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Sexual Characteristics of *Nemipterus peronii* (Valenciennes, 1830) in the Bali Strait

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ABSTRACT

Nemipterus peronii is a demersal fish species distributed in the Indo-Pacific region and is one of the main fishing targets. This fish is very popular because it is available throughout the year. However, the high demand and intensity of fishing threaten the sustainability of its population. Moreover, limited information about this species hinders effective regulation and management efforts. This study aimed to analyze reproductive aspects such as differences in primary and secondary sexual characteristics between males and females, as well as gonadal maturity levels and growth patterns. A total of 300 samples of *N. peronii* were used in this study. Morphometric and meristic data were analyzed using a t-test with a 95% confidence level to identify differences between males and females. In addition, histological observations of the gonads were conducted to determine the stages of gonadal maturity in both sexes. No sexual dimorphism was detected in the external characteristics of males and females. Interestingly, several morphometric parameters in male *N. peronii* were significantly ($P< 0.05$) larger than in females. However, no significant differences were observed in the meristic parameters. Histological analysis showed that oocyte development in this species is asynchronous, allowing spawning to occur over an extended period. Furthermore, the growth pattern of *N. peronii* in both males and females was found to be isometric.

INTRODUCTION

Nemipterus peronii is a demersal fish species from the Nemipteridae family, characterized by a pink body with pale golden-yellow lines along the body **(Vagha *et al.*, 2022; Roul *et al.*, 2022)**. This fish is distributed from the Indian Ocean to the western Pacific waters, including East

Africa, the Red Sea, and the Indo-Malay Islands **(Ogwang *et al.*, 2021)**, as well as the Bali Strait. It is the main target of trawl net fishing, with catches having increased steadily over the past five years **(Amira *et al.*, 2016; Widagdo *et al.*, 2019)**. In Indonesia, this fish is commonly found in territorial waters at depths of about 40 meters, with a mud and sand seabed. Additionally, this fish is often caught in fishermen's nets at various sizes. Increased fishing pressure and climate change affect its habitat and reproduction, threatening the population **(Imtiaz & Naim, 2018; Roul *et al.*, 2022)**. Consequently, the size of the fish caught is decreasing, and the fishing time is increasing **(Yusrizal *et al.*, 2019)**.

The population of this fish is highly dependent on natality rates and environmental sustainability. In addition, the availability of food in the ecosystem is one of the factors that determine the maturity of its reproductive organs and growth **(Sululu *et al.*, 2017)**. The growth pattern of this fish is influenced by its specific prey, as feeding habits depend on size. Juveniles *Nemipterus* sp. feed on plankton, medium-sized individuals consume anchovies, and adults tend to be more selective in their diet **(Asriyana & Syafei, 2012)**. Visually, *N. peronii* is difficult to distinguish between males and females, since they have relatively similar body shapes, sizes, and colors. Information related to the biological aspects of this species is crucial for sustainable management and utilization efforts. The purpose of this study was to determine the growth pattern and differences in primary and secondary sexual characteristics, as well as the histological profile of the gonads at different developmental stages.

MATERIALS AND METHODS

Preparation

N. peronii samples were obtained from Muncar Harbor, Banyuwangi, East Java, Indonesia, from December 2023 to April 2024. A total of 300 male and female specimens (150 each), with an average weight and length of 192.42g and 24.67cm for males, and 172.77g and 23.77cm for females, were used in this study. Samples were observed in sequence, starting with length and weight measurements, followed by morphometric and meristic analyses, and observations of the gonads and testes. This research was conducted in accordance with the Law of the Republic of Indonesia No. 18 of 2002 concerning the National System for Research, Development, and Application of Science and Technology. It also adhered to ethical standards and received supervision and approval from the Faculty of Health, Medicine, and Life Science (FIKKIA), Airlangga University, as outlined in the Dean's Assignment Number: 1627/B/UN3.FIKKIA/I/TD.06/2024.

Parameters observed

Secondary sexual characteristics

A total of 20 male and 20 female *N. peronii* specimens were observed for meristic traits and measured using a Vernier caliper (0.01 mm accuracy) to determine the morphometric parameters (Fig. 1).

Primary sexual characteristics

Observation of primary sexual characteristics was conducted macroscopically on the gonads of *N. peronii* males and females using histological methods. Ovarian and testicular samples were fixed in 10% neutral buffered formalin (NBF) for 24 hours and then processed using the standard histological preparation technique described by **Suvarna *et al.* (2013)**, with minor modifications. The gonads were embedded in paraffin and sectioned at a thickness of 5µm, followed by staining with hematoxylin and eosin (H&E). Subsequently, the histological structure of the gonads was observed using a trinocular microscope (Olympus CX23, Japan) at magnifications of 40× and 100× for the ovaries, and 100× and 400× for the testes. This facilitated the identification of spermatocyte developmental phases, as their cells are smaller than oocytes.

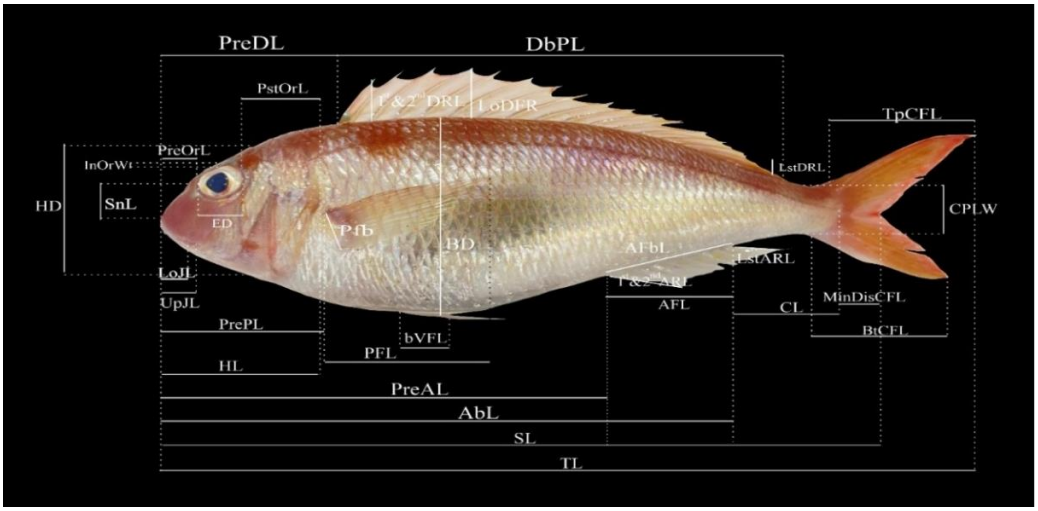

Fig. 1. Measurement of morphometric characteristics of *Nemipterus* sp. **TL** (Total length), **SL** (Standart length), **HW** (Head width), **HD** (Head depth), **HL** (Head length), **ED** (Eyes diameter), **SnL** (Snout length), **EyD** (Eyes distance), **PreAL** (Pre-Anal length), **BD** (Body depth), **BW** (Body width), **bVFL** (baseVentral Fin Length), **CPLW** (Caudal peduncle least width), **CL** (Caudal length), **DbPL** (Dorsal base peduncle length), **LoDFR** (Longest dorsal fin ray), **PFL** (Pectoral fin length), **PrePL** (Pre-Pectoral length), **AbL** (Anal base length), **PreDL** (Pre-Dorsal length), **TpCFL** (Top Caudal Fin length), **MinDisCFL** (Minimum distance Caudal fin length), **BtCFL** (Bottom caudal fin length), **AFl** (Anal fin length), **1st&2nd DRL** (1st&2nd Dorsal ray length), **1st&2nd ARL** (1st&2nd anal ray length), **LstARL** (Last anal ray length), **AFbL** (Anal fin base length), **PreOrL** (Pre-Orbital length), **InOrW** (Inter Orbital width), **PstOrL** (Post-Orbital length), **UpJL** (Upper jaw length), **LoJW** (Lower jaw length), **PFb** (Pectoral fin base)

The oocyte developmental stages were used to identify the ovaries of *N. peronii* following the description of **Senarat *et al.* (2024)**. Oocyte differentiation was divided into primary growth and secondary growth based on nucleolus development and the formation of vitellogenin. The differentiation phases included: oogonia, single-nucleolus stage, multiple-nucleoli stage, perinucleolar stage, oil droplet stage, cortical alveolar stage, early secondary growth stage, late secondary growth stage, fully grown oocyte stage, and post-ovulatory oocyte stage. Furthermore, the testicular developmental stages were based on the study of **Budi *et al.* (2024)**, who postulated that spermatocyte differentiation in fish consists of the spermatogonia, spermatocyst, spermatid, and spermatozoa phases.

Length and weight relationship

A total of 300 *N. peronii* specimens, 150 males and 150 females, with an average weight and length of 192.42g and 24.67cm for males, and 172.77g and 23.77cm for females, respectively, were used in this study. All samples were analyzed for the length–weight relationship (LWR) following **Le Cren (1951)** to determine the growth pattern of both sexes.

$$W = aL^b$$

Where:

L= Length of fish

W= Weight of fish

a = Intercept, and "b" is slope

Data analysis

Determination of sex in *N. peronii* was carried out using two approaches: primary and secondary sexual characteristics. The primary sexual characteristics were analyzed descriptively, while the secondary sexual characteristics (morphometric and meristic) were analyzed using a t-test with a 95% confidence interval. Furthermore, length–weight relationship analysis was performed to determine the growth pattern of this species.

RESULTS

Meristic and morphometric characteristics of *N. peronei*

Characteristics of male and female *N. peronii* based on morphometrics and meristics showed that most of the morphometric parameters observed did not show significant differences (Table 1). However, based on the independent t-test**,** there were significant differences in head depth (P= 0.041), eye diameter (P= 0.036), longest dorsal fin ray (P= 0.013), first and second dorsal fin ray length (P< 0.001), and last dorsal fin ray length (P= 0.015), as shown in Fig. (2). On the other hand, there was no significant difference (P> 0.05) between male and female *N. peronii* based on meristic characteristics (Table 2).

Table 1. Morphometric characters of male and female *N. peronii* (n = 20)

Characters	Male		Female		*P**	Sig.**
	Range	Mean ± SD	Range	Mean ± SD		
TL	22-27.5	24,28 ± 1,82	20-25	23,48 ± 1,34	0.122	NS
SL	18.5-24.5	20,29 ± 1,53	19-25	20,81 ± 1,46	0.283	NS
HW	1.5-2.3	1,72 ± 0,22	1.4-2	1,80 ± 0,18	0.246	NS
HD	3.3-4.5	3,75 ± 0,35	3-3.8	3,56 ± 0,22	0.041	S
HL	4-6	5,27 ± 0,58	4.3-5.6	5,11 ± 0,44	0.277	NS
ED	1-1.7	1,26 ± 0,26	1-1.3	1,13 ± 0,09	0.036	S
SnL	1.5-2.7	2,03 ± 0,35	1.6-2.2	1,92 ± 0,20	0.254	NS
EyD	1.3-1.9	1,57 ± 0.22	1-1.8	1,52± 0.24	0.447	NS
PreAL	9.6-13.2	10,74 ± 0,97	10-11.3	10,67 ± 0,45	0.772	NS
BD	5-7	5,93 ± 0,71	5.7-6.5	6,04 ± 0,26	0.520	NS
BW	1.6-2.5	2,23 ± 0,25	2.1-2.5	2,35 ± 0,12	0.174	NS

Characters	Male		Female		*P**	Sig.**
	Range	Mean ± SD	Range	Mean ± SD		
bVFL	0.6-1.5	0,96 ± 0,26	0.8-1.6	1,04 ± 0,22	0.269	NS
CPLW	1.6-2.5	1,87 ± 0,22	1.5-2	1,79 ± 0,15	0.308	NS
CL	1-1.8	1,37 ± 0,27	1.1-1.7	1,37 ± 0,20	1.000	NS
DbPL	10-13.1	11,19 ± 0,99	10.4-12	10,98 ± 0,53	0.420	NS
LoDFR	1.5-3	2,14 ± 0,38	1.5-2.2	1,88 ± 0,24	0.013	S
PFL	3.2-5	4,07 ± 0,53	4-5	4,29 ± 0,30	0.112	NS
PrePL	5-6.3	5,67 ± 0,47	3.8-6.5	5,62 ± 0,61	0.772	NS
AbL	14-17.5	16,04 ± 1,21	13.16.5	15,47 ± 0,87	0.094	NS
PreDL	5.5-6.8	6,08 ± 0,44	5.5-6.5	5,91 ± 0,35	0.195	NS
TpCFL	4.5-6	5,49 ± 0,49	5-6.3	5,36 ± 0,39	0.358	NS
MinDisCFL	1.1-1.9	1,49 ± 0,26	1.-2.5	1,44 ± 0,37	0.660	NS
BtCFL	4.5-5.3	4,89 ± 0,26	4.4-5.2	4,77 ± 0,28	0.169	NS
AFL	1.4-1.8	1,56 ± 0,13	1-1.7	1,48 ± 0,16	0.093	NS
1^{st}&2^{nd} DRL	2-3	2,44 ± 0,25	1.5-2.5	2,14 ± 0,24	<0.001	S
LstDRL	1.5-2	1,74 ± 0,18	1-2	1,56 ± 0,25	0.015	S
1^{st}&2^{nd} ARL	1.2-2	1,73 ± 0,22	1.4-2	1,65 ± 0,18	0.215	NS
LstARL	1.5-2	1,71 ± 0,19	1.5-1.9	1,64 ± 0,13	0.221	NS
AfbL	3-4	3,62 ± 0,33	3.2-4	3,50 ± 0,20	0.158	NS
PreOrL	1.1-2	1,63 ± 0,22	1.4-2	1,60 ± 0,16	0.630	NS
InOrW	1.4-1.8	1,61 ± 0,13	1.5-1.8	1,60 ± 0,09	0.671	NS
PstOrL	1.5-2.6	1,96 ± 0,37	1.6-2.2	1,97 ± 0,21	0.876	NS
UpJL	0.6-1.9	1,35 ± 0,44	0.5-1.6	1,16 ± 0,39	0.158	NS
LoJW	1.2-1.8	1,55 ± 0,17	1.4-1.8	1,57 ± 0,13	0.685	NS
PFb	1-1.7	1,12 ± 0,20	0.9-1.8	1,18 ± 0,26	0.380	NS
Weight	128-288	188,20 ± 52,66	160-230	189,35 ± 24,35	0.930	NS

Note: **TL** (Total length), **SL** (Standart length), **HW** (Head width), **HD** (Head depth), **HL** (Head length), **ED** (Eyes diameter), **SnL** (Snout length), **EyD** (Eyes distance), **PreAL** (Pre-Anal length), **BD** (Body depth), **BW** (Body width), **bVFL** (baseVentral Fin Length), **CPLW** (Caudal peduncle least width), **CL** (Caudal length), **DbPL** (Dorsal base peduncle length), **LoDFR** (Longest dorsal fin ray), **PFL** (Pectoral fin length), **PrePL** (Pre-Pectoral length), **AbL** (Anal base length), **PreDL** (Pre-Dorsal length), **TpCFL** (Top Caudal Fin length), **MinDisCFL** (Minimum distance Caudal fin length), **BtCFL** (Bottom caudal fin length), **AFl** (Anal fin length), **1^{st}&2^{nd} DRL** (1^{st}&2^{nd} Dorsal ray length), **1^{st}&2^{nd} ARL** (1^{st}&2^{nd} anal ray length), **LstARL** (Last anal ray length), **AFbL** (Anal fin base length), **PreOrL** (Pre-Orbital length), **InOrW** (Inter Orbital width), **PstOrL** (Post-Orbital length), **UpJL** (Upper jaw length), **LoJW** (Lower jaw length), **PFb** (Pectoral fin base), all parameters are measured in (**cm**) units except weight parameter.

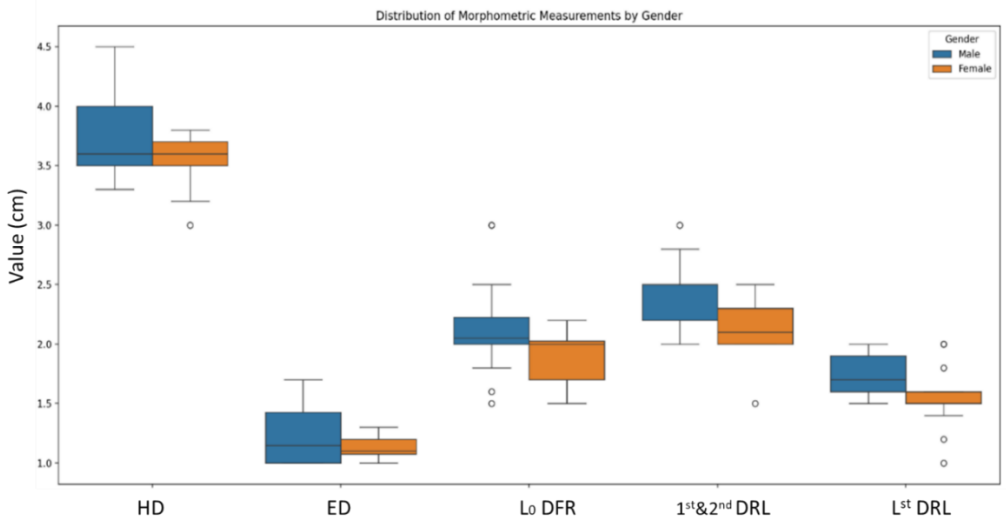

Fig. 2. Distribution of morphometric parameters that differ significantly between male and female *N. peronii* based on independent t-test

Table 2. Differences in meristic characters between males and females (n = 20)

Characters	Male		Female		*P**	Sig.**
	Range (%)	Mean ± SD (%)	Range (%)	Mean ± SD (%)		
PeFR	P.VI.16-P.X.24	8.10 ± 1.20	P.VI.20-P.X.24	8.15 ± 0.81	0.879	NS
VFR	V.II.6-V.II.12	2.00 ± 0.00	V.I.8-V.II.12	1.90 ± 0.30	0.154	NS
DFR	D.IX.8-.XI.10	9.95 ± 0.39	D.X.6-D.XIII.9	10.30 ± 0.73	0.068	NS
AFR	A.II.6-A.III.9	2.80 ± 0.41	A.I.5-A.V.8	2.70 ± 0.80	0.622	NS
CFR	C.IX.4-.XVI.8	12.10 ± 2.15	C.X.3-.XVIII.8	13.10 ± 2.55	0.188	NS

PeFR (pectoral fin rays), VFR (ventral fin rays), DFR (dorsal fins rays), AFR (anal fin rays), CFR (caudal fin rays). *By independent T–test, **Significant (S) and not significant (NS)

Macroscopic and histological characteristics of the gonads of *N. peronei*

Male and female *N. peronii* gonads are similar to those of other fish, both macroscopically and histologically. Both male and female *Nemipterus* sp. develop through four stages: stage I, stage II, stage III, and stage IV.

Gonad stage I — early maturation

At this stage, the ovaries are yellowish and more transparent than the testes, with a cylindrical shape although they still appear flat. Oocytes are not yet visible, but blood vessels are clearly visible (Fig. 3c). Histologically, the ovarian tissue is dominated by oogonia (O) and primary oocytes. The primary oocytes observed include one-nucleolus (ON), multiple-nucleoli (MN), and perinuclear (PN) types. On the other hand, the testes have a smooth, shiny, salmon-colored surface. In terms of shape, the paired testes are of the same length but thinner than in later stages, and blood vessels are not yet visible. Microscopically, the testis tissue is composed of spermatogonia (Sg), spermatocytes (Sc), spermatids (St), and spermatozoa (Sz). At this stage, the seminiferous tubules

contain numerous spermatogonia (Fig. 3f). However, the seminiferous tubules (Tc) are not yet clearly visible.

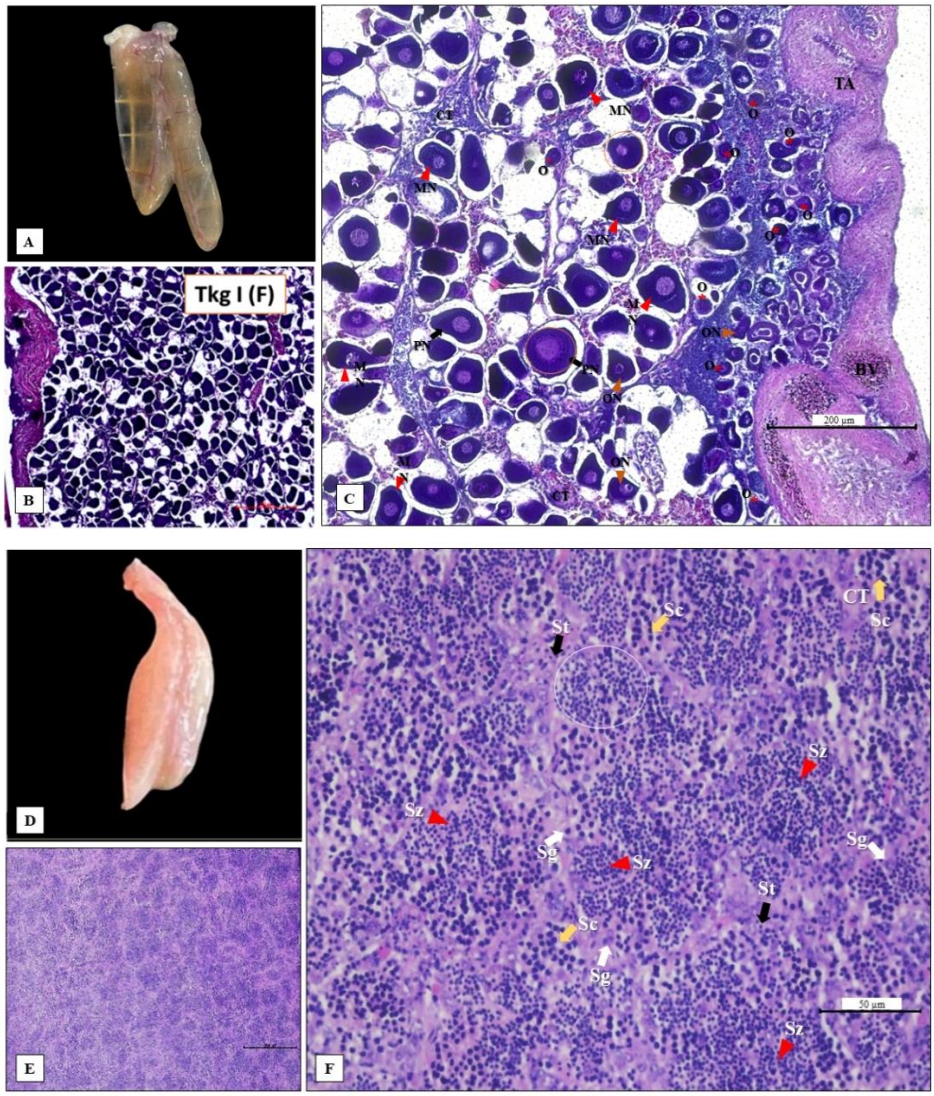

Fig. 3. Gonads of *N. peronii.* in the Bali Strait. A) **Ovary stage 1** in maxroscopic view; B) Histology of ovary stage 1 at 100× magnification; C) Histology of ovary stage 1 at 200× magnification; D) Testis stage 1 in maxroscopic view; E) Histology of testis stage 1 at 100× magnification; F) Histology of testis stage 1 at 400× magnification. Description of section C. red asterisks: Oogonium (O); red arrowhead: Multiple nucleoli (MN); black arrow: Perinucleolar (PN); Yellow arrow: one oocyte nucleus; Blood Vesicle (BV); Tunica Albuginea (TA); Connective Tissue (CT). Part description F. White arrow: Spermatogonium (Sg); Yellow arrow: Spermatocyte (Sc); Black arrow: Spermatid (St); Red arrowhead: Spermatozoa (Sz) and Connective Tissue (CT); White circle: Seminiferous tubules

Gonad stage II- primary growth stage

Gonad stage II — developing

Entering the second stage, development shows an increase in volume compared to stage I, and oocytes are not yet visible macroscopically. External blood vessels become more developed around the ovaries (vascularization). At this stage, the ovaries are mostly still composed of primary

oocytes in the form of multiple-nucleoli (MN) and perinuclear (PN) oocytes, whose numbers are increasing. In addition, secondary oocytes at the early secondary growth (ESG) stage are also beginning to be observed, although the number is still small (Fig. 4c). The testes, which were previously flat and salmon-colored, develop to become denser and begin to appear ivory white. The seminiferous tubules (Tc) are more clearly visible than in stage I (Fig. 4f). The number of spermatozoa (Sz) and spermatocytes (Sc) increases, filling the lumen of the seminiferous tubules (Tc).

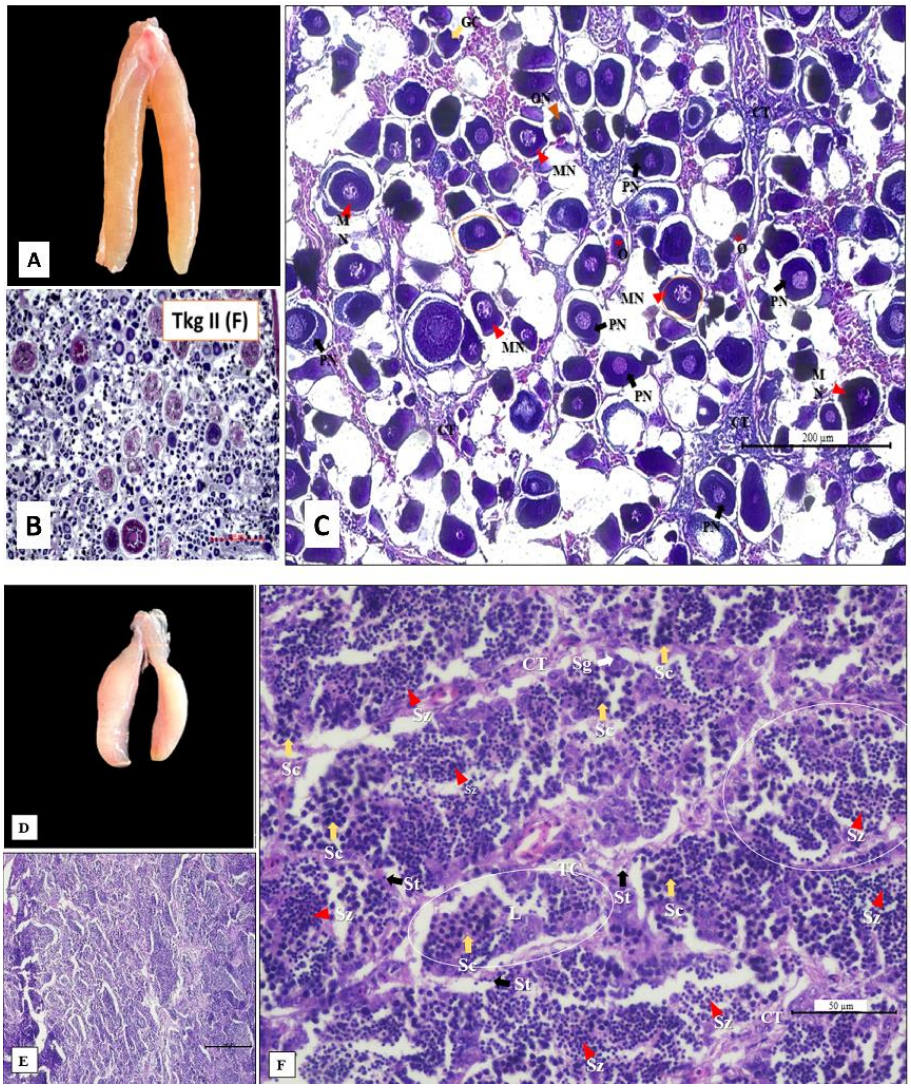

Fig. 4. Gonads of *N. peronii* in the Bali Strait. A) **Ovary stage 2** in macroscopic view; B) Ovary stage 2 histology at 100× magnification; C) Ovary stage 2 histology at 200× magnification; D) Testis stage 2 in macroscopic view; E) Testis stage 2 histology at 100× magnification; F) **Testis stage 2** histology at 400× magnification.

Gonad stage III — secondary growth

Visually, the ovaries become increasingly yellow as the yolk granules accumulate, and they become firmer and thicker, with a network of blood capillaries visible from within. However, the oocytes appear opaque. Histologically, the number of oocytes entering the early secondary growth

(ESG) and late secondary growth (LSG) stages increases, whereas oogonia and primary oocytes remain detectable in the tissue. In this phase, the accumulation of yolk granules occurs intensely, causing the size of oocytes in the secondary growth phase to become several times larger. In contrast, although the ovaries increase in size, the size of the testes is not much different from the previous stage. The color of the testes becomes whiter with more wavy edges**.** Histologically, spermatozoa begin to fill the lumen of the seminiferous tubules, and their number exceeds that of spermatogonia and spermatocytes.

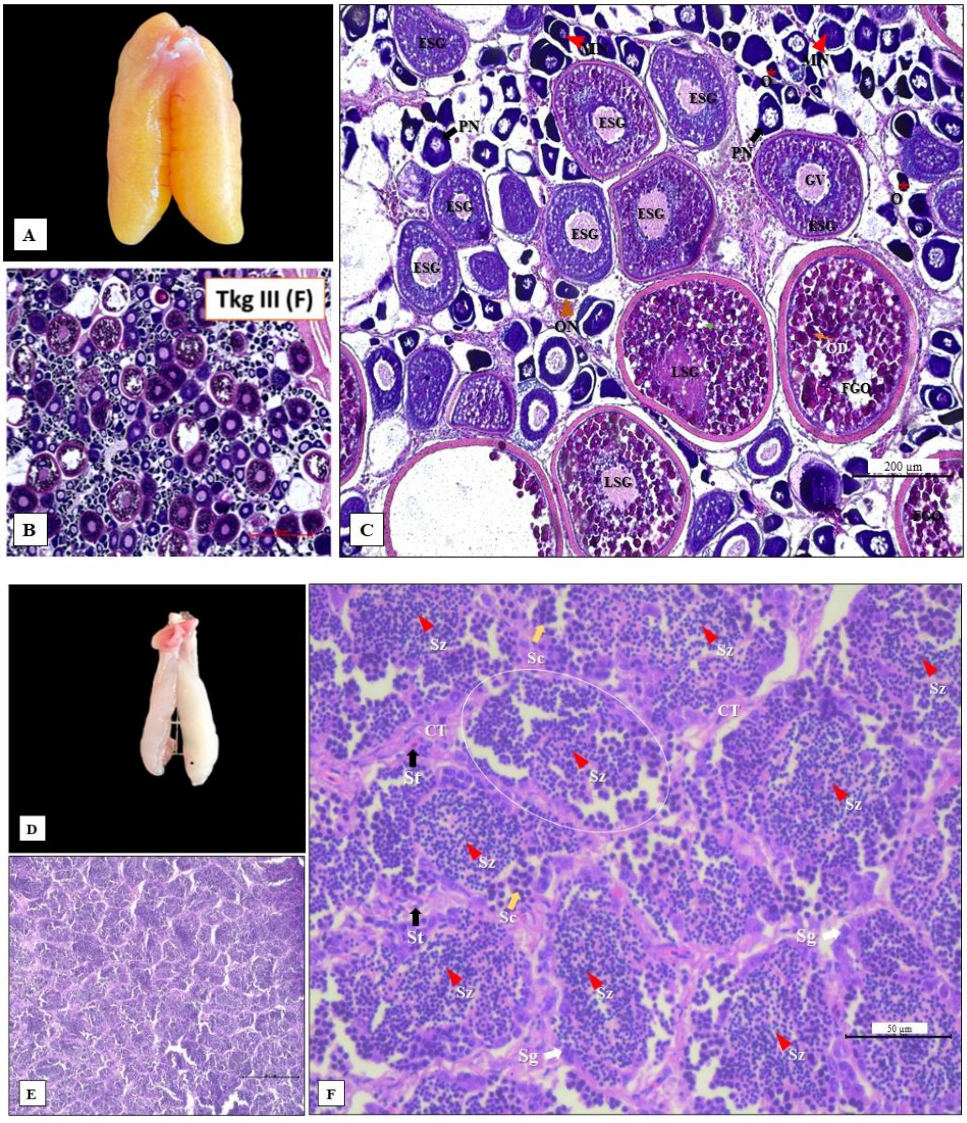

Fig. 5. Gonads of *N. peronii* in the Bali Strait. A) **Ovary stage 3** microscopically; B) Ovary histology stage 3 in 100× magnification; C) Ovary histology stage 3 in 200× magnification; D) **Testis stage 3** microscopically; E) Testis histology stage 3 100× magnification; F) **Testis histology stage 3** in 400× magnification. Note C: red arrowheads: Multiple nucleoli (MN); red asterisk: Oogonium (O); black arrowhead: Perinucleolar (PN); Early Secondary Growth Stage (ESG); Late Secondary Growth Stage (LSG); Connective Tissue (CT); Vesicular Vesicles (GV); green arrowheads: Corticol Alveoli (CA); orange arrows: Egg Yolk Granules (Yg). Description of F: Ceminiferous tubule (Tc); Lumene (L); Spermatocyte (Sc); Spermatozoa (Sz) and Connective Tissue (CT). White circle: Seminiferous tubule

Gonad stage IV- ripe

At this stage, the ovaries enlarge significantly and appear light orange. The capillary network becomes increasingly visible around the ovary, and the oocyte granules are more clearly visible macroscopically. Histologically, this phase is dominated by oocytes in the fully grown oocyte (FGO) stage. The FGO stage is when oocytes have reached peak maturation, marked by an abundant number of yolk granules and an indistinct nucleus. Oogonia and primary oocytes are not visible in the tissue, having been replaced by the appearance of postovulatory follicles (POF) as a sign that the oocytes have been released. At the peak phase of gonadal development (stage IV), the testes become larger and more compact, filled with sperm. The color becomes completely creamy white with a clearly visible capillary network. The seminiferous tubules (Tc) appear enlarged because the number of spermatozoa (Sz) increases rapidly and dominates the testicular tissue.

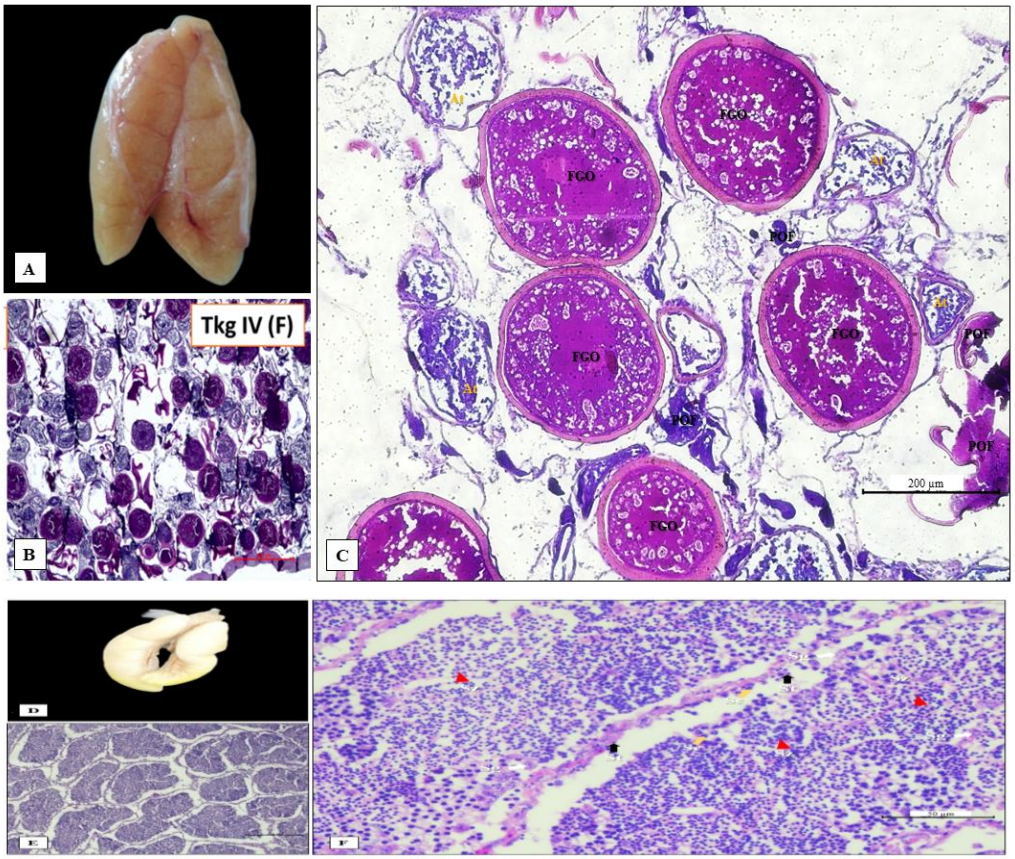

Fig. 6. Gonad of *N. peronii* in Bali Strait. A) Macroscopically, **stage 4 ovary**; B) Histology of stage 4 ovary at 100× magnification; C) Histology of stage 4 ovary at 200× magnification; D) Macroscopically, stage 4 testis; E) Histology of stage 4 testis at 100× magnification; F) **Histology of stage 4 testis** at 400× magnification. Caption of section C: Fully Growth oocyte (FGO); Postovulatory Follicle (POF); Atresia (At). Caption of section F: white arrow: spermatogonia (Sg); black arrow: Spermatid (St); yellow arrow: Spermatocytes (Sc); red arrow head: Spermatozoa (Sz) and Connective Tissue (CT)

Growth pattern of N. peronei

The mean weight of male *N. peronii* was 192.42g, with minimum and maximum values of 151.0 and 283.0g, respectively, while the mean length was 24.67cm, with minimum and maximum values of 21.0 and 27.5cm, respectively (Fig. 6a). Analysis of the relationship between weight and

length of male *N. peronii* showed a moderate positive correlation (r = 0.76) close to 1, indicating that as weight increases, length tends to increase proportionally. A similar growth pattern was also found in female *N. peronii*, with a length–weight relationship of r = 0.631. The average weight was 172.77g (range: 109.0–316.0g), and the average length was 23.77cm (range: 25.0 – 29.0cm) (Fig. 6b).

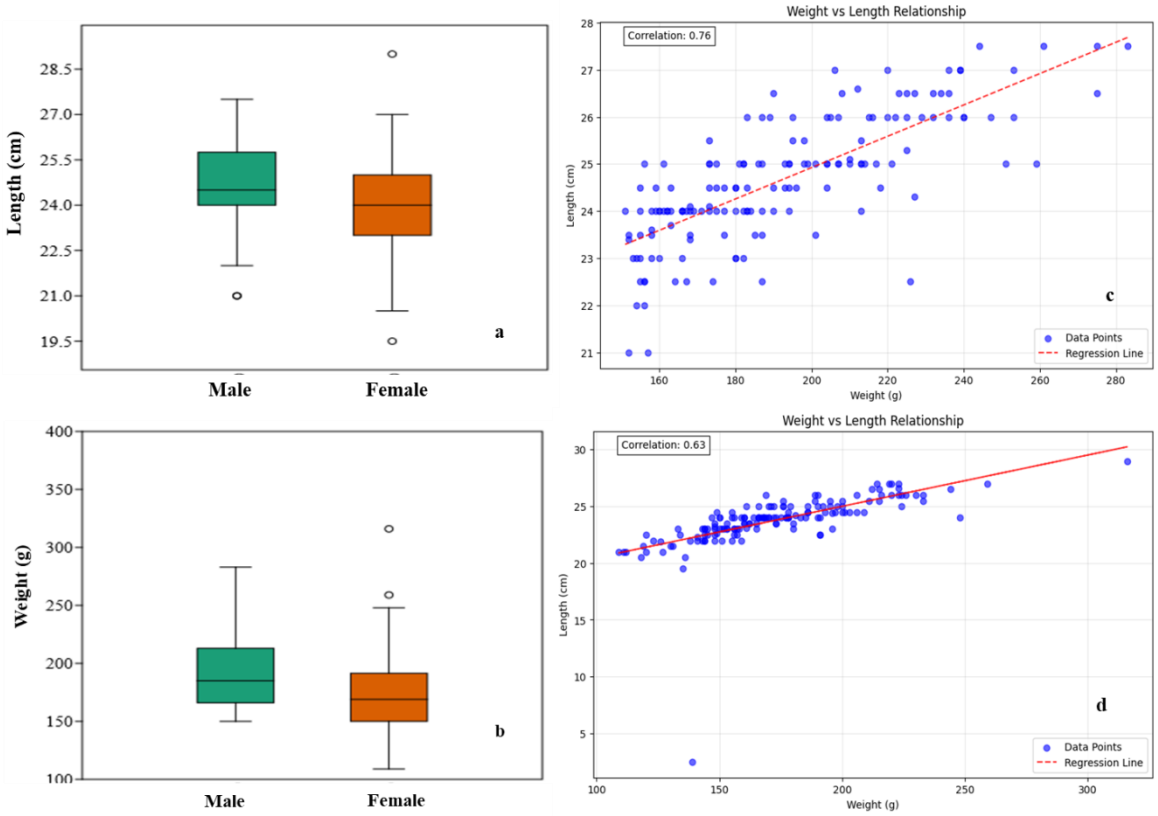

Fig. 6. Boxplots of mean length (a), and weight (b) of *N. peronni*, and length-weight relationship of males (c), females (d), n =150

DISCUSION

N. peronii from the Bali Strait has a fusiform body shape, which is common in fish inhabiting open waters. This body form allows them to swim rapidly and efficiently **(Larouche *et al.*, 2020)**. No significant sexual dimorphism was found between males and females, either in size or body shape. Meristically, there were also no differences between the two sexes. Similar findings were reported for *N. japonicus* off the coast of India, where no meristic differences were observed between males and females **(Sreekanth *et al.*, 2013)**. A comparable phenomenon has also been observed in other species, such as *Nemipterus furcosus* **(Rahman & Samat, 2021)**. However, differences in morphometric values between males and females were evident in several parameters, including head depth, eye diameter, length of the longest dorsal fin ray, length of the first and second dorsal fin rays, and length of the last dorsal fin ray. Male *Nemipterus* spp. generally show higher values for these parameters, possibly influenced by differences in feeding habits

(Imtiaz & Naim, 2018). Greater head depth may also be related to larger brain size, as fish with larger brains tend to have larger eyes **(Corral-López *et al.*, 2017)**.

Furthermore, the primary sexual characteristics of male and female *N. peronii* consist of a pair of symmetrical gonads. The ovaries of female *N. peronii* are classified as the cystovarian type. This type is characterized by mature oocytes that remain in the ovarian membrane and then exit through the ovarian duct into the environment **(Dymek *et al.*, 2022)**. This differs from the gymnovarian type, where oocytes are released into the coelomic cavity before exiting through the oviduct **(Ambily & Bijoy, 2024)**.

Histologically, the ovaries of *N. peronii* in the Bali Strait show asynchronous oocyte development, with oocytes at various developmental stages and without a dominant population. This type of development allows spawning to last longer, with fish laying eggs several times in one season **(Ganias & Lowerre-Barbieri, 2018)**. This reproductive strategy helps reduce competition for space and food resources for larvae **(Kerdgari *et al.*, 2013)**. Unlike the ovaries, the histology of the testes of *N. peronii* reveals lobular tissue composed of spermatogonia, spermatocytes, spermatids, and spermatozoa at each stage. Comparable findings have been reported for *Nemipterus randalli*, which also has lobular testes divided into lobes by connective tissue septa (testicular lobulation) **(Özen, 2021)**.

Furthermore, the histology of the ovaries of *N. peronii* at stages I and II (early maturation and primary growth stages) is characterized by the dominance of oogonia and primary oocytes. The early maturation stage of the ovaries in *Nemipterus furcosus* is composed mainly of oogonia (unyolked oocytes) and primary oocytes, while stage II is marked by the presence of primary oocytes and primary vitellogenic oocytes **(Rahman & Samat, 2021)**. Entering stage III, many oocytes undergo secondary growth and accumulate yolk droplets (vitellogenesis). Vitellogenesis causes the diameter of the oocytes to increase drastically. Yolk droplets, also called vitellogenin, contain proteins, carbohydrates, lipids, minerals, vitamins, and other essential components for embryogenesis **(Gupta *et al.*, 2021)**. This has also been reported in *Nemipterus japonicus*; oocytes in the secondary growth phase are filled with yolk, with nuclei that begin to migrate to the cell periphery **(Nettely, 2016)**. In stage III, clear granules called cortical alveoli are also observed, marking oocytes entering this stage **(Özen, 2021)**. Lastly, stage IV is characterized by fully grown oocytes and the presence of postovulatory follicles. In this phase, vitellogenin in the oocyte is hydrolyzed, and the cell nucleus degenerates and is no longer visible **(Nettely, 2016)**. Postovulatory follicles that accumulate in peripheral tissue indicate that the oocyte has been released and serve as a sign of active spawning **(Nettely, 2016)**.

On the other hand, the length–weight relationship of *N. peronii* in the Bali Strait shows an isometric growth pattern. The length–weight relationship can provide insights into fish growth patterns, habitats, water productivity, physiological condition, and overall health **(Dewiyanti *et al.*, 2020)**. Fish with isometric growth actively rely on fin movements for swimming **(Berrios-**

Lopez *et al.*, 1996). Previously, the *Nemipterus* species reported to have an isometric growth pattern was *N. japonicus* **(Suresh *et al.*, 2011; Sreekanth *et al.*, 2014; Prabakaran *et al.*, 2018)**. This isometric pattern was also found in both male and female *N. peronii* in the Bali Strait. The absence of differences in growth patterns between males and females has likewise been reported in *N. peronii* **(Wu *et al.*, 2008)** and *Nemipterus isacanthus* **(Longenecker *et al.*, 2017)**, both of which showed no significant sex-based differences in the length–weight relationship. This can occur because female *N. peronii* do not mature all their gonads simultaneously (asynchronous ovaries), thereby maintaining an isometric growth pattern. Ecologically, this pattern enables fish to safeguard their offspring by distributing environmental risks across multiple spawning events, thus reducing the negative effects of environmental fluctuations **(Domínguez-Castanedo *et al.*, 2024)**.

CONCLUSION

Male and female *N. peronii* from the Bali Strait have a fusiform body shape, an isometric growth pattern, and show no significant sexual dimorphism overall. Males differ significantly from females in head depth, eye diameter, and dorsal fin length, traits that may be linked to feeding preferences and brain size. Furthermore, this species has symmetrical gonads, with cystovarian ovaries and asynchronous oocyte development. This reproductive strategy promotes prolonged spawning and helps reduce competition among larvae while buffering against environmental fluctuations.

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Conflict of interest

All author declared that no conflict of interest in this research.

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