

Research Article



Distribution and Morphometric Variation Updates of Critically Endangered Peat Swamp Fish, *Parosphromenus ornaticauda* from West Kalimantan

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ABSTRACT

Parosphromenus ornaticauda is a critically endangered dwarf labyrinth fish restricted to peat swamp waters in West Kalimantan, Indonesia. Previous records were limited to the type locality, and morphological variation across its geographic range remained poorly understood. This study aims to update the distribution records and assess morphometric variation between sexes and populations. Field surveys were conducted at 20 locations across six rivers in West Kalimantan. Morphometric analysis was performed on 40 specimens (21 males and 19 females) from two populations using 13 body measurements. Statistical analyses included MANOVA, Mann-Whitney U test, and Principal Component Analysis. The species was recorded at seven locations, including five sites outside its IUCN distribution range, thereby extending its known occurrence to the Mempawah, Tempayan, and Ambawang rivers. Notably, only one location occurred within protected forest areas. Significant sexual dimorphism was detected in anal-fin base length, with males exhibiting shorter fins than females. Population-level differences were identified in five morphometric characters, with specimens from lentic peat-swamp habitats exhibiting smaller body depth and larger orbital diameter than those from lotic canal habitats. These results demonstrate that *P. ornaticauda* has a broader distribution than previously recognized and exhibits morphometric plasticity related to habitat type. Immediate conservation measures are recommended, given that the species occur predominantly in unprotected, fragmented habitats.

1. Introduction

The family Osphronemidae belongs to the order Anabantiformes (Betancur *et al.* 2017), a group of freshwater fishes commonly known as labyrinth fishes, which can breathe atmospheric oxygen (Ruber *et al.* 2006; Schindler and Linke 2012). Within Osphronemidae, the genus *Parosphromenus* has 23 known species, inhabiting peat swamp waters across the Sunda Shelf, of which 80% are considered

threatened according to the IUCN Red List (Low 2019). *Parosphromenus ornaticauda* is the second smallest species of the genus after *P. parvulus*. It is distinguished from all other *Parosphromenus* species by the conspicuous color pattern of the male caudal fin and the extensive black pigments on the dorsal, anal, and caudal fins, along with a marginal blue stripe (Kottelat *et al.* 1993; Goodwin and Zimmerman 2024). Species in the genus *Parosphromenus* are currently known only by their type localities. However, limited sampling means that their full distribution ranges remain uncertain, and *P. ornaticauda* is endemic to Kalimantan (Patricio *et al.* 2023).

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This species is considered stenotopic, restricted to a specific peat-swamp habitat characterized by unique environmental conditions (Giam *et al.* 2012). *P. ornaticauda* occurs in water with a brownish to dark brown tint, with pH 4.5–5 and a temperature of approximately 27°C (Roberts 1989).

The distribution of *P. ornaticauda* has been poorly documented since its original description. In a study conducted in 1976, the *P. ornaticauda* (previously identified as *P. parvulus*) was recorded from western Borneo at several small stream tributaries, such as Sungai Pinyuh 1 (0°18.5N 109°07E), Sungai Pinyuh 2 (0°20N 109°08E), and Sungai Kepayang (0°19N 109°08E), in the former Pontianak Regency, now known as Mempawah Regency (Roberts 1989). According to IUCN data, this species is currently restricted to Mempawah, Landak, and Kubu Raya Regency (Low 2019).

Despite its restricted distribution and critically endangered status, morphological variation across the geographic range of *P. ornaticauda* remains poorly understood. In the original description, *P. ornaticauda* was described based on only five specimens, including the holotype, from a single locality (Kottelat 1991). No comparative morphometric study has examined population-level variation across its range. Understanding morphometric variation among populations is essential for identifying conservation units and developing effective management strategies for this threatened species. Therefore, this study aimed to: (1) document the current distribution of *P. ornaticauda* in West Kalimantan, including areas beyond the previously known IUCN distribution range; and (2) evaluate morphometric variation among populations and between sexes based on 13 body measurements from two locations. These findings will contribute to a better understanding of the species' ecology and inform future conservation efforts.

2. Materials and Methods

2.1. Study Area and Sampling Sites

We conducted this research from April 2024 to July 2025. We selected sampling sites based on type localities (Roberts 1989; Kottelat 1991), the IUCN Red List distribution range (Low 2019), and information obtained from local fish collectors. We surveyed six rivers in West Kalimantan, Indonesia: Pinyuh River, Mempawah River, Mandor River, Tempayan River, Ambawang River, and Tempurukan River (Figure 1). Within these rivers, we focused sampling on tributaries,

plantation drainage canals, and peat swamp areas. We employed an exploratory survey approach. To protect wild populations from potential collection pressure, we do not disclose precise coordinates of presence locations. The Ethics Committee granted the research ethical approval for this research for the Care and Use of Animals, National Research and Innovation Agency (BRIN) under approval number 072/KE.02/SK/05/2025, and permission to access the study site was issued by the Division of Protected Area and Ecosystem Management (PKSDAE), Environmental and Forestry Service of West Kalimantan Province, Indonesia under letter number 500.4.6.5/1153/LHK.

2.2. Fish Sampling and Specimen Collection

We collected fish using a hand-made dip net with a diameter of 74 cm, constructed with two-layered netting, each layer with a mesh size of 0.75 cm. We identified species following the original description by Kottelat (1991). We determined sex based on coloration patterns, with males exhibiting more vivid coloration and longer dorsal and anal fins than females. *P. ornaticauda* is a small-sized fish (<5 cm) and was therefore euthanized using the rapid chilling method with an ice slurry, which is appropriate for small tropical fish. A two-liter plastic container was filled to three-quarters of its volume with ice cubes or crushed ice, after which water from the fish's temporary holding container was added to achieve a minimum 1:1 ice-to-water ratio. The mixture was left for ten minutes to allow the temperature to stabilize at 1.5–2.0°C. The fish were then slowly transferred into the slurry portion containing water. Opercular movements were observed until they ceased within one to two minutes. The procedure was then completed using the pithing technique (brain puncture) by inserting a needle through the cranial opening (Jones and Daly 2013). Afterwards, the specimens were preserved in 96% ethanol. Voucher specimens were deposited at the Museum Zoologicum Bogoriense (MZB) of BRIN, Cibinong, West Java, Indonesia. Catalog numbers MZB. Fish 26743—26782.

2.3. Environmental Parameters

We recorded the geographic coordinates of each sampling site using a Garmin GPS 62S. We measured the following environmental parameters in situ: water pH, water temperature (°C), dissolved oxygen (mg/L), total dissolved solids (ppm), and electrical conductivity (µS/cm) using a portable water-quality meter. Water clarity (%) was measured using a Secchi disk, while stream

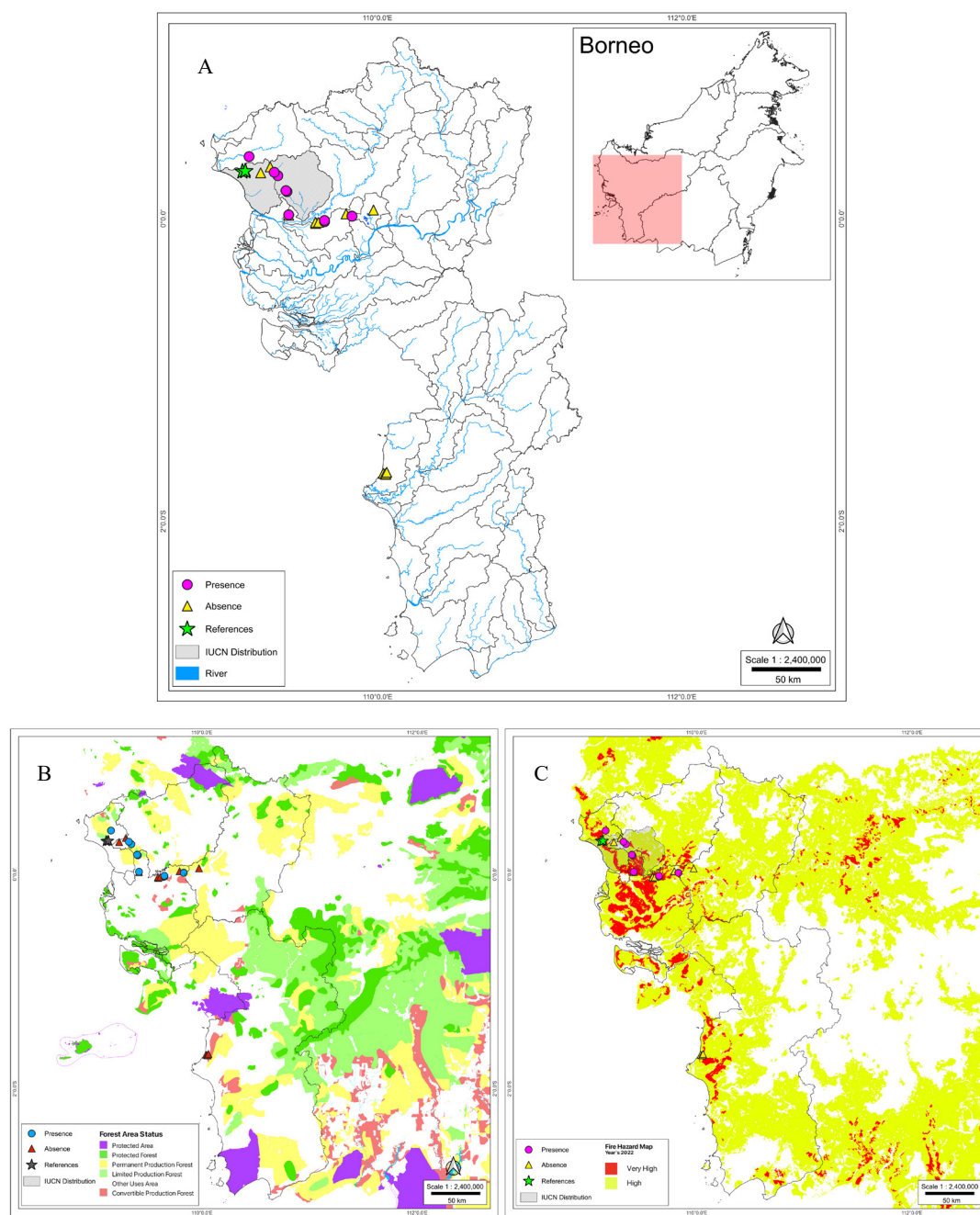


Figure 1. Study location of *Parosphromenus ornaticauda* in West Kalimantan, Indonesia. (A) Distribution within the river; (B) forest area status, (C) fire hazard vulnerability

width (m) and water depth (m) were measured using a measuring tape.

2.4. Distribution Mapping

We generated distribution maps in QGIS version 3.40.5-Batavia using presence-absence records. We overlaid maps with data on forest status and land-fire vulnerability obtained from the Geospatial Information System (SIGAP) of the Ministry of

Environment and Forestry of the Republic of Indonesia and HydroBASINS Level 8 watershed boundaries (Carvajal-Quintero *et al.* 2019).

2.5. Morphometric and Meristic Analysis

Due to the low number of individuals found at most sites, we restricted morphometric analysis to specimens from the Mempawah River (natural peat swamp forest; Figure 2C) and Ambawang River (man-made canal;



Figure 2. Habitat views at survey locations. (A–B Kepayang River) type locality area; (C Mempawah River; D–E Mandor River; F Tempayan River; G Ambawang River; H Ngarak; I Ambawang River) sites where *P. ornatacauda* was present; (J–K Subah; L Teluk Bakung) sites where *P. ornatacauda* was absent. Note: *P. anjunganensis* was recorded at sites H and I

Figure 2G). We measured a total of 40 individuals, comprising eight males and seven females from the Mempawah River and 13 males and 12 females from the Ambawang River.

We took morphometric measurements using digital calipers (Insize 1108-150) to the nearest 0.01 mm. The same person took all measurements from the left side of each specimen to ensure consistency. We measured thirteen morphometric characters following Shi *et al.* (2021) (Figure 3): standard length (SL), total length (TL), predorsal length (PrDL), postdorsal length (PoDL), head length (HL), body depth (BD), pectoral-fin length (PEL), anal-fin base length (AL), dorsal-fin base length (DL), caudal peduncle depth (CPD), orbit diameter (OD), postorbital length (POL), and interorbital width (IO).

We performed meristic counts under an Olympus SZX12 Binocular, supplemented by using photographs. We counted fin rays only in specimens with fully extended fins, with the frequency of each count indicated in brackets.

2.6. Statistical Analysis

We standardized morphometric measurements to minimize the effect of body size variation as follows: we expressed body measurements as percentages of standard length (SL), while we expressed head-related measurements (OD, POL, and IO) as percentages of head length (HL) (Nur *et al.* 2020).

Mahalanobis distance was used to screen for potential multivariate outliers; however, no specimens exceeded the critical threshold, and no data

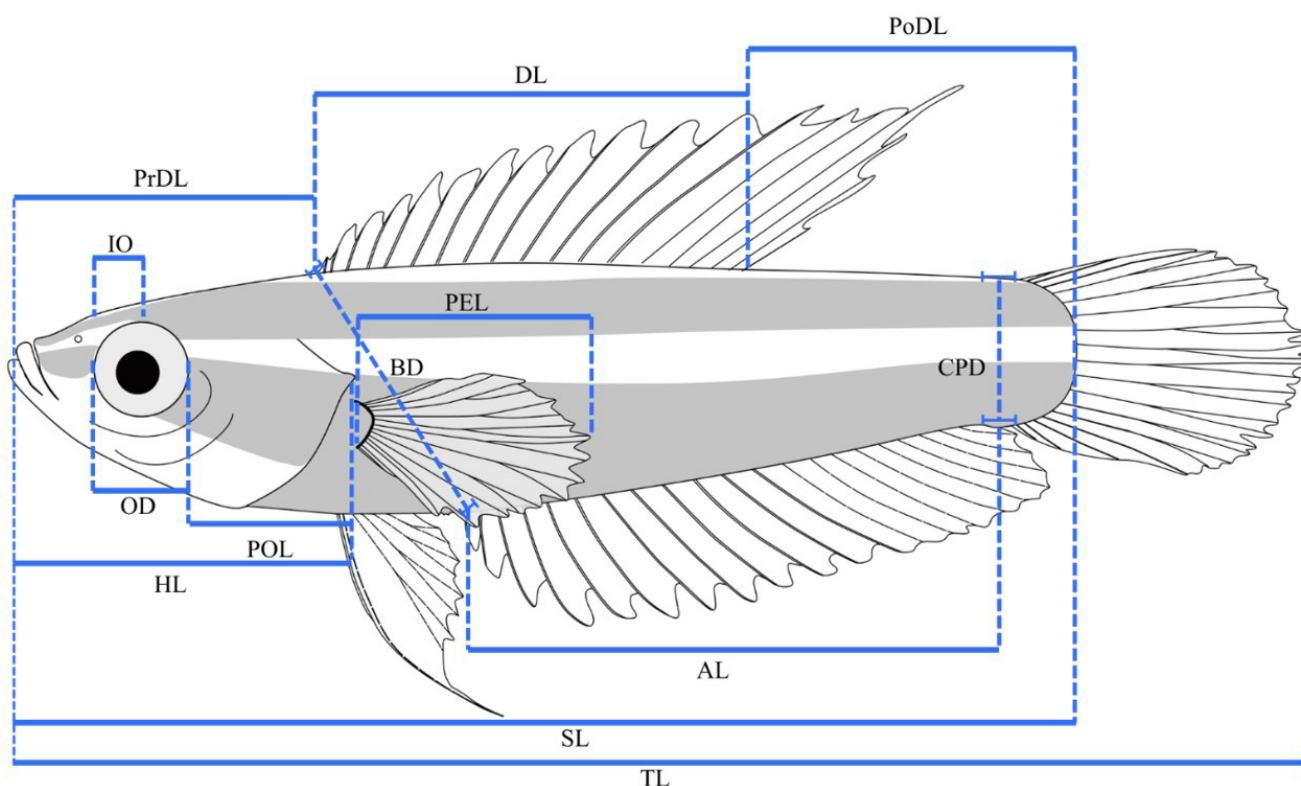


Figure 3. Illustration of morphometric measurements of *Parosphromenus ornaticauda*, Standard length (SL), total length (TL), predorsal length (PrDL), postdorsal length (PoDL), head length (HL), body depth (BD), pectoral-fin length (PEL), anal-fin base length (AL), dorsal-fin base length (DL), caudal peduncle depth (CPD), orbit diameter (OD), postorbital length (POL), and interorbital width (IO). The figure was drawn using the author's personal photo collection as a template with the help of the Inkscape application

were excluded. A multivariate analysis of variance (MANOVA) was used as a screening test for sexual dimorphism (Chan and Grismer 2021). We performed sex-specific analyses using nonparametric Mann–Whitney U tests to identify morphometric characters that differed significantly between sexes and sampling locations. Principal Component Analysis (PCA) to visualize clustering patterns across populations and sexes (Xiao and Yang 2024). We set statistical significance at $\alpha = 0.05$. We performed all analyses using R version 4.5.1 (R Core Team 2025).

3. Results

3.1. Environmental Parameters

In-situ environmental parameters measured at presence ($n = 7$) and absence ($n = 13$) sites. At present sites, water pH ranged from 2.8 to 5.4 (mean $\pm$ SD: 3.7 ± 0.60), with the lowest value recorded at the Ambawang River and the highest at the Mandor River. Dissolved oxygen ranged from 1.95 to 5.05 mg/L (mean $\pm$ SD: 3.6 ± 1.20), with the lowest value

recorded in the natural peat swamp of the Mempawah River and the highest in man-made canals of the Mempawah River. Water temperature ranged from 25 to 29.4°C (mean $\pm$ SD: 27.2 ± 1.30). Environmental parameters at presence and absence sites showed broadly similar ranges (Table 1).

3.2. Distribution of *Parosphromenus ornaticauda*

We surveyed a total of 20 locations: six within the IUCN distribution range and 14 outside (Figure 1). We recorded *P. ornaticauda* at seven locations, with two sites inside the IUCN distribution and five sites outside. Within the IUCN distribution, we found the species at two sites in the Mandor River: a peat swamp area (Figure 2D) and a man-made canal (Figure 2E). Outside the IUCN distribution, we newly recorded the species at one site in a peat swamp forest along the Mempawah River, two sites in man-made canals along the Tempayan River, and two sites in man-made canals along the Ambawang River. Only one presence location fell within protected forest areas (Figure 1).

3.3. Morphometric and Meristic Characteristics

3.3.1. General Morphology

Parosphromenus ornaticauda exhibits clear coloration differences between males and females. In life, males display a dark reddish hue along the body with bluish metallic reflections on the fins. Females exhibit paler coloration than males (Figure 4A and B). In preserved specimens, overall coloration becomes markedly faded in both sexes; however, males have reddish hue extending continuously along the body to the tip of the caudal fin compared to females, allowing sex differentiation to remain discernible, albeit less distinct than in live individuals (Figure 4C and D). A detailed set of morphometric measurement data is provided in Supplementary Table 1.

3.3.2. Morphometric Measurements and Meristic Counts

Separated by sex on morphometrics and meristics characters, males *Parosphromenus ornaticauda* had

a slightly larger body size than females based on standard length, ranging from 16.5 to 18.8 mm, with males (18.2–18.8 mm) slightly larger than females (16.5–17.0 mm) from both locations. Meristic counts showed similar ranges between the two rivers. Anal-fin rays ranged from VII–X spines and 10–13 soft rays across both locations. Dorsal-fin rays varied between X–XI spines and 5–7 soft rays. Caudal-fin rays ranged from 12 to 20 in Mempawah River specimens and 15 to 20 in Ambawang River specimens. Pectoral-fin rays remained consistent at 12–14 in both rivers, and lateral scale counts ranged from 28–30 (Table 2). A detailed set of meristic count data is provided in Supplementary Table 2.

3.3.3. Sexual Dimorphism

The MANOVA results showed that morphometric characters did not differ significantly between male and female *Parosphromenus ornaticauda* (Pillai's trace = 0.40, $Pr(>F) = 0.19$). The Mann-Whitney U test revealed that only anal-fin base length differed significantly

Table 1. Environmental parameters (mean $\pm$ SD and range) at presence and absence sites of *P. ornaticauda*

Parameter	Presence (n = 7)	Absence (n = 13)
Water pH	3.7 $\pm$ 0.60 (2.8–5.4)	3.7 $\pm$ 0.8 (2.4–5.2)
Dissolved Oxygen (DO) (mg/L)	3.6 $\pm$ 1.20 (1.95–5.05)	2.7 $\pm$ 1.1 (1.40–5.0)
Water Temperature (°C)	27.2 $\pm$ 1.30 (25–29.4)	28.1 $\pm$ 0.5 (27.2–28.8)
Electrical Conductivity (μ S/cm)	61.0 $\pm$ 22.67 (28–88)	50.8 $\pm$ 24.6 (12–94)
Total Dissolved Solids (TDS)	30.1 $\pm$ 10.87 (13–42)	24.3 $\pm$ 10.7 (6–39)
Water Depth (m)	0.9 $\pm$ 0.35 (0.34–1.7)	0.8 $\pm$ 0.5 (0.25–1.7)
Stream Width (m)	3.5 $\pm$ 3.39 (1–13)	4.4 $\pm$ 4.1 (1–14)
Water Clarity (%)	81.1 $\pm$ 23.42 (0.03–0.25)	80.8 $\pm$ 26.3 (0.03–0.2)

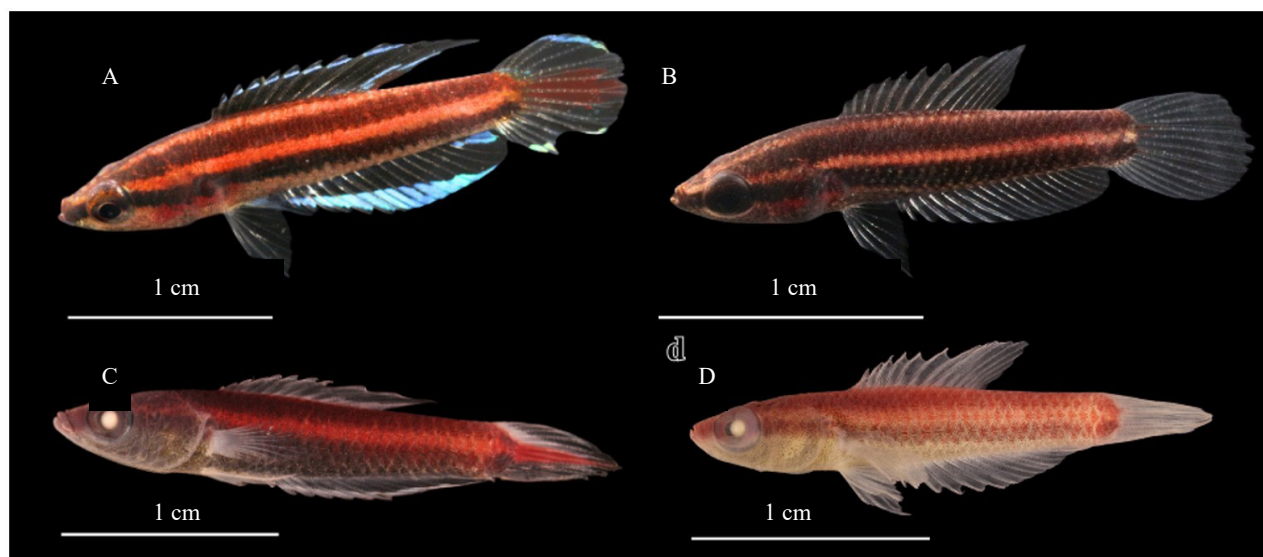


Figure 4. Adult *Parosphromenus ornaticauda* from West Kalimantan. Live specimens: (A) male, (B) female; preserved specimens: (C) male MZB.Fish 26759, (D) female MZB.Fish 26773

Table 2. Morphometric and meristic measurements of *Parosphromenus ornatinauda* from Mempawah and Ambawang River

Characters	Ambawang river (ind)				Mempawah river (ind)			
	Male (13)		Female (12)		Male (8)		Female (7)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Standard length (mm) (SL)	18.8 ±	1.3	17.0 ±	1.1	18.2 ±	1.1	16.5 ±	1.8
In % SL								
Total length	121.7 ±	11.7	126.7 ±	4.7	128.7 ±	2.9	127.5 ±	1.9
Predorsal length	38.5 ±	3.7	40.6 ±	2.0	38.7 ±	2.5	37.4 ±	0.6
Postdorsal length	26.1 ±	4.2	26.4 ±	2.4	26.5 ±	2.1	25.8 ±	1.7
Head length (HL)	31.9 ±	1.9	32.6 ±	2.3	32.1 ±	2.7	33.0 ±	1.6
Body depth	19.2 ±	2.0	21.3 ±	1.8	23.6 ±	1.3	22.6 ±	1.1
Pelvic-fin length	21.5 ±	4.0	20.4 ±	2.6	20.7 ±	2.8	19.2 ±	1.3
Anal-fin base length	42.2 ±	3.8	44.5 ±	5.0	42.0 ±	2.7	44.4 ±	0.7
Dorsal-fin base length	32.7 ±	4.0	35.2 ±	2.7	32.0 ±	1.6	33.2 ±	3.7
Caudal peduncle depth	13.2 ±	1.5	13.1 ±	0.9	13.4 ±	2.2	13.4 ±	0.6
In % HL								
Orbit diameter	39.4 ±	6.5	35.0 ±	3.1	33.5 ±	4.0	34.0 ±	3.1
Postorbital length	43.8 ±	5.6	45.2 ±	5.2	50.3 ±	4.1	43.4 ±	2.0
Interorbital distance	29.9 ±	5.1	30.8 ±	6.0	33.0 ±	3.7	27.9 ±	5.3
Meristic								
Anal-fin rays	VII. 11-13		VII. 11-12		VII-VIII. 10-12		VII. 10-13	
Dorsal-fin rays	X. 6-7		X. 5-7		VII-X. 5-7		IX-X. 5-6	
Caudal-fin rays	12-20 (11)		13-18 (11)		15-20		17-18	
Pelvic-fin rays	I.1.4		I.1.4		I.1.4		I.1.4	
Pectoral-fin rays	12-14		13-14		12-14		13-14 (2)	
Lateral scales	28-29		28-30		28-29		28-30	

ind: individuals, SD: standard deviations

between sexes ($p = 0.029$; Figure 5A). Females had longer anal-fin bases (mean: 44.4–44.5% SL) than males (mean: 42.0–42.2% SL) at both locations.

3.3.4. Population Variation

The Mann-Whitney U test identified significant morphometric differences between the two populations. Among females, predorsal length ($p < 0.001$) and body depth ($p = 0.045$) differed significantly between locations (Figure 5B and C). Females from Mempawah had longer predorsal length than those from Ambawang, whereas females from Ambawang had deeper bodies.

Among males, we detected significant differences between locations in four characters (Figure 5D-G): total length ($p = 0.003$), body depth ($p < 0.001$), orbit diameter ($p = 0.030$), and postorbital length ($p = 0.013$). Males from Mempawah were shorter in total length but deeper in body depth compared to those from Ambawang. Additionally, Mempawah males had larger orbit diameters but shorter postorbital lengths than Ambawang males.

3.3.5. Principal Component Analysis

Morphometric variation of *Parosphromenus ornatinauda* is illustrated using the PCA scatter plots between the Ambawang River (red) and Mempawah River (blue) populations, separated by sex. In females

(Figure 6A), PC1 accounted for 25.4% and PC2 for 16.1% of the total variance. In males (Figure 6B), PC1 and PC2 accounted for 24.1% and 16.8% of the total variance, respectively. Overall, each sex from the two rivers showed partial overlap in morphometrics, indicating generally similar morphometric characteristics. Both females and males showed partially overlapping distributions. Mempawah females, with a small cluster, and Ambawang females displayed a wider spread along both PC1 and PC2 (Figure 6A and B). The overlap between populations within each sex indicates that the two populations are not morphologically distinct, despite significant differences in individual characters.

4. Discussion

Our findings revealed that *Parosphromenus ornatinauda* has a broader distribution than previously documented, with five new occurrence records outside the IUCN distribution range. We also detected significant morphometric variation both between sexes (sexual dimorphism in anal-fin base length) and between populations from different habitat types (lentic peat swamp vs. lotic man-made canals). These results have important implications for the conservation of this critically endangered species.

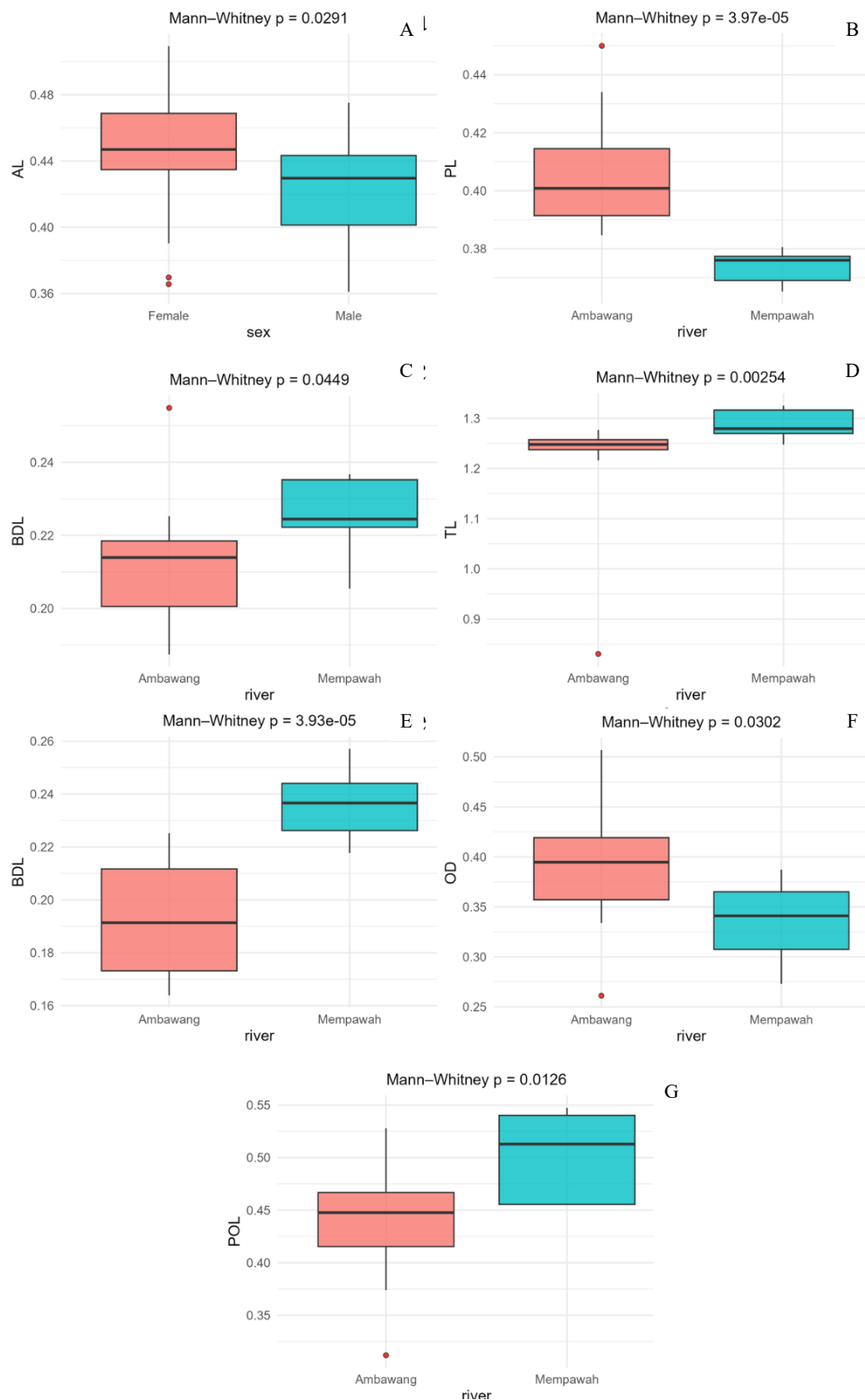


Figure 5. Boxplots showing significant morphometric differences in *P. ornaticauda*. Between sexes: (A) anal-fin base length, between locations: (B) predorsal length in females, (C) body depth in females, (D) total length in males, (E) body depth in males, (F) orbit diameter in males, (G) postorbital length in males

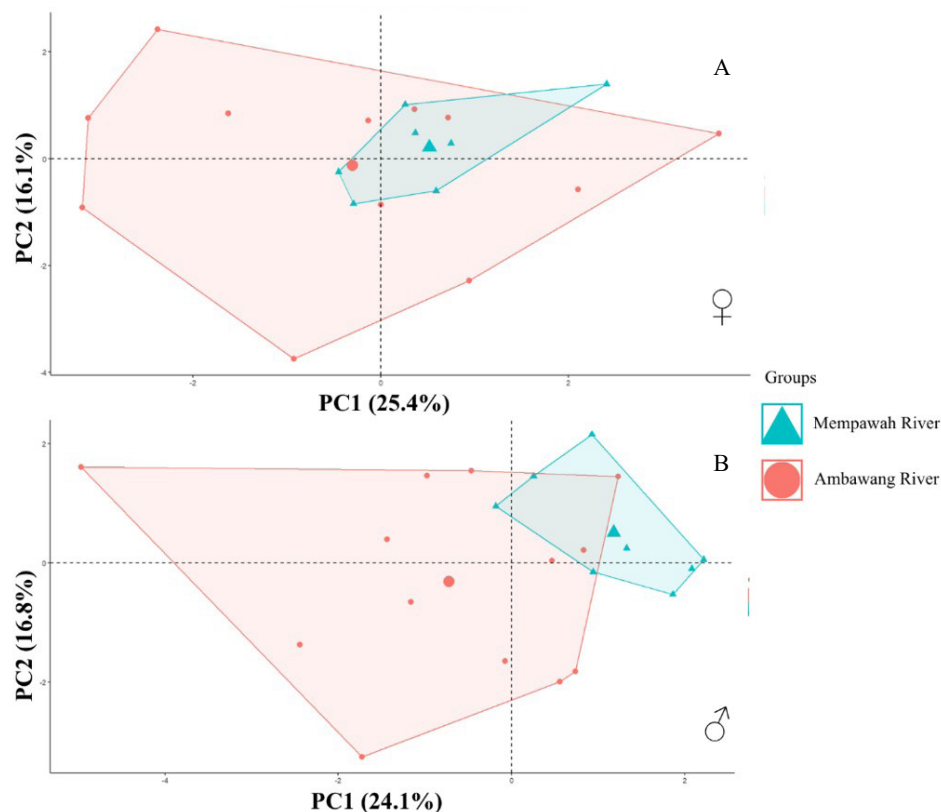


Figure 6. Principal component analysis (PCA) scatter plot showing morphometric variation of *Parosphromenus ornaticauda* from Ambawang River (red) and Mempawah River (blue). (A) females (♀), (B) males (♂)

4.1. Extended Distribution Range

Thirty-four years after its original description, *Parosphromenus ornaticauda* was previously known only from its type locality at Sungai Kepayang (Roberts 1989; Kottelat 1991). Our survey documented the species at seven locations across four river systems: Mempawah River, Mandor River, Tempayan River, and Ambawang River. Although we did not find individuals of the type locality during our survey, we recorded *P. ornaticauda* in a peat swamp forest of the Mandor River, which lies within the same river system and basin. We suggest that these populations belong to the same metapopulation, as observed for *Oryzias asinua* in Southeast Sulawesi (Yamahira *et al.* 2016). Based on our observations during the survey, we identified possible reasons why *P. ornaticauda* was not found at this type locality: the presence of oil palm plantations and the possibility that the population has shifted upstream toward areas closer to the nature reserve around the Mandor River.

Significantly, five of the seven presence locations fell outside the previously recognized IUCN distribution range, indicating that the species' actual range is broader than currently understood. This finding highlights the need for

further surveys in surrounding peat swamp areas to fully delineate the species' distribution. Additionally, at one site in the Ambawang River, we recorded another congeneric species, *P. anjunganensis*, occurring sympatrically with *P. ornaticauda*. These are the same conditions as those at the type locality, but in this study, we cannot find both. The co-occurrence of these two species warrants further investigation into their ecological interactions and potential niche partitioning.

4.2. Morphometric Variation Between Populations

We detected significant morphometric differences between the Mempawah (lentic peat swamp) and Ambawang (lotic man-made canal) populations in five characters. Both males and females from Mempawah had deeper bodies compared to those from Ambawang. Males from Mempawah had shorter total length, larger orbit diameter, and shorter postorbital length than males from Ambawang. Females from Mempawah had longer predorsal length than those from Ambawang (Table 2, Figure 5B-G). In the two populations examined, morphometric differences may reflect phenotypic plasticity

associated with different hydrological conditions; however, additional populations from similar lentic and lotic environments are needed to clarify and confirm this interpretation. Fish in lentic (still-water) habitats typically develop deeper bodies, while those in lotic (flowing-water) habitats tend to have more streamlined bodies to reduce drag during swimming (Langerhans 2008; Acar and Kaymar 2023). Our findings are consistent with this pattern: *P. ornaticauda* from the lentic peat swamp habitat (Mempawah) exhibited deeper bodies, whereas individuals from the lotic canal habitat (Ambawang) showed slimmer body shapes. The larger orbit diameter observed in Mempawah males may be an adaptation to the dense vegetation. Similar patterns have been reported in other freshwater fishes (Gunawickrama 2008).

Despite significant differences in individual characters, the PCA results showed substantial overlap between the two populations, with a low percentage of variance accounted for. These results indicate that they are not morphologically distinct, but an intraspecific variation in population that also has a low percentage (Macossay-Cortez *et al.* 2022)

4.3. Sexual Dimorphism

We detected significant sexual dimorphism in anal-fin base length, with females having longer anal-fin bases than males. In most fish species, males possess larger anal fins than females (Iguchi *et al.* 1991; Sumarto *et al.* 2020; Mainero *et al.* 2023; Davis *et al.* 2025). In contrast, our study found that males have shorter anal-fin bases than females. A minority of fish species exhibit reversed or atypical dimorphic patterns (Davis *et al.* 2025) consistent with our findings. Notably, anal-fin base length did not differ between habitat types, suggesting that this character is influenced primarily by sex rather than environmental conditions (Welsh and Fuller 2015).

4.4. Habitat Characteristics and Threats

Parosphromenus ornaticauda occurred in waters with pH ranging from 2.8 to 5.4, confirming tolerance to highly acidic conditions typical of *Parosphromenus* species (Morris *et al.* 2021; Goodwin and Zimmerman 2024). We found the species in peat swamp forests and man-made canals with muddy substrates, leaf litter, and aquatic vegetation. The species was absent from canals that are intensively used for transporting oil palm fruit, which are subject to periodic vegetation clearance. Swamp

fish rely on aquatic vegetation for spawning and rearing fry (Ismail *et al.* 2018; Dharmono *et al.* 2022).

The peat swamp habitat in the Mempawah River dries out entirely during the dry season, leaving only small, isolated pools where *P. ornaticauda* persists. This suggests a drought-survival strategy similar to that reported for *Betta dimidiata* in West Kalimantan and *B. iaspis* in Sumatra (Kottelat and Widjanarti 2005; Ding *et al.* 2025)

4.5. Conservation Implications

Our findings indicate that the IUCN distribution data for *Parosphromenus ornaticauda* requires updating. However, only one presence location fell within a protected area, suggesting that most populations occur in unprotected habitats. This indicates that protected areas are likely important for the persistence of the species (Purnama and Masunaga 2025). Conservation strategies should protect habitat diversity across the species range, including both lentic peat swamps and lotic canals. Buffer zones and sustainable land-use practices are needed in peat swamp areas, and dry-season refugia must be protected from drainage and conversion. The co-occurrence of multiple threatened *Parosphromenus* species further emphasizes the conservation value of West Kalimantan's peat swamp ecosystems. Further behavioral and molecular analyses of *P. ornaticauda* are needed to clarify the species under the phylogenetic species concept, elucidate its evolution, and examine interpopulation dynamics in relation to environmental factors.

In conclusion, this study documented seven locations of *P. ornaticauda* in West Kalimantan, including five new records outside the IUCN distribution range. The broader distribution and occurrence in fragmented, largely unprotected habitats underscore the urgent need for conservation action to protect this critically endangered species and its peat-swamp ecosystem.

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Supplementary Materials

Supplementary Table 1. Morphometric measurements in mm of *Parosphromenus ornatinauda* from Mempawah and Ambawang River

Location	Sex	SL	TL	PrDL	PoDL	HL	BD	PEL	AL	DL	CPD	OD	POL	IO
Ambawang	Male	19.25	23.41	7.30	4.04	6.56	3.23	3.16	6.95	7.06	2.95	2.36	2.94	2.53
Ambawang	Male	19.83	24.68	7.18	5.59	6.07	3.74	3.28	8.97	6.60	2.42	2.44	2.27	2.07
Ambawang	Male	19.32	24.23	7.02	6.21	5.93	4.09	4.98	6.99	7.25	2.65	2.09	3.13	1.84
Ambawang	Male	17.36	21.80	6.68	5.45	5.44	3.72	4.57	8.25	5.32	2.73	2.28	2.76	1.43
Ambawang	Male	19.11	24.16	7.55	5.58	6.70	4.07	3.91	7.67	7.34	2.14	1.75	2.69	1.61
Ambawang	Male	16.46	20.11	6.00	4.62	5.27	3.15	2.54	6.21	5.38	2.01	2.08	2.46	1.62
Ambawang	Male	18.22	23.18	7.85	4.24	6.05	3.72	4.54	7.89	6.29	2.75	2.02	2.54	1.46
Ambawang	Male	18.96	23.56	7.04	5.55	6.02	4.27	4.28	8.87	5.64	2.33	2.15	2.79	2.20
Ambawang	Male	19.46	24.85	7.18	3.37	6.23	3.37	4.49	8.51	7.19	2.66	2.64	2.74	1.92
Ambawang	Male	18.70	23.51	7.75	4.60	6.25	3.60	5.20	8.06	5.07	2.38	2.62	2.94	2.18
Ambawang	Male	17.02	21.06	6.54	4.00	5.48	3.20	3.37	7.15	5.58	2.19	2.72	1.71	1.47
Ambawang	Male	19.21	23.97	9.07	5.11	5.92	3.19	3.93	8.69	5.50	2.50	3.00	2.65	1.38
Ambawang	Male	21.17	17.58	6.76	5.19	5.85	3.47	4.23	8.68	5.54	2.34	2.29	2.43	1.57
Ambawang	Female	18.42	22.30	7.28	4.85	5.57	3.99	3.88	8.79	7.12	2.74	2.13	2.95	2.04
Ambawang	Female	18.59	22.86	7.19	4.25	5.80	3.98	3.82	8.57	6.41	2.38	1.77	2.77	1.45
Ambawang	Female	17.87	23.29	7.18	5.49	5.30	3.49	4.03	8.94	6.26	2.32	1.83	2.57	2.17
Ambawang	Female	16.87	21.36	6.63	4.98	5.40	3.80	3.27	7.43	6.34	2.09	1.66	1.97	1.77
Ambawang	Female	17.73	21.48	7.09	5.04	5.67	3.79	3.77	8.74	5.42	2.50	2.11	2.43	1.50
Ambawang	Female	15.89	20.89	6.48	4.07	5.82	4.05	3.12	5.81	6.01	2.04	1.76	2.67	1.35
Ambawang	Female	16.63	21.40	6.86	4.39	5.55	3.43	3.38	8.47	5.50	2.02	2.14	2.23	1.43
Ambawang	Female	15.78	20.05	6.07	4.47	5.24	3.11	4.17	7.52	5.96	2.20	1.88	2.19	1.85
Ambawang	Female	15.58	19.07	7.01	3.69	5.14	3.38	2.82	5.76	4.85	2.04	1.96	2.14	1.74
Ambawang	Female	16.45	22.34	7.14	4.21	5.40	3.67	3.03	6.42	6.01	1.99	1.98	2.26	1.57
Ambawang	Female	17.85	21.88	6.87	4.37	5.33	3.60	2.83	7.33	6.05	2.15	1.92	2.83	1.97
Ambawang	Female	16.22	21.10	6.82	4.12	5.97	3.04	3.40	7.25	5.80	2.18	1.97	2.94	1.42
Mempawah	Male	20.04	26.36	5.41	1.77	2.93	7.55	6.67	5.23	4.68	3.63	8.03	2.72	1.99
Mempawah	Male	18.36	24.33	6.48	2.02	2.95	7.01	5.92	5.21	4.72	4.01	8.14	2.43	2.31
Mempawah	Male	18.21	22.91	5.93	1.62	3.20	7.30	5.61	5.11	4.06	3.95	7.32	3.36	1.59
Mempawah	Male	17.91	23.63	5.87	2.18	3.06	7.37	6.17	4.37	4.37	4.49	7.89	2.32	2.06
Mempawah	Male	17.25	22.02	5.73	1.69	2.89	7.29	5.08	4.92	3.92	3.07	7.73	1.98	2.09
Mempawah	Male	18.88	24.21	5.50	2.13	3.01	6.99	5.84	4.92	4.11	4.30	6.97	2.37	1.85
Mempawah	Male	18.69	23.32	6.17	2.19	2.81	6.44	6.05	4.26	4.48	3.21	8.03	2.25	1.82
Mempawah	Male	16.30	20.76	5.51	2.00	2.51	6.26	5.27	4.49	3.98	3.45	6.98	2.09	1.66
Mempawah	Female	15.96	20.47	5.15	1.92	2.35	5.83	5.34	4.03	3.75	3.12	6.98	2.27	1.82
Mempawah	Female	17.32	21.97	5.57	1.76	2.28	6.53	5.09	4.61	4.10	3.66	7.85	2.37	1.67
Mempawah	Female	18.84	23.54	6.00	2.26	2.68	7.00	6.00	5.07	3.87	3.42	8.31	2.35	1.60
Mempawah	Female	18.74	23.77	5.87	1.72	2.60	6.87	6.61	4.66	4.20	3.30	8.34	2.43	1.78
Mempawah	Female	14.48	18.95	5.20	1.71	2.11	5.47	4.12	3.84	3.25	2.61	6.26	2.00	0.96
Mempawah	Female	15.16	19.50	5.13	1.85	2.20	5.77	5.94	3.44	3.34	3.08	6.80	2.07	1.27
Mempawah	Female	15.29	19.32	5.16	1.73	2.31	5.75	5.32	4.25	3.60	2.98	6.84	2.00	1.53

Standard length (SL), total length (TL), predorsal length (PL), postdorsal length (PDL), head length (HL), body depth length (BDL), pectoral-fin length (PEL), anal-fin base length (AL), dorsal-fin base length (DL), caudal peduncle depth (CPD), orbit diameter (OD), postorbital length (POL), and interorbital width (IO)

Supplementary Table 2. Meristic counts of *Parosphenomenus ornatICAUDA* from Mempawah and the Ambawang River

Location	Sex	Anal fin (spine)	Anal fin (soft)	Dorsal fin (spine)	Dorsal fin (soft)	Caudal fin simple (upper)	Caudal fin branched	Caudal fin simple (bottom)	Pelvic fin (Spine + simple)	Pelvic fin branched	Pectoral fin rays	Lateral scales until operculum
Ambawang	Male	VII	12	X	7	4	12	4	2	4	12	29
Ambawang	Male	VII	11	X	6	4	12	4	2	4	12	29
Ambawang	Male	VII	11	X	6	-	-	-	2	4	14	29
Ambawang	Male	VII	11	X	7	3	11	2	2	4	14	29
Ambawang	Male	VII	13	X	6	2	11	3	2	4	14	30
Ambawang	Male	VII	12	X	6	2	12	2	2	3	14	30
Ambawang	Male	VII	12	X	6	2	-	-	2	4	14	29
Ambawang	Male	VII	13	X	6	3	10	2	2	4	14	29
Ambawang	Male	VII	13	X	6	3	10	1	2	4	13	29
Ambawang	Male	VII	11	X	6	-	-	-	2	4	14	28
Ambawang	Male	VII	12	X	6	3	9	2	2	4	13	30
Ambawang	Male	VII	11	X	6	3	9	-	2	4	13	29
Ambawang	Male	VII	12	X	6	3	12	2	2	4	14	28
Ambawang	Female	VII	12	X	6	5	4	4	2	4	14	30
Ambawang	Female	VII	11	X	6	2	11	3	2	4	13	30
Ambawang	Female	VII	11	X	6	-	-	-	2	4	13	30
Ambawang	Female	VII	12	X	6	4	10	4	2	4	14	29
Ambawang	Female	VII	11	X	6	3	11	1	2	4	13	30
Ambawang	Female	VII	11	X	6	4	11	3	2	4	14	29
Ambawang	Female	VII	11	X	5	3	10	2	2	4	14	30
Ambawang	Female	VII	11	X	5	4	7	4	2	4	13	29
Ambawang	Female	VII	11	X	7	4	9	3	2	4	13	29
Ambawang	Female	VIII	12	IX	7	3	10	3	16	4	13	28
Mempawah	Male	VII	11	VII	5	3	11	4	18	4	11	29
Mempawah	Male	VIII	10	X	6	2	10	4	16	4	13	29
Mempawah	Male	VII	12	X	6	3	10	4	17	4	13	28
Mempawah	Male	VIII	12	IX	6	3	9	3	15	4	12	29
Mempawah	Male	VI	12	X	6	2	9	4	15	4	12	28
Mempawah	Male	VII	11	X	7	3	11	3	17	4	13	29
Mempawah	Male	VI	10	X	6	4	12	4	20	4	13	29
Mempawah	Female	VII	11	X	5	3	11	4	18	4	14	28
Mempawah	Female	VII	11	IX	6	3	12	3	18	4	13	30
Mempawah	Female	VII	11	X	6	3	10	4	17	4	-	30
Mempawah	Female	VII	11	X	6	3	11	4	18	4	13	29
Mempawah	Female	VII	13	X	6	3	11	4	18	4	-	30
Mempawah	Female	VII	10	IX	6	3	11	3	17	4	-	28
Mempawah	Female	VII	12	IX	6	3	11	3	17	4	-	30