at the Beba Fish Landing Site in Takalar Regency. Biological analyses and gonad observations were conducted at the Fisheries Biology Laboratory, Department of Fisheries, Faculty of Marine Sciences and Fisheries, Hasanuddin University, Makassar. The sampling locations are shown in [Figure 1](#).

Sample Collection and Handling

The research samples consisted of ponyfish (*Leiognathus equula*) obtained from fishermen's catches in the waters off Takalar and landed at the Beba fish auction. Sampling was conducted periodically during the study period, from April to September 2023. A total of 900 fish were analyzed. Each fish was assigned an identification code based on the time of sampling to ensure data traceability during the analysis process.

The fish that were collected were immediately placed in a cool box and kept cold with ice to minimize changes in the biological condition of the samples. Upon arrival at the laboratory, the samples were cleaned and prepared for morphometric measurements and gonad examination.

Length and Weight Measurements

The total length (TL) of each individual was measured using a digital caliper with a precision of 1 mm. Total length was measured from the anterior tip of the head or mouth to the farthest tip of the caudal fin. Next, body weight was measured using a digital scale with a precision of 0.01 g. After morphometric measurements, the fish were dissected for gonadal examination and sex determination.

Sex Determination

Sex is determined based on direct observation of the gonads after the fish's abdominal cavity has been opened. Male fish are identified by the presence of testes, which are generally white to off-white in color, while female fish are characterized by yellowish ovaries. Identification is performed on an individual basis before determining the gonadal maturity stages

Observation of Gonadal Maturity Stages

Table 1. Classification of fish gonadal maturity according to [Novitriani et al. \(2004\)](#)

GMS	Ovarium	Testis
I	The ovary is yellowish-white in color and has a smooth surface. It is relatively small, round-oval in shape, and solitary. The eggs are not visible to the naked eye. The ovary is located at the posterior end, near the anus.	The testicles consist of two fan-shaped structures; one is underdeveloped and relatively smaller than the other, located at the end of the body cavity near the anus, and is brownish-white in color with a smooth surface.
II	The ovaries are larger and yellowish in color. They are round-oval in shape. A short indentation is formed on the anterior part of the ovary. The eggs are not yet clearly visible to the naked eye. The diameter of the eggs	The testicles are larger; both are fully developed and of equal size. They are white in color with a slightly ridged surface.

- ranges from 36 to 468 μm . In the middle of both lateral sides, there are red spots indicating the formation of blood vessels.
- | | |
|--|--|
| <p>III The ovaries are bright yellow. Eggs, ranging in diameter from 36 to 540 μm, are now visible to the naked eye. Blood vessels are clearly visible on both lateral sides of the ovaries. The ovaries occupy nearly a quarter of the body cavity at the posterior end, near the anus.</p> | <p>The testicles become whiter, and their ridged surface is clearly visible. The testicles occupy less than one-fifth of the body cavity at the posterior end, near the anus.</p> |
| <p>IV The ovaries increase in size and take on a reddish-yellow color. There are more blood vessels than in the ovaries of GMS III. The oocytes are clearly visible because the gonadal membrane is transparent; their diameters range from 36 to 816 μm. The ovaries occupy nearly one-third of the abdominal cavity and push the intestines forward. The ovaries are oval in shape with a distinct indentation on the anterior side, indicating that the paired organs have fused.</p> | <p>The testes are larger and firmer. They are milky white in color and occupy nearly a quarter of the body cavity at the posterior end, near the anus. At the same stage of maturity, the testes are generally smaller than the ovaries.</p> |
| <p>V The ovaries are deflated at the posterior end; this is observed in fish that have finished spawning.</p> | <p>The testis is shriveled at the posterior end.</p> |
-

Weight-Length Relationship

The length-weight relationship was analyzed to describe the growth patterns of ponyfish and to support the interpretation of biological conditions based on body size. To determine the length-weight relationship of the fish, the fish growth formula proposed by [Gubiani et al. \(2020\)](#) was used:

$$W = a L^b$$

Where:

- W : Weight (g)
- L : Length (mm)
- A and b : constants

The equation above was transformed into the logarithmic form presented by [Gubiani et al. \(2020\)](#).

$$\log W = \log a + b \log L$$

Where (W) is the fish weight (g), (L) is the total length of the fish (mm), (a) is the intercept, and (b) is the growth coefficient. The parameters (a) and (b) were obtained through linear regression analysis of logarithmic data on length and weight.

Analysis of the Distribution of Gonadal Maturity Stages

The distribution of GMS was analyzed by gender and month of observation. Each individual was classified into GMS I, II, III, IV, or V. The proportion of each GMS was calculated using the following equation:

$$Pi = \frac{ni}{N} \times 100$$

Where:

- Pi : proportion of individuals in maturity stage (GMS) i(%)
- ni : number of individuals in maturity stage (GMS) i
- N : total number of individuals in the observation group.

The analysis was conducted separately for male and female fish so that changes in GMS composition from month to month could be compared. The distribution was then visualized as a proportion diagram to illustrate changes in gonadal maturity structure from April through September 2023.

C. Results and Discussion

Gonadal Maturity Stages

Observations of 900 ponyfish (*Leiognathus equula*) from April through September 2023 revealed changes in gonadal maturity stage (GMS) composition based on sex and observation period. GMS was determined macroscopically based on gonadal morphological characteristics and classified into five stages, namely GMS I through GMS V. In general, both male and female fish from the early to mid-observation period were dominated by GMS II, while an increase in the proportion of individuals at GMS III and IV began to be observed in August–September. Individuals with GMS V began to be found in September. This pattern indicates changes in the population's reproductive structure during the observation period. Determining gonadal maturity stages based on gonadal morphological development is a commonly used approach in fish reproductive biology studies because it provides insights into gonadal development at the population level and over a specific time period ([Brown-Peterson et al., 2011](#); [Lowerre-Barbieri et al., 2023](#)).

[Figure 2](#) illustrates the morphological differences in the gonads between male and female fish, which are used as the basis for classifying gonadal maturity stages (GMS). These differences are generally evident in the size, color, shape, surface texture, and degree of vascularization of the gonads, which collectively serve as the primary visual indicators for distinguishing the stages of fish reproductive development ([Heins & Brown-Peterson, 2022](#)). In female gonads, morphological changes are generally easier to observe because they are related to oocyte development, which

affects the size and texture of the ovaries, whereas in male gonads, changes in testis color and density serve as the primary markers of spermatogenesis (Sauger et al., 2026). However, macroscopic interpretation of gonadal morphology does not always provide clear boundaries between developmental stages; therefore, consistent observation criteria are necessary to ensure that GMS classification results are comparable across time and among observers.

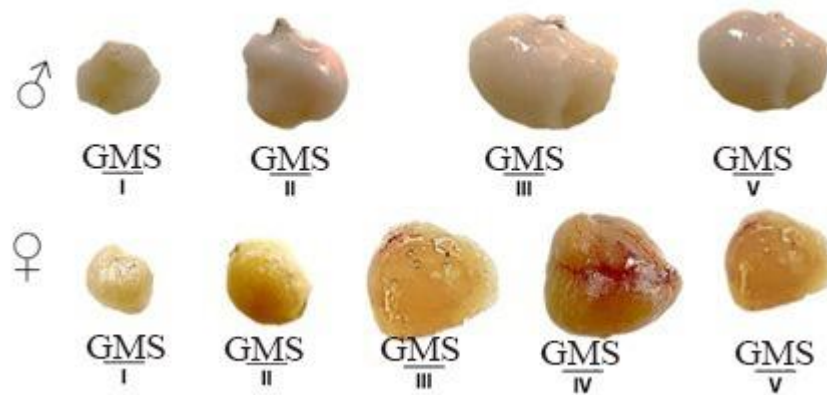


Figure 2. Gonadal morphology of male (top) and female (bottom) *Leiognathus equula* in the waters off Takalar, South Sulawesi

The lack of clear morphological boundaries has the potential to lead to misclassification, particularly at closely related developmental stages, such as between immature gonads and gonads that have just finished spawning (regenerating), which may appear visually similar (Min et al., 2022). Flores et al. (2019) demonstrated that macroscopic observations are relatively quick and practical but carry a higher degree of error and subjectivity compared to histological observations, particularly when not supported by standardized visual guidelines and inter-observer calibration. Therefore, the GMS results in this study are more appropriately used to describe patterns of change in gonadal maturity composition over the observation period.

Distribution of GMS in Male Fish

Among male fish, April was dominated by GMS II at 52%, followed by GMS I at 28% and GMS III at 20%. The proportion of GMS II then increased to 71% in May, 64% in June, and 78% in July. The dominance of GMS II during April–July indicates that most of the male fish caught were in the gonadal development phase, while individuals at the advanced maturity stage had not yet become the dominant group. The simultaneous presence of GMS I and GMS III in several months also suggests that individuals within the population do not undergo gonadal development uniformly.

This pattern indicates heterogeneity in gonadal development among individuals. In fish populations, gonadal maturation does not always occur simultaneously because individuals may be in different reproductive phases at the same time. This variation is related to reproductive timing, that is, the temporal patterns of reproductive development and activity, which can differ at the individual, population, seasonal, and reproductive cycle stages (Lowerre-Barbieri et al., 2011). The diversity in maturity stages observed in this study may thus reflect differences in the reproductive phases of individuals captured during the same period.

Changes in the GMS composition began to emerge in August. That month, GMS III became the dominant stage, accounting for 53%, while GMS II accounted for 33% and GMS IV for 11%. In September, the GMS distribution shifted further toward more advanced developmental stages, with GMS II at 34%, GMS III at 26%, GMS IV at 32%, and GMS V at 7%. Thus, the most noticeable changes in male fish occurred starting in August, when the proportion of GMS III increased, followed by an increase in GMS IV and the appearance of GMS V in September.

The shift from GMS II dominance to GMS III–V indicates increased gonadal development toward the end of the study period. From a reproductive biology perspective, the presence of individuals at advanced developmental stages indicates that a portion of the population has entered a more active reproductive phase; similar patterns have also been reported in other marine fish species that experience an increase in the proportion of individuals at advanced maturity stages approaching the spawning period (Reed et al., 2023).

However, these changes cannot yet be used to definitively determine the peak spawning month, as the identification of the spawning season ideally requires a combination of reproductive indicators and a longer-term observation period (Lowerre-Barbieri et al., 2023). Thus, the increase in GMS in August–September is more appropriately interpreted as an indication of increased reproductive development in the male population toward the end of the observation period, given that similar patterns of male gonadal enlargement are also generally associated with increased gametogenesis activity leading up to the active reproductive phase in other marine fish species (Pham et al., 2025).

Distribution of GMS in Female Fish

In female fish, GMS II also dominated most of the observation period. During April–July, the proportion of GMS II ranged from 73–82%. In June, GMS I was still present at 20%, indicating that some female individuals were still in the early stages of gonadal development. In August, GMS II reached its highest proportion, at 89%, while GMS III and GMS IV accounted for only 8% and 3%, respectively.

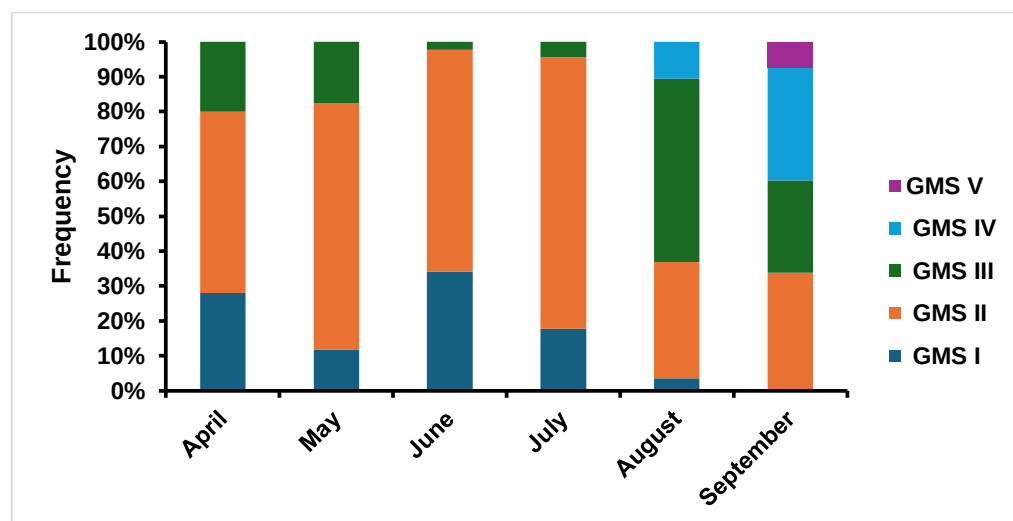
The dominance of GMS II during most of that period indicates that the majority of female fish caught were in a gonadal development phase prior to reaching full maturity. This does not mean that the population was not engaging in reproductive activity, as the simultaneous presence of individuals at different GMS indicates variation in reproductive phases within the population. According to Lowerre-Barbieri et al. (2023), fish reproductive development proceeds through several phases, and not all individuals in a population need to be in the same phase at any given time. This phenomenon is also supported by findings in other marine fish species showing a varied distribution of gonadal maturity stages among individuals within a single population at the same observation time (Cao et al., 2021), as well as the asynchronous pattern of ovarian development in flatfish, where oocytes at various stages of development appear simultaneously throughout the year (Ugrin et al., 2023). Therefore, a GMS structure dominated by a single stage must be understood in the context of the sampling time, the size of the caught fish, and the population structure.

A more pronounced change occurred in September. The proportion of GMS II decreased to 32%, while GMS III increased to 41%, GMS IV to 22%, and GMS V to 5%. Thus, the cumulative proportion of GMS III–V reached 68% in September. This indicates that the majority of female fish

caught in September had reached a more advanced stage of gonadal development compared to previous months.

The increase in the proportion of GMS III–V in September indicates that reproductive development in female fish increased toward the end of the observation period. This finding is consistent with the principle that temporal changes in gonadal maturity composition can be used to characterize the reproductive timing of a population (Lowerre-Barbieri et al., 2011). Patterns of increasing proportions of advanced maturity stages leading up to a specific period have also been reported in other commercial marine fish species, indicating that the proportion of reproductive phases tends to increase as the spawning period approaches (Reed et al., 2023). However, September cannot yet be declared the peak spawning period based solely on GMS distribution. Determining the spawning peak requires additional indicators, such as gonadal maturity indices, oocyte development, gonadal histology, spawning frequency, or the presence of post-spawning individuals (Flores et al., 2019; Lowerre-Barbieri et al., 2023). This combination of indicators is important because standardizing reproductive phases based on histology and secondary indicators has been shown to provide a more accurate picture of the spawning season than relying solely on the distribution of macroscopic GMS (Brown-Peterson et al., 2011).

The findings of this study can also be compared with research on *Leiognathus equula* in the coastal area of Cilincing, North Jakarta. Awwali et al. (2024) reported that the gonadal development of female *Leiognathus equula* reached the mature stage, and based on a combination of gonadal maturity stages and the somatic gonadal index, spawning activity was estimated to occur around June–July. Differences in the reproductive development period between Cilincing and Takalar indicate that the reproductive patterns of *Leiognathus equula* are not necessarily the same across locations. Differences in the environment, habitat characteristics, population size structure, food availability, and oceanographic conditions may contribute to temporal variations in fish reproduction, as demonstrated in other marine fish species that experience shifts in spawning timing and location due to differences in sea surface temperature, plankton productivity, and interregional current patterns (Lima et al., 2022).



(A)

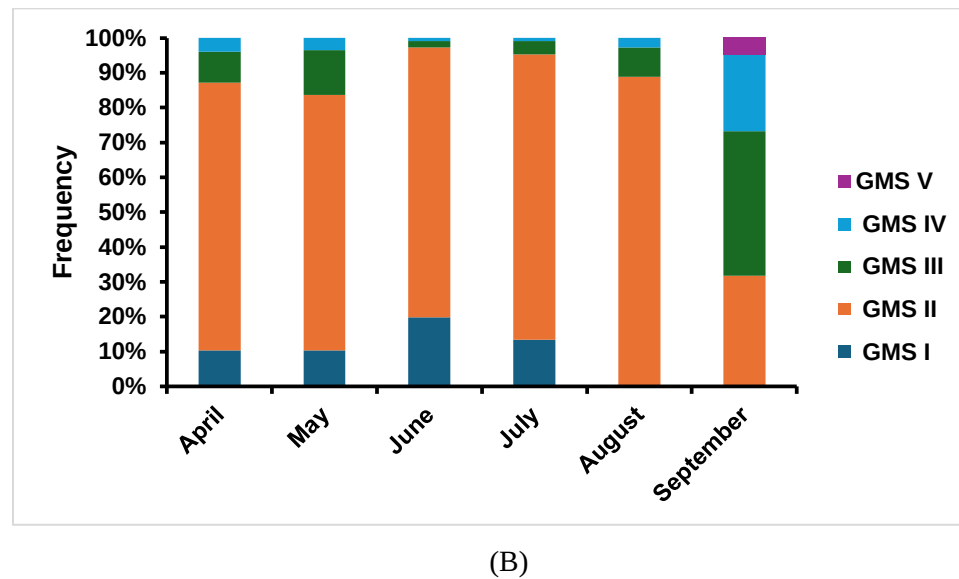


Figure 3. Gonadal maturity stages of the ponyfish (*Leiognathus equula*). A Male; B Female, in the waters off Takalar, South Sulawesi

Figure 3 shows changes in the proportions of male and female fish GMS groups during April–September 2023. This visualization illustrates that the GMS structure at the beginning of the study was relatively dominated by GMS II, then shifted toward GMS III–V by the end of the observation period. Presenting the distribution by month is important because fish reproduction is a temporal process, and changes in the proportion of mature individuals can provide preliminary information regarding the reproductive development period of the population (Lowerre-Barbieri et al., 2011; Lowerre-Barbieri et al., 2023).

Temporal Patterns of Gonadal Development

The GMS distribution shown in Figure 3 reveals temporal changes in the gonadal development of *Leiognathus equula*. From April through July, most individuals were at GMS II. This pattern changed in August, particularly among males, when GMS III became the dominant stage. In September, an increase in advanced maturity stages was observed in both sexes, marked by a rise in the proportion of GMS IV and the appearance of GMS V.

This pattern indicates that gonadal development did not proceed uniformly throughout the study period. The shift from GMS II to GMS III–V toward the end of the period indicates an increase in the population's reproductive readiness. In fish reproductive studies, temporal changes in gonadal development are a key indicator for understanding reproductive timing, as maturation and spawning occur within a cycle influenced by temporal scales and ecological conditions (Lowerre-Barbieri et al., 2011).

Findings in Takalar also show a different pattern compared to several other locations. Sitindaon et al. (2023), for example, found variations in the gonadal development of *Leiognathus equula* landed at the Palabuhanratu Fishery Port from September 2021 to February 2022 and reported that there were more gonadally mature female fish than males. Meanwhile, a study by Awwali et al. (2024) in Cilincing, North Jakarta, found that female GMS were at the mature stage

of development, while male GMS ranged from immature to mature. Based on GMS and the somatic gonad index, the study estimated that spawning activity occurred around June–July.

Differences in Gonadal Development Between Male and Female Fish

A comparison of GMS distributions shows that gonadal development in male and female fish follows temporal patterns that are not entirely the same. In male fish, a shift toward GMS III begins to be observed in August, whereas in female fish, the increase in GMS III–V is most pronounced in September. In September, the cumulative proportion of GMS III–V in male fish reached approximately 65%, while in female fish it reached 68%. Thus, both sexes showed increased gonadal development by the end of the study period, although the composition of their maturity stages differed. This pattern of temporal asymmetry in gonadal development between the sexes has also been reported in other tropical fish species, where females generally reach different sizes and stages of gonadal maturity than males due to gonadal development rates that are not always synchronized between the sexes within a single population ([Kahar et al., 2024](#)).

These differences indicate that the developmental dynamics of male and female gonads may not occur entirely simultaneously. However, the available data are insufficient to conclude that male fish always reach sexual maturity later than female fish. Such a conclusion requires an analysis linking maturity status to size or age, such as the size at first gonadal maturity (length at 50% maturity/L50), GMS distribution by length class, or a probability model of maturity. The maturity ogive is a key parameter for describing the proportion of mature fish in a given size class and is directly linked to estimates of a population's reproductive potential ([Flores et al., 2019](#); [Lowerre-Barbieri et al., 2023](#)). The accuracy of L50 estimates is highly influenced by the statistical methods used and the level of model uncertainty; therefore, comparing maturity status between sexes without considering these factors risks leading to biased conclusions ([Mainguy et al., 2024](#)).

Differences in development between the sexes must also be understood within the context of fish reproduction as a whole. Gonadal maturation is not merely a morphological change but a biological process that encompasses the development of reproductive cells until they reach reproductive competence. Therefore, while macroscopic gonadal development provides important information about general population patterns, it cannot fully describe the entire cellular developmental process within the gonads. Histology can offer higher resolution in distinguishing gonadal developmental phases, particularly when it is difficult to differentiate between morphologically similar stages ([Caiger et al., 2021](#)).

Comparison with Studies on *Leiognathus equula* in Other Regions

The increase in the proportion of individuals in the late GMS during August–September has important implications for the management of *Leiognathus equula* resources in the waters off Takalar. The presence of GMS III–V individuals at the end of the study period indicates that some of the fish caught were already in an advanced reproductive stage. In fisheries management, information regarding the timing of maturity and reproduction is crucial because population productivity is linked to the success of individuals in producing offspring and maintaining population recruitment ([Lowerre-Barbieri et al., 2023](#)).

This issue is all the more relevant given that the Leiognathidae family is recorded as the dominant group of fish in the catches of South Sulawesi's coastal waters, as reported in the

Lantebung mangrove area in Makassar, where *Leiognathidae* was the most dominant family among a total of 9,985 fish individuals caught (Muslim et al., 2026). Therefore, if the pattern of continued GMS increase in August–September can be confirmed through research with a longer time frame, this period can be considered as one of the biological factors in formulating a management strategy for the harvest of *Leiognathus equula*. Management measures could be directed toward reducing fishing pressure on individuals in the reproductive phase, particularly if follow-up research succeeds in identifying gonadal maturity sizes and spawning periods more accurately.

Information on size and maturity is also important because size-selective fishing pressure can affect population structure and life history characteristics of fish. The literature on exploitation indicates that fishing can exert selective pressure on life history traits, including size at maturity and reproductive investment (Heino et al., 2015; Gao & Munch, 2019), and overfishing can alter the size composition and reproductive structure of fish populations in general (Sundoko et al., 2026; Wardani et al., 2026). Therefore, the management of *Leiognathus equula* should consider not only catch volume but also the biological characteristics of the fish being caught.

F. Conclusion

Based on an analysis of the gonadal maturity stages of ponyfish (*Leiognathus equula*) in the waters off Takalar, it can be concluded that the gonadal maturity stages of ponyfish changed during April–September 2023. At the beginning of the observation period, both male and female fish were predominantly at gonadal maturity stage II (GMS II). In August, there was an increase in the proportion of male fish at GMS III and IV, while a significant increase in high GMS levels among female fish was most evident in September. The increase in the proportion of GMS III and IV, as well as the high GMS levels in female fish in September, indicate an increase in reproductive activity toward the end of the study period. Male ponyfish tend to reach gonadal maturity later than female fish.

Acknowledgement. The authors declare that they have no conflict of interest related to this article, reflecting their commitment to maintaining transparency and upholding ethical standards in presenting the information and analysis contained herein.

Author Contribution. Sri is in charge of collecting data. Sri, Asrul, and Khairil came up with the research idea. Asrul, Khairil, and Syamsinar are in charge of drafting the manuscript.

Data Availability. The data that support the findings of this study can be obtained from the corresponding author, subject to a reasonable request.

Declaration of Interest. Authors have declared that no competing interests exist.

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