Sexual Dimorphism and Reproductive Biology of Bronze Featherback (Notopterus notopterus, Pallas 1769) from Kelekar River, Ogan Ilir, South Sumatra, Indonesia

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Sexual dimorphism and reproductive biology of bronze featherback (*Notopterus notopterus,* Pallas 1769) from Kelekar River, Ogan Ilir, South Sumatra, Indonesia

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Abstract

Sexual dimorphism and reproductive biology are fundamental aspects of fish breeding studies. The aim of this research was to analyze the sexual dimorphism and reproductive biology of *Notopterus notopterus*. A total of 74 *N. notopterus* were collected from the Kelekar River in Ogan Ilir Regency, Indonesia, consisting of 38 males (TL: 18–23.6 cm; BW: 35.1–92.1 g) and 36 females (TL: 19.6-26.3 cm; BW: 49.4–133.8 g). Seventeen morphometric characters, three meristic characters, and five reproductive biological parameters were analyzed. The results showed the differences in the morphometric characteristics of male and female *N. notopterus*. However, there was no difference in the meristic characters. The male gonadosomatic index ranged from 0.15 to 0.61%, and the female from 1.12 to 9.10%. The hepatosomatic index of males ranged from 0.19 to 1.38%, and that of females ranged from 0.15 to 1.23%, with a sex ratio of 1.056:1, fecundity of 1.007–3.901 eggs, ova diameters of 1.1–3.9 mm, and maturity levels of developed gonads to mature for males and mature to spawning for females. In conclusion, the differences between male and female *N. notopterus* can be identified morphologically.

Keywords: Broodstock selection; fish reproduction; gonochorism; Indonesian fish; knifefish; notopteridae; secondary sexual characteristics.

Introduction

Bronze featherback (*Notopterus notopterus*, Pallas 1769) is a freshwater fish species native to Indonesia. *N. notopterus* is one of the fish species of the Notopteridae family [1]. The Notopteridae consist of approximately ten species in four genera: Chitala, Notopterus, Xenomystus, and Papyrocranus [2]. The only recognized species of Notopterus at present is *N. notopterus* [3]. The *N. notopterus* distribution in Asia includes Indonesia, India, Malaysia, Thailand, Bangladesh, Pakistan, and Vietnam [1,2,4-7]. In Indonesia, this species is distributed in Java, Sumatra, and Kalimantan [1,8]. *N. notopterus* was found in Kolong-Bendungan Simpur, Bangka Island [9], Ogan River (tributary of Musi River, South Sumatra), waters in Bangka Island as well as Kota Bangun and Tanah Ulu (Mahakam River, East

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Kalimantan) [10], East Pedamaran Floodplain, Ogan Komering Ilir [11], Sei Gesek Reservoir, Bintan, Riau Islands [12], and Kelekar River [13].

Several studies on *N. notopterus* have been conducted, among others, on aspects of length-weight relationship, relative condition factor and fecundity [14-17], genetic diversity [10], morphometrics and growth patterns [11], food and feeding habits [12], reproductive biology [9], determination of condition factors, somatic condition, hepatosomatic index and gonadosomatic index [18], behavior and reproduction [19], potential biomarkers of oxidative stress [20], embryo and larval development [21], relative condition factors [22,23], population dynamics [5], relationship of ecological factors and commercial [24], and its early domestication [25,26].

Fishery management mainly depends on knowledge of fish reproductive biology [27,28]. In adult fish, sexual dimorphism is a frequent and well-known phenomenon [29]. The majority of fishes are gonochoristic and have various sexually dimorphic characteristics in their secondary sexual characteristics [30]. Distinguishing characteristics for the morphological qualities of many teleosts have been documented, including body color, ornamental patterns, breeding tubercles on the snout, pectoral fins and scales, fin hooks, body shape, fin size and shape [31-35].

N. notopterus is one of the most valuable freshwater fish in South Sumatra, Indonesia. This fish is utilized by the community in South Sumatra, especially as a daily side dish and a raw material for the culinary industries of pempek (fish cake) and kerupuk-kemplang (fish crackers). Therefore, this species has the potential for cultivation. There is relatively little known about sexual dimorphism and reproductive biology in *N. notopterus*. Such information is crucial for initial data in the breeding of *N. notopterus*. The study aimed to analyze the sexual dimorphism and reproductive biology of *N. notopterus* from Kelekar River, Ogan Ilir. The results of this study are beneficial in the selection of *N. notopterus* broodstock candidates for breeding programs.

Materials and Methods

The fish collection was conducted in Kelekar River, Tanjung Baru Village, North Indralaya District, Ogan Ilir Regency, South Sumatra, Indonesia (Fig 1). Sampling was conducted in February–May 2023. The temperature, water acidity, and dissolved oxygen at the sampling site ranged from 24.4°C to 28.3°C, 5.5 to 6.4, and 4.9 to 6.4 $mg.L^{-1}$, respectively. Fishing was conducted by fishermen using fish traps. A total of 74 *N. notopterus* samples were collected: 38 males (TL: 18–23.6 cm; BW: 35.1–92.1 g) and 36 females (TL: 19.6-26.3 cm; BW: 49.4–133.8 g). The *N. notopterus* samples were transported to the Fisheries Basic Laboratory, Aquaculture Study Program, Department of Fisheries, Faculty of Agriculture, Universitas Sriwijaya, for analysis of morphometric-merisitc characters and also aspects of reproductive biology.

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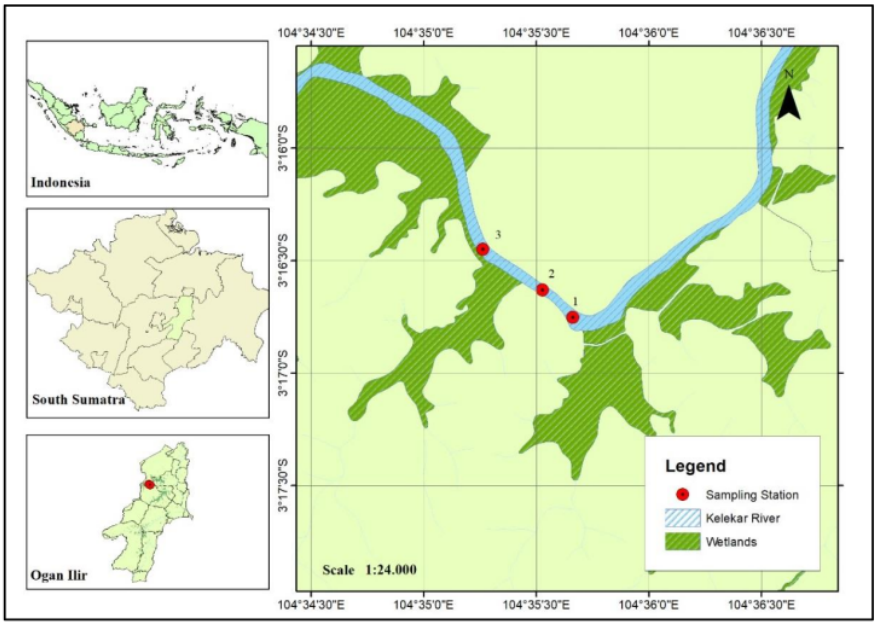

Figure 1. Map of *Notopterus notopterus* (Pallas 1769) sample collection in Kelekar River, Ogan Ilir Regency, South Sumatra, Indonesia

In the laboratory, fish were weighed using a digital scale (accuracy 0.01 g). Then observe the fish morphologically and count the meristic characters (number of rays of the dorsal fin, number of rays of the pectoral fin, and number of rays of the anal fin). Furthermore, the samples were measured for morphometric characters using a caliper (accuracy 0.01 cm) and a ruler (accuracy 0.1 cm). The morphometric characters measured were seventeen characters (Fig 2). Next, the fish were dissected, and the gonads and liver were taken, separated from other organs. Gonads and liver were weighed for the calculation of gonadosomatic index (GSI) = [gonad weight (g) / fish weight (g) x 100] and hepatosomatic index (HSI) = [liver weight (g) / fish weight (g) x 100] [36]. The calculation of fecundity was done gravimetrically, namely, the fish gonads were taken partially, and then the number of eggs in the partial gonads was calculated. Fecundity = [number of sample gonad eggs x (total gonad weight/partial gonad weight)] [37]. Oocyte diameter was observed under a digital microscope. The maturity level of fish gonads was categorized based on the morphology and color of the gonads, GSI, and oocyte diameter. The sex ratio was calculated based on the number of male and female fish. The data obtained were grouped into two categories, namely male and female fish. Data tabulation using the Microsoft Excel program was then analyzed descriptively to obtain differences between male and female fish.

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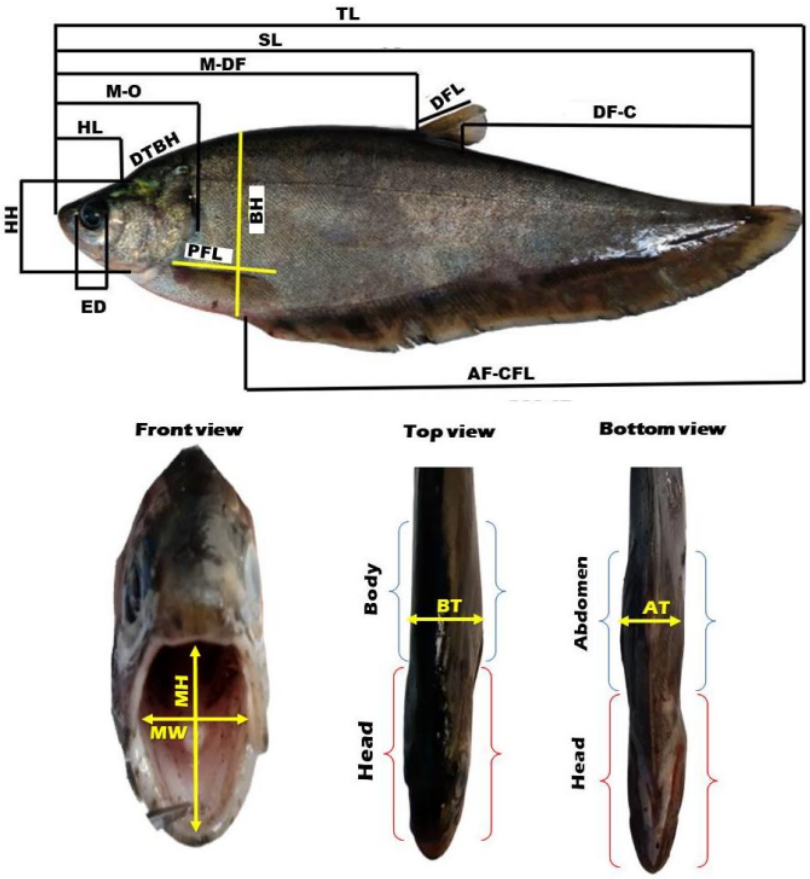

Figure 2. Morphometric character measurements of bronze featherback (*Notopterus notopterus*, Pallas 1769): TL (total length), SL (standard length), M-O (mouth to operculum distance), M-DF (mouth to dorsal fin distance), DF-C (dorsal fin to caudal distance), DFL (dorsal fin length), PFL (pectoral fin length), AF-CFL(anal fin to caudal fin length), BH (body height), HL (head length), HH (head height), ED (eye diameter), DTBH (degree of tilt of the back of the head), BT (body thickness), AT (abdominal thickness), HM (height of mouth), WM (width of mouth)

Results and Discussion

A total of 74 *N. notopterus* samples, consisting of 38 males and 36 females, have been successfully measured for morphometric characters and calculated for meristic characters. The results of measurements and calculations of *N. notopterus* samples in this study are presented in Table 1.

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Table 1. Morphometric and meristic characters of male and female *Notopterus notopterus* (Pallas, 1770) from Kelekar River, Ogan Ilir Regency, South Sumatra, Indonesia

Morphometric character	Male		Proportion (%)	Female		Proportion (%)
	Range (cm)	AVG±SD		Range (cm)	AVG±SD	
TL	18-23.6	20.39±1.39	-	19.6-26.3	22.46±1.56	-
SL	16-21.6	18.60±1.45	91.25 TL	17.3-24.2	20.45±1.59	91.07 TL
HL	1.3-3.5	2.07±0.51	10.18 TL	1.6-3.7	2.16±0.47	9.64 TL
HH	2.1-3.5	2.63±0.38	12.90 TL	2.4-4.3	2.85±0.39	12.70 TL
ED	0.5-0.7	0.64±0.06	30.91 HL	0.8-1.0	0.86±0.06	39.81 HL
BH	3.1-5.1	4.29±0.44	21.07 TL	4.8-6.4	5.62±0.50	25.05 TL
PFL	2.1-3.3	2.53±0.35	12.44 TL	2.2-3.6	2.73±0,37	12.16 TL
DFL	1.7-2.8	2.19±0.27	10.77 TL	1.9-3.2	2.33±0.30	10.38 TL
AF-CFL	13.2-18.4	15.42±1.22	75.62 TL	14.0-19.1	16.44±1.36	73.20 TL
M-O	3.0-4.7	3.65±0.40	17.91 TL	3.0-4.9	3.90±0.44	17.40 TL
M-DF	8.1-11.5	9.75±0.68	47.85 TL	9.5-12.3	10.58±0.80	47.14 TL
DF-C	8.0-11.6	9.85±1.02	48.32 TL	8.5-12.5	10.94±0.98	48.72 TL
BT	1.1-1.3	1.19±0.08	-	1.4-1.9	1.51±0.14	-
AT	0.6-1.0	0.89±0.11	-	1.1-1.6	1.26±0.13	-
MH	0.8-1.2	1.02±0.09	-	0.8-1.2	1.05±0.09	-
MW	0.8-1.1	0.96±0.10	-	0.8-1.2	1.00±0.11	-
DTBH (°)	32.0-50.0	42.36±3.51	-	47.0-63.0	52.6±3.06	-
Meristic character	**Number of rays of the male fish**			**Number of rays of the female fish**		
Pectoral (P)	10-14			11-14		
Dorsal (D)	6-9			6-9		
Anal+Caudal (A+C)	107-118			110-118		

The total length of *N. notopterus* used in this study ranges from 18 cm to 23.6 cm; body weight ranges from 35.1 g to -92.1 g for male fish; The length ranges from 19.6 cm to 26.3 cm; and body weight ranges from 49.4 g to 33.8 g for female fish. According to the study results of [9], the total length of female fish ranged from 130 mm to 249 mm, males from 120 mm to 232 mm, and the body weight of males was 22.17–97.17 g and females 38.98–120.47 g. The total length of *N. notopterus* ranges from 401 mm to 950 mm [10]. The male *N. notopterus* measured between 19.1 cm and 24.1 cm in length and weighed between 48.7 g and 133.4 g, while the female measured between 17.2 cm and 25.6 cm in length and weighed between 69.7 g and 151.2 g [16].

The dorsal fin of *N. notopterus* fused with the caudal fin and anal fin. Each fin contains only rays and no spine. Meristic characters have been successfully counted. The results showed that P.10-14, D.6-9, and A+C.107-118. The results of the study by [38] showed that P.11-14, D.5-7, and A.98-111. According to [39], the number of rays on the P.13-14, D.7-9, and A.97-111. However, [40] stated that D.7-9, and A.97-111. According to [8], P.13-14, and A. 99-111.

One of the vital physiological processes that is essential to the life cycle of any organism, including fish, is reproduction [41]. Planning improved conservation and management strategies for fishery resources requires a fundamental understanding of the reproductive cycle of fish [28,42]. Some aspects of *N. notopterus* reproductive biology observed in this study are presented in Table 2.

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Table 2. Reproductive aspects of male and female *Notopterus notopterus* (Pallas, 1770) from Kelekar River, Ogan Ilir Regency, South Sumatra, Indonesia

Parameters	Sampling Period							
	February		March		April		May	
	Male	Female	Male	Female	Male	Female	Male	Female
GSI (%)	0.31±0.05	5.18±1.04	0.39±0.11	4.50±1.16	0.30±0.14	3.22±1.69	0.28±0.06	3.59±2.57
HSI (%)	0.65±0.22	0.53±0.10	0.52±0.19	0.51±0.22	0.79±0.23	0.80±0.36	0.79±0.27	0.73±0.19
Ova diameter (mm)	-	1.2-3.6	-	1.1-3.9	-	1.2-3.9	-	1.2-3.8
Fecundity	-	1361-3543	-	1455-3121	-	1060-1471	-	1007-3901
Sex ratio	1:1		1.14:1		1.5:1		0.86:1	

The GSI utilized to ascertain the fish's reproductive periodicity [43]. Table 2 shows that the GSI value of female fish was highest in February, and the male fish was highest in March. The GSI of female fish is higher than that of male fish. The GSI value is also related to the stage of gonad maturity. The GSI value increases with increasing gonad maturity. The increase in GSI indicates a developmental process in the gonads. The GSI value will reach a maximum value before spawning occurs. In addition, the GSI value is influenced by environmental factors related to the food availability as an energy source for somatic development and fish reproduction [44].

HSI values for female fish were highest in April and for males in May. HSI is the percentage value of the ratio between liver weight and total body weight. One of the organs that plays a role in fish reproduction is the liver. The liver plays an important role in the vitellogenesis process. This process is triggered by the increasing concentration of estradiol in the blood. Estradiol is an important hormone produced by the ovaries in female fish that is beneficial in the process of vitellogenesis. The higher the level of estradiol concentration in the blood, the earlier the liver will carry out the vitellogenesis process, and gonad maturation will be faster [45,46]. The HSI indicated an energy reserve in the liver [47] and a bio-indicator of contaminant exposure [48,49]. The fecundity of *N. notopterus* in this study ranged from 1.007 to 3.901 eggs per individual. [50] showed that fecundity values ranged from 53 to 748 and from 175 to 4.494 [51]. The value of fecundity is influenced by several factors, one of which is environmental. Variations in the number of fish fecundities are also caused by variations in the length and weight of fish.

The diameter of the ova of *N. notopterus* in this study ranged from 1.1 mm to 3.9 mm. Previous studies ranged from 1.05 to 2.2 mm [9]. The oocyte diameter is categorized as a mature ovary. The higher the oocyte diameter value, the higher the ovary's maturity. The results showed that the diameter of the oocyte in the ovary varied. This indicates that the development of oocytes in the ovary is not uniform. It is suspected that *N. notopterus* spawns gradually. This is by the opinion of [9] that *N. notopterus* releases mature oocytes gradually. *N. notopterus* spawns more than once during a spawning season. The sex ratio is an important component in the study of fish reproduction [42,52]. The balance of the number of male and female fish in a body of water affects the continued existence of a species. The results of this study show that the number of male fish is higher than the number of female fish, except in the May sampling period. This result indicates that the population of male fish is greater than that of female fish.

Conclusion

There are differences in the morphometric characteristics of male and female *N. notopterus*. However, there are no differences in meristic characters. The gonadosomatic index of male fish ranged from 0.15% to 0.61%, and that of females ranged from 1.12% to 9.10%. The hepatosomatic index of male fish ranged from 0.19% to 1.38%, and females ranged from 0.15 to 1.23%; the sex ratio of the sample fish obtained was 1.06:1. The fecundity value of the sampled fish ranged from 1.007 to 3.901. The oocyte diameter of the sample fish ranged from 1.1 to 3.9 mm. The gonadal maturity stage of the sample fish was at the developing to mature stage for males and mature to spawning for females.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- The author has signed an animal welfare statement
- Ethical Clearance: The project was approved by the local ethical committee in Universitas Sriwijaya, Indralaya, Indonesia

Authors' Contribution Statement

MM in conception, design, acquisition of data, analysis, interpretation, drafting the manuscript, revision and proofreading, MS in acquisition of data, analysis interpretation, drafting the manuscript, revision and proofreading, FHT in conception, design, acquisition of data, drafting the manuscript, revision, MIS in acquisition of data.

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إزدواج الشكل الجنسي و بيولوجيا الإنجاب للـ Bronze featherback *Notopterus* (*notopterus*، Pallas 1769) من نهر كيليكار، أوغان إلير، جنوب سومطرة، إندونيسيا

مسلم مسلم، محمد سيف الدين، فرديناند حكما تقوى، محمد إقبال سابوترا

برنامج دراسة تربية الأحياء المائية، قسم مصايد الأسماك، كلية الزراعة، جامعة سريويجايا، إندرالايا، إندونيسيا.

الخلاصة

يعد إزدواج الشكل الجنسي وعلم الأحياء الإنجابي من الجوانب الأساسية لدراسات تربية الأسماك. كان الهدف من هذا البحث هو تحليل إزدواج الشكل الجنسي والبيولوجيا الإنجابية لـ N. notopterus. تم جمع ما مجموعه 74 N. notopterus من نهر كيليكار في منطقة أوغان إلير، إندونيسيا، وتتكون من 38 ذكرًا (طول الجسم: 18-23.6 سم؛ وزن الجسم: 35.1-92.1 جم) و36 أنثى (طول الجسم: 19.6-26.3 سم؛ وزن الجسم: 35.1-92.1 جم) و36 أنثى (طول الجسم: 19.6-26.3 سم؛ وزن الجسم: 49.4-133.8 جم). تم تحليل سبعة عشر شخصية مورفومترية وثلاثة صفات مرسية وخمسة معايير بيولوجية إنجابية. أظهرت النتائج وجود اختلافات في الخصائص المورفومترية للذكور والإناث N. notopterus. ومع ذلك، لم يكن هناك اختلاف في الشخصيات المرسية. ويتراوح مؤشر الغدد التناسلية عند الذكور من 0.15 إلى 0.61%، وعند الإناث من 1.12 إلى 9.10%. تراوح المؤشر الكبدي عند الذكور من 0.19 إلى 1.38%، وتراوح عند الإناث من 0.15 إلى 1.23%، مع نسبة جنس 1.056:1، وخصوبة 1.007-3.901 بيضة، وأقطار البويضات 1.1-3.9 ملم، ومستويات النضج. من الغدد التناسلية المتطورة لتنضج عند الذكور وتنضج لوضع البيض عند الإناث. في الختام، يمكن تحديد الاختلافات بين الذكور والإناث N. notopterus شكليا.

الكلمات المفتاحية: اختيار الأمهات؛ تكاثر الأسماك داء البنية. الخصائص الجنسية الثانوية.

Sexual Dimorphism and Reproductive Biology of Bronze Featherback (Notopterus notopterus, Pallas 1769) from Kelekar River, Ogan Ilir, South Sumatra, Indonesia

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