SEXUAL MATURATION OF *DERMOGENYS ORIENTALIS* FROM THE SAMBUEJA RIVER, MAROS KARST REGION, INDONESIA

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Abstract

The endemic viviparous fish *Dermogenys orientalis* is locally known as the "Anculung fish" and belongs to the family Zenarchopteridae. There is presently no data available regarding the maturation aspect of Anculung fish. This research examines sexuality, gonadal maturity, size at first maturity, and gonado somatic index as maturation features. From October 2021 to March 2022, the sampling period lasted six months. This research collected 366 fish samples, including 126 males and 240 females. Anculung fish exhibit size dimorphism, with males being smaller than females. Based on their sexuality, andropodium is present in males but absent in females. The acquisition of distinct maturation levels differs. Males are also smaller than females when mature. The total length at first maturity for males is 48.3 mm, and for females it is 53.6 mm. Females have higher GSI values than males. According to the analysis, Anculung fish are capable of reproducing every month.

***Keywords**: Dermogenys orientalis, viviparous fish, maturation feature, Sambueja River*

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1. Introduction

Dermogenys orientalis is one of the endemic fish from the Maros Karst Region, that has been reported based on taxonomy and phylogenetics (Hadiaty, 2019: Omar et al., 2021). Locally, *D. orientalis* is known as Anculung and belongs to the Zenarchopteridae family of viviparous halfbeaks because, it reproduces internally. Similar to other *Dermogenys* species, Anculung fish have elongated jaws (Nelson et al., 2016). The Anculung fish distribution is restricted to a handful of streams around karst slopes (Miesen et al., 2015) such as the Sambueja River. This river is a part of the Maros Karst region and is renowned for its karst zone, especially in its upper reaches (Barkey et al., 2019). The Maros Karst is a unique area from a geographical point of view with a subterranean river system (Taslim, 2014: Duli et al., 2019). In addition, this area is distinct due to the presence of endemic species, such as the anculung fish. It is an endemic species, meaning it is limited to that region. The term endemic describes the restricted distribution (Fattorini, 2017).

There have been studies conducted on the Anculung fish, especially on biological aspects such as size distribution, length-weight relationship, growth pattern (Ilmi et al., 2021: Irawati et al., 2022) and reproductive aspects such as sex ratio, and size at first maturity (Wardhani et al. 2022). More information, especially on their maturation aspect, is limited. According to Arula et al. (2017), maturation is the process by which fish reach sexual maturity and become able to reproduce. Depending on the species of fish and

environmental factors, the timing and method of maturation may differ. Maturation is an indicator of the rate of reproduction. Fundamentally, reproduction proves an individual's ability to have offspring in order to maintain their type (Parawangsa et al, 2022). It plays a crucial role in the implementation of management methods, especially for endemic species that are susceptible to a variety of factors in the aquatic environment (Radhakrishnan et al, 2020). To explain the principles of biology in the management of fish species, reproductive information such as maturation is needed. Sexuality, stage of maturation, size at maturity, and the gonadosomatic index are all vital aspects of fish maturation. Several of these aspects can be used to determine the timing of reproduction and the duration of the reproductive cycle (Khatun et al., 2019:Treasurer, 2021).

In fish, size at maturity is frequently used as an indicator for maturation (Da Silva Freitas et al., 2016). The mature size of each species can be standardised to reduce the effects of fishing pressure and for conservation and management purposes (Lappalainen et al., 2016: Pérez-Palafox et al., 2022). It is varying and closely related to sex, life duration, and growth rate (Hasan et al., 2020). Each fish can be designated mature based on the shape, size, and colour of the gonad (Ergun et al., 2020). On the basis of these characteristics, at least several phases of maturation are distinguishable (Saber et al., 2019). Additionally, maturation is a multifactoral process involving the acquisition of somatic reproductive characteristics (Rivera et al., 2021). This characteristic is measured using the gonadosomatic index (GSI). It is employed as an indicator of reproductive activity (Flores et al, 2015). Scientists can use it to determine the spawning season and manage reproductive performance (Madihah et al., 2021).

Therefore, the purpose of this research is to provide detailed information on the maturation of anculung fish, including sexual characteristics, phase at maturity, size at first maturity, and gonado somatic index. Information about fish maturation can be used to better understand fish population or reproduction and to inform fisheries management decisions, such as determining when fish are most likely to spawn, setting minimum size limits for fish, and ensuring the long-term sustainability of fish populations, especially for the Anculung fish, *Dermogenys orientalis* in the Sambueja River, Maros Karst Region.

2. Methods

Study Area and Collected Data

This study was carried out in the Sambueja River, Simbang District, Maros Regency, South Sulawesi. Geographically, the research site is located in position of 5°06'96.0675" S and 119°69'03.3214" E (Fig. 1). The area has a karst geological structure and is situated near the natural attractions of Sambueja (Sambueja Karst). This research was conducted from October 2021 to March 2022. A total of 366 fish samples were collected, with 126 males and 240 females. The fish samples were collected using a modified trawl net (4.70 m length, 1.2 m height, and 1 mm mesh size).

To maintain their integrity until the Laboratorium, all fish samples were placed in a container containing a 10% formaldehyde solution. At the Fisheries Biology Laboratory, Faculty of Marine and Fisheries Sciences, Hasanuddin University, the total length and body weight of fish samples were measured using a digital calliper (C&A Tools, accuracy 0.01 mm) and a digital scale (Fujitsu, accuracy 0.01 g). Each fish sample was dissected using a dissecting instrument (Onemed, SNI), and the gonads were examined to identify sexual maturity.

3. Data analysis

The sexuality of the Anculung fish, *Dermogenys orientalis*, is determined by identifying or observing morphological characteristics such as body shape, anal fin structure, and reproductive organs. An abdominal dissection is executed to ascertain the sexuality of both. This relates to the development and existence of reproductive organs, which are necessary for maturation. By examining its macroscopic features, Varghese's modification (2005) was used to determine the Anculung fish's maturing or developing phase.

Using the total length of the fish, the measure at first maturity (L_{50}) was used to determine the development of male and female fish at the onset of sexual maturity (size at first maturity).

L_{50} statistical analysis using the sizeMat package on the R Studio software. Using the logistic regression model on the sigmoid curve, the L_{50} value is estimated using the following equation (Ramírez-García et al., 2021) :

$$M(L) = \frac{1}{(1 + e^{(-aL+b)})}$$

where:

M(L) = the probability of an individual fish maturing at a determinate *L* length;

a = the intercept;

b = the slope.

To estimate the average size at first maturity with a value of 50% on the RStudio, the sizeMat (R Package) is used with confidence limits derived from Bayesian inference based on stochastic simulations (Torrejon-Magallanes, 2020).

To determine the percentage of maturity, gonado maturity index analysis is carried out using the following equation (Parawangsa et al., 2022):

$$\text{GSI} = \frac{W_G}{W_B} x100\%$$

where:

GSI = Gonado somatic index;

W_G = Gonad weight;

W_B = Body weight.

To identify significant or non-significant GSI value differences between months in each species (males and females), the Kruskal Wallis test was used in the SPSS (v25) software program.

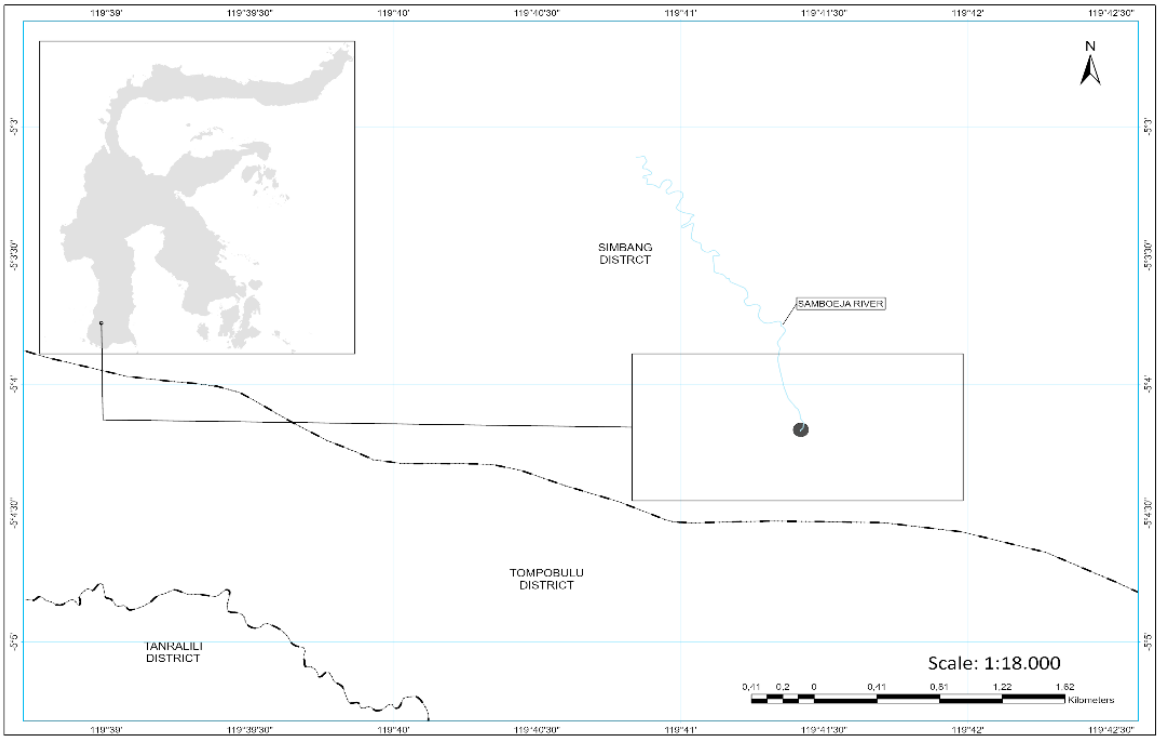

Figure 1. Map of the research site

4. Results and Discussion

During this study, 366 fish samples, including 126 males and 240 females, were identified. The sexual characteristics of male and female Anculung fish, *Dermogenys orientalis* are different. Fig. 2 illustrates a substantial distinction between the two. This species indicates size dimorphism, with males being smaller than females. Another fish, such as *G. holbrooki*, shows the same characteristic (Mousavi et al., 2021). This is consistent with the general pattern of sexual size dimorphism, wherein females tend to be larger than males (Horne et al., 2020). In addition to distinctions in body sizes, male viviparous fish possess an andropodium, a modified anal fin. Males can modify their anal fin. In contrast, females cannot. Anculung fish is a species that practises internal fertilisation. The male fish uses a modified anal fin to direct sperm into

the female's genital organ. The sexual characteristics of *D. orientalis* are similar to those of other fish with certain traits (viviparous).

The reproductive characteristics of Anculung fish can be described as internal fertilisation occurring, embryos developing within the female body, and offspring being born alive. There is no information available on the maturation of *D. orientalis* specifically, but it is likely that they exhibit similar behaviours to other species of the genus *Dermogenys* and *Nomoramphus*. Other species exhibited the same characteristic, including *Dermogenys colletei* (Meisner, 2001) and *Nomoramphus* sp. (Kraemer et al., 2019: Kobayashi et al., 2020). According to Meisner & Burns (1997), there are five distinct types of viviparity in freshwater halfbeaks, and *Dermogenys orientalis* is an example of Type II viviparity, which indicates that fertilised eggs are retained in the ovarian follicle and up to three broods can result from a single mating.

The development and maturity of the gonads is one indicator that shows every fish has reached maturity. In this study, gonad maturity in Anculung fish, *Dermogenys orientalis* differed based on their sexuality. Morphological observations based on reproduction organ size, shape, and colour are what determine the maturation of male and female fish (testis and ovary). Table 1 indicates that egg formation occurs at Level I. During this phase, the egg cell is not completely developed. At level II, the egg matures. During this phase, the immature egg develops into a mature egg. In addition, levels III through V exhibit embryonic development. On a macroscopic scale, embryonic development can be observed as the embryo's structure transforms from fragmentary to complete.

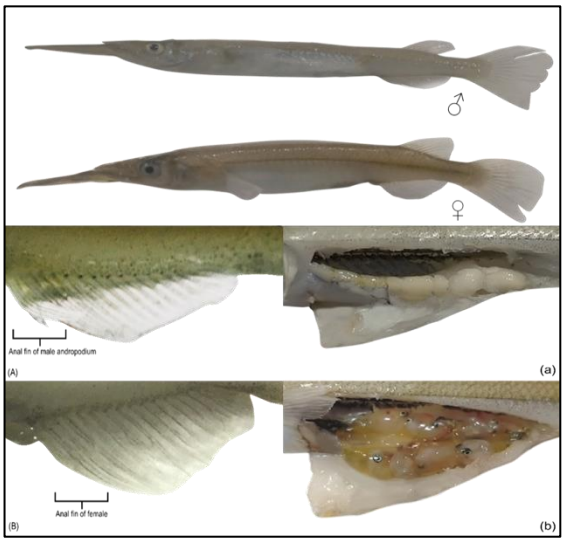

Figure 2. Sexual characteristics of *Dermogenys orientalis* male (a) and female (b).

In this study, female fish produce eggs and embryos due to their viviparous nature. Male fish produce sperm similarly to other species, and their testes are structurally comparable to those of other fish in the family Zenarchopteridae. The genitalia of this species are paired and elongated. Downing & Burns (1995) identified this trait in numerous species of *Dermogenys*, *Nomoramphus*, and *Hemiramphodon*. Zúñiga-Vega et al. (2022) confirmed certain conditions in viviparous freshwater fish, such as Poeciliidae and Goodeidae.

As depicted in the diagram (Fig. 3), the gonads of *D. orientalis* from the Sambueja River were fully developed during each sampling period. The diagram differentiates the maturation of males and females. Analysing fish with developed gonads (levels III, IV, and V) aids in predicting the reproductive period of this species, although level V is only detectable during certain months. There is a presumption that *D. orientalis* reproduces monthly. Males have testes that meet the requirements for reproduction, and females have eggs and embryos that are ready to be released as larvae. The gonadal maturation composition of *D. orientalis* varies from month to month. The monthly composition is fluctuating. Males possessed the greatest proportion of mature

gonads in October and March, while females possessed the highest proportion in October and November.

Table 1. Maturation of *Dermogenys orientalis*, based on the level of gonad maturity.

Level	Male	Female
I	The testicles are elongated and translucent, and sperm cannot be seen under a microscope.	The ovaries are translucent and elongated. Under the microscope, the ovum is visible, and the membranes are transparent.
II	The testicles begin to form. Sperm appears as tiny black grains.	The ovaries are beginning to mature and are pale yellow in colour. The egg is becoming increasingly visible.
III	The testicles are becoming more distinct. Increasingly more sperm.	The ovaries begin to contract, and their membranes begin to thin. Eye spots and tiny embryos began to appear in multiple spots.
IV	The testicles are getting larger and denser.	The ovaries are shrinking and becoming hazy. The egg membrane is thinning as the embryo develops.
V	The testicles are not growing, thinning, or shrinking.	The development of the ovaries has ceased. The egg membrane is extremely thin, the embryo is becoming more different, and it appears to be ready for birth.

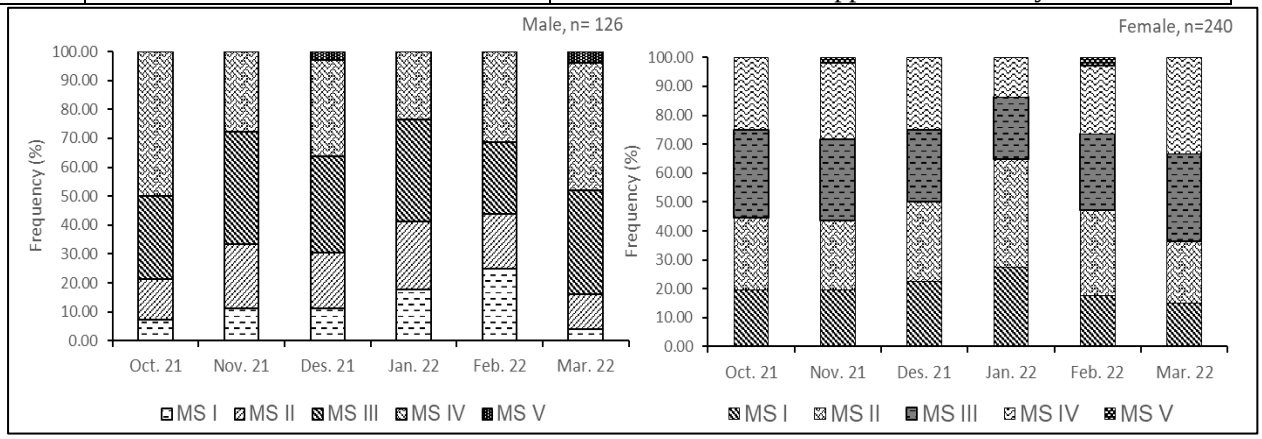

Figure 3. Frequency of *Dermogenys orientalis* maturation in the Sambueja River

The size at first maturity is a quantitative measure of each fish species that has attained maturity and is ready to spawn. The measure was estimated using the R-Package software program. During the study, the average size of fish length (L50) was found to be different in males and females (Fig. 4). Based on the results of the analysis, it was indicated that male fish matured at a smaller size. Male fish matured at 48.30 mm (range 47.3–49.3 mm) and female fish at 53.60 mm (range 52.20–54.90 mm). In this study, the L_{50} value of anculung fish (*D. orientalis*) in the Sambueja River differed between male and female fish.

The results of this analysis indicate that male fish are more gonadal mature at a smaller size than females. Similar conditions were found in *D. orientalis* from the Bantimurung and Pattunuang Rivers (Wardhani et al., 2022). However, different conditions were found in *D. pusilla* from the Ganges River. Early maturity occurs in female fish (Hossen et al., 2019). Most male viviparous fish have also been reported to mature at a smaller size, including *A. robustus*, *G. atripinnis*, *S. lermae*, *X. variata*, and *Z. quitzeoensis* (Ramírez-García et al., 2021). One of the main factors affecting the size of the gonad is food availability. Food is vital for viviparous fish (Tobler & Culumber, 2018). Female fish will reproduce at a smaller size if the availability of food in their habitat decreases (Magalhães & Jacobi, 2017). Based on this study, the higher L50 value in the female fish indicates that the availability of food in the Sambueja River is thought to be good enough to support the reproductive activity of this species.

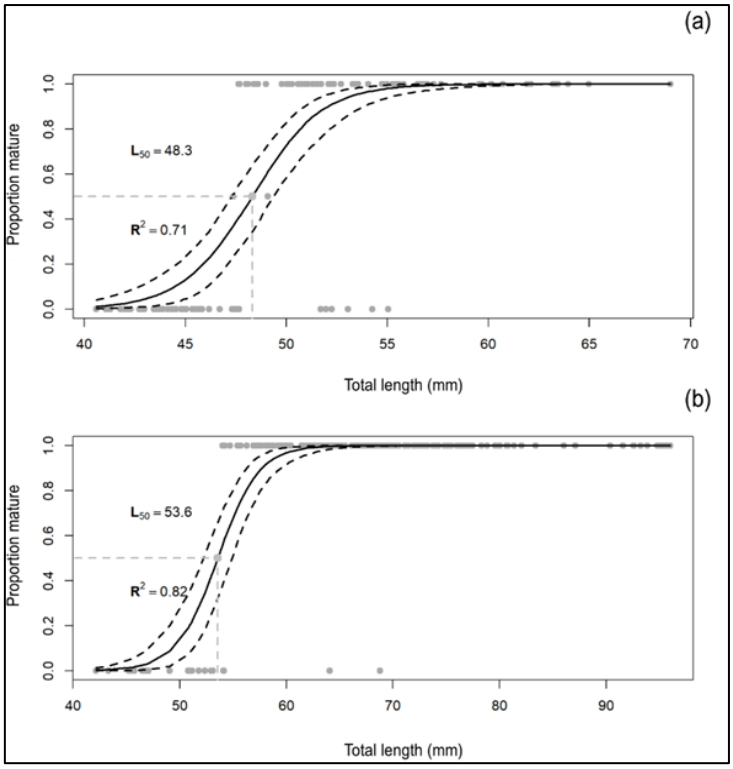

Figure 4. L_{50} value of *Dermogenys orientalis* in the Sambueja River: (a) male, (b) female.

In this study, the reproductive strategy involves the early maturation of male fish of a smaller size. This is connected to the allocation of energy utilised in reproduction, which differs between the two. During the observation, each of the observed gonads had distinct gonad development features. Female fish mature at a slower rate. Since the formation of eggs and the growth of embryos always come during the development of gonads, females need a larger body size than males. On the other hand, males do not need a lot of energy to develop their gonads. This trait is assumed to be the trigger for female fish to attain maturity at a larger size. In addition, gonadal development can also be assessed based on the gonado somatic index (GSI).

The results of GSI observations on *D. orientalis* with varying values are presented in Table 2. Each month, GSI values obtained from male and female fish fluctuate. Overall, female fish have a higher GSI value than their male counterparts. This value's magnitude indicates that the development of the gonads is also greater. The acquisition of GSI scores is statistically distinct as well. The Kruskal-Wallis H test revealed a *p value* less than 0.05, indicating that the GSI value for male fish varied significantly from month to month. In contrast, the female fish's *p value* was greater than 0.05, indicating that there was no statistically significant difference between months. The magnitude of the GSI value obtained in females is assumed to be impacted by gonad size and their developmental variations. The same condition was discovered in other endemic fish, including *M. ladigesi* (Nasyrah et al., 2020) and *T. prognatha* (Chadijah, 2020). Gonad development is also related to how each fish allocates its energy. Jonsson et al. (2012) reported that male fish typically have only about 3% of their available energy to allocate to the maturation of their gonads. In females, it has increased tenfold, or 30%.

Table 2. Gonado somatic index of *Dermogenys orientalis* in the Sambueja River.

Month	Male		Female	
	Range	r ± SE	Range	r ± SE
Oct/21	0.26 – 7.35	4.02 ± 0.68	0.59 – 11.72	5.79 ± 0.55
Nov/21	0.26 – 7.46	3.76 ± 0.56	0.36 – 13.07	6.47 ± 0.47
Dec/21	0.33 – 7.40	2.47 ± 0.45	0.48 – 11.48	5.07 ± 0.51

Jan/22	0.27 – 6.81	3.37 ± 0.49	0.15 – 11.29	5.38 ± 0.39
Feb/22	0.23 – 8.03	3.42 ± 0.60	0.75 – 11.22	6.19 ± 0.53
Mar/22	0.32 – 7.94	3.96 ± 0.49	0.20 – 10.90	6.49 ± 0.55

In this study, the fluctuating GSI value indicates that the Anculung fish, *D. orientalis* is capable of reproducing each month. However, the estimated reproductive transition period for male and female fish varied. This is indicated by the high values of various GSI. This condition is believed to be influenced by the reproduction of characters in this species, given that the reproduction processes, such as copulation and birth, in their habitat are unknown. However, it is estimated that the transition endured only a brief period of time, given the monthly occurrence of possible reproduction.

5. Conclusion

Based on the results of this study, the maturation aspects, including sexuality, level of maturation, size at first maturity, and gonadosomatic index, of male and female Anculung fish, *Dermogenys orientalis* captured in the Sambueja River differed. This distinction is part of the reproductive strategy.

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