

Reproductive biology and gonadal maturity of *Channa striata* (Bloch, 1793) in three types of swamp waters in South Kalimantan: implications for domestication

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Abstract. The population of striped snakehead, *Channa striata* (Bloch, 1793), in nature is greatly declining, so efforts are needed for domestication. The reproductive biology of fish plays a significant role in fish domestication. The purpose of this study was to determine the morphology of the gonadosomatic index (GSI) and gonado maturity level (GML) of snakehead fish in three types of swamp waters. Data were analyzed using descriptive methods and one-way ANOVA followed by Tukey's Honestly Significant Difference (HSD) post hoc test to determine significant differences across maturity stages and habitats. The study was conducted from May to September 2025. The fishing locations were in swamp waters in Danau Bangkai, Tanah Laut, and Batola, South Kalimantan. Fifty fish samples were taken, with almost the same weight and length, every 15 days at five stations. The study found peak GSI in monotonous swamps ($5.07 \pm 0.07\%$) in September, indicating optimal spawning conditions. Maximum GSI values and peak period. The identification of monotonous swamps as the habitat supporting the highest reproductive investment and September as the peak spawning period offers clear guidance for broodstock sourcing and breeding schedules. Selecting broodstock during peak maturity and from habitats with naturally elevated GSI values may enhance spawning success, egg quality, and seed production efficiency in hatchery systems. These findings support habitat-informed broodstock management and reproductive synchronization strategies, thereby strengthening the scientific basis for sustainable domestication and large-scale aquaculture development of snakehead fish.

Keywords: Batola, Danau Bangkai, gonadosomatic index, habitat, Tanah Laut.

Introduction. The striped snakehead, *Channa striata* (Bloch, 1793), is an economically important freshwater fish species in several developing countries, including Vietnam, Malaysia, Bangladesh, and Indonesia (Arma et al., 2022). South Kalimantan comprises three types of swamp ecosystems: monotonous swamps, tidal swamps, and rain-fed swamps. Gustiano et al. (2015) reported that *C. striata* is one of the potential local fish species inhabiting swamp waters, including those in South Kalimantan. Gustiano & Sugama (2005) reported a diverse composition of freshwater fish species, including jambal catfish, mouse catfish, jelawat, betutu, belida, baung, tambakan, betok, gourami, semah, tawes, lampan, arowana, kalabau, nilam, catfish, bilih, snakehead, tengadak, botia, and rainbow fish.

With increasing demand for fish, fishing activities targeting *C. striata* in natural habitats have also increased. This trend has contributed to a decline in wild snakehead fish populations. In recent years, reductions in capture fisheries have increased the need to enhance striped murrel aquaculture production (Puspaningdiah et al., 2014; Kumar et al., 2022). Currently, the culture production of striped murrel remains limited and primarily depends on natural breeding populations for seed supply (Kumar et al., 2022). Moreover, fish captured from natural habitats often possess mature gonads. Therefore, efforts are needed to develop *C. striata* cultivation strategies (Muslim, 2007).

The decline in snakehead fish production is also associated with river mouth siltation, the introduction of pollutants into public waters, and fishing pressure that has

reached maximum levels along swamp and river systems (Parvez et al., 2025). However, these challenges have not been accompanied by sufficient domestication efforts, namely the adaptation of wild fish to controlled conditions for cultivation and reproduction. Research on fish reproductive biology plays an important role in domestication programs because it provides essential information for cultivating wild fish outside their natural habitats. With the remarkable growth of aquaculture, the need for system diversification and species diversification has increased among producers to achieve profitable production. *C. striata* has been identified as a suitable candidate for modern aquaculture systems due to its rapid growth rate, air-breathing ability, high market value, and consumer acceptance (Kumar et al., 2022; Damle et al., 2024).

Understanding fish reproductive biology is fundamental for sustainable aquaculture development because reproductive performance directly determines seed availability, stock continuity, and production stability. The reproductive cycle of *C. striata* is essential information for developing management strategies for natural fish populations (Boonkusol et al., 2020). Knowledge of gonadal maturation cycles, spawning seasons, fecundity, and environmental influences enables effective broodstock selection, optimal timing of induced spawning, and improved hatchery management efficiency. Previous studies have demonstrated that reproductive performance, including egg quality, fertilization rate, and larval survival, is closely related to broodstock physiological condition and environmental factors (Izquierdo et al., 2001; Migaud et al., 2013; Damle et al., 2023).

The first maturation of female *C. striata* occurs at a body length of 27.75 cm (Selviana et al., 2020). Saputra (2017) reported that *C. striata* is a potential local fish species; however, its production in Indonesia still relies mainly on capture fisheries. This situation has contributed to the decline of wild populations. Domestication represents one potential solution to this problem; therefore, information regarding reproductive biology is essential to support breeding programs. Research conducted in Parung and Babelan, Indonesia, showed that the gonadosomatic index (GSI) ranged from 0.67 to 9.94% and from 2.03 to 8.17%, respectively. The gonad index ranged from 6.17-76.73 and 18.48-76.77, respectively.

Furthermore, integrating reproductive biology into aquaculture systems can enhance year-round seed production, reduce dependence on wild stocks, and support genetic improvement programs (Zohar & Mylonas, 2001; Duong et al., 2019; Food and Agriculture Organization of the United Nations, 2020; Mndeme et al., 2020). Spawning activity has also been reported during the monsoon season, which represents the main breeding period (Damle et al., 2024). Therefore, reproductive biology research provides the scientific basis for improving productivity, economic feasibility, and long-term sustainability in fish farming.

The present study aimed to determine whether, GSI and gonad maturity level (GML) of *C. striata* differ among swamp habitats

Materials and Method

Study area. The study was conducted from May to September 2025, covering the period of gonadal development and maturation of *C. striata* in swamp habitats. Three swamp habitat types were investigated: monotonous swamps (Danau Bangkai; Location I), tidal swamps (Barito Kuala; Location II), and rainfed swamps (Tanah Laut; Location III) in South Kalimantan, Indonesia (Figure 1).

The fishing grounds included three types of swampy waters: monotonous swampy waters (Danau Bangkai) (location I), tidal marshes (Barito Kuala) (location II), and rainfed swamps (Tanah Laut) (location III) in the South Kalimantan region (Figure 1). Analysis of sample fish parameters was carried out in the field, as well as in the Basic Laboratory, Water Quality and Hydro Bioecology Laboratory, Faculty of Fisheries, Marine Science, Lambung Mangkurat University. South Kalimantan, Indonesia.

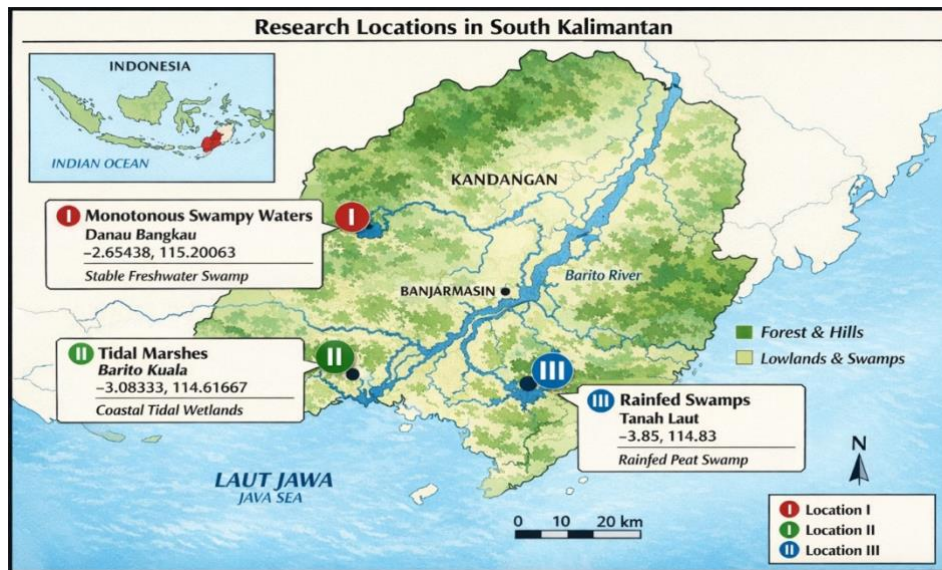


Figure 1. The research locations.

Fish sampling. Approximately 50 individual females were collected from each habitat during each sampling period. Fish with standard lengths of 25-28 cm and body weights of 300-500 g were selected for analysis. Because that is the size frequently caught by fishermen. Fish were sampled biweekly (every 15 days) from May to September 2025. Fish sampling in each type of swamp waters was carried out at 5 (five) stations then put in containers or iceboxes to be taken to the laboratory.

Determination of gonadal maturity level (GML). Gonadal maturity level (GML) was determined through macroscopic examination according to Effendie's (2002) criteria. The assessment was based on gonad size, color, vascularization, elasticity, and visibility of oocytes.

Gonadosomatic index (GSI) calculation. It was performed using the formula:

$$GSI = \frac{Gw (g)}{Bw (g)} \times 100\%$$

Where:

GSI - gonadosomatic index

Gw - gonad weight

Bw - body weight

After dissection, gonads were carefully removed, cleaned from surrounding tissues, and weighed to the nearest 0.01 g using a digital balance. Gonadal maturity was determined immediately after dissection, prior to preservation. Gonads were subsequently fixed in 10% formalin for further examination.

Statistical analysis. The research methods used are survey, observation, descriptive methods, and ANOVA. The data obtained is expressed in the form of presentations, tabulations, and graphs. Prior to the One-way ANOVA, the data were subjected to normality and homogeneity tests. Shapiro-Wilk test was employed to evaluate the normality of the GSI distribution, while Levene's test was used to assess the homogeneity of variances.

Statistical analysis was performed only for mature individuals classified as GML V because sample sizes for GML II-IV were insufficient for reliable statistical comparisons. Differences in GSI among habitats were analyzed using one-way ANOVA followed by Tukey's HSD test.

Caution: Tukey must be true. Data were presented as tables and figures.

Results

Monotonous marsh waters. Gonadal development of *C. striata* in monotonous swamp waters was monitored from late May to the end of September 2025. No significant gonadal development was observed from late May to mid-July. Gonads began developing at the end of July, with GSI increasing steadily and reaching peak values by late September (Table 1). Statistical comparisons were performed only for GSI values, whereas changes in GML distribution were evaluated descriptively based on monthly frequencies.

Table 1

Gonadosomatic index and gonadal maturity stages of *Channa striata* from monotonous swamp waters during the reproductive season

Period	Average gonadosomatic index (%)	Gonado maturity level	Specimens (N)
End of July	0.260±0.011	Final II (immature)	15
	0.000	Not developed	35
Middle August	0.765±0.032	Early III (Immature)	10
	1.610±0.060	Early IV (immature)	5
	0.000	Not developed	35
End of August	0.270±0.022	Final II (immature)	5
	0.587±0.034	Early III (Immature)	10
	1.916±0.054	Early IV (immature)	12
	0.000	Not developed	23
Middle September	0.266±0.006	Final II (immature)	8
	0.540±0.022	Early III (Immature)	23
	1.970±0.025	III late early IV (immature)	14
	1.789±0.013	Final IV (Almost ripe)	2
	5.076±0.076	V (Mature)	3
End of September	0.262±0.009	Final II (immature)	15
	0.530±0.115	Early III (Immature)	30
	1.893±0.099	III late early IV (immature)	2
	2.703±0.018	Final IV (Almost ripe)	2
	4.891±0.178	V (mature)	1

Note: GSI - gonadosomatic index; increased significantly from July to September (ANOVA, $p < 0.001$).

GSI values differed significantly among sampling periods (ANOVA, $p < 0.001$). The proportion of vitellogenic oocytes increased significantly from August to September, indicating progressive ovarian maturation. Gonadal development remained slow during July and August, when most females were classified as GML II-III. In contrast, GML V individuals first appeared in mid-September, coinciding with the highest recorded GSI ($5.08 \pm 0.08\%$), which reflects the peak reproductive investment in this habitat (Figure 1).

Tidal marsh waters. GSI values differed significantly among sampling periods (ANOVA, $p < 0.001$). Gonadal development of *C. striata* in tidal marsh waters was monitored from late May to the end of September. No significant gonadal development was observed from the end of May to the end of June. Gonads began developing at middle of July, with GSI increasing steadily and reaching peak values by late September (Table 2). Statistical comparisons were performed only for GSI values, whereas changes in GML distribution were evaluated descriptively based on monthly frequencies.

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Table 2

Gonadosomatic index and gonadal maturity stages of *Channa striata* from tidal swamp waters during the reproductive season

Period	Average gonadosomatic index (%)	Gonado maturity level	Specimen (N)
Middle July	0.066±0.011	Final II (immature)	22
	0.000	Not developed	28
End of July	0.266±0.003	Final II (immature)	9
	1.629±0.022	Early III (immature)	7
	1.278±0.001	Final III (not yet mature)	4
	1.139±0.085	Early IV (immature)	13
Middle August	3.169±0.075	Initial V (mature)	17
	0.367±0.032	Final II (immature)	5
	1.577±0.040	Early III (immature)	5
	1.325±0.006	Final III (not yet mature)	5
	1.150±0.054	Early IV (immature)	20
	3.172±0.211	Initial V (mature)	15
End of August	0.437±0.007	Final II (immature)	3
	1.341±0.018	Early III (immature)	2
	1.448±0.055	Final III (not yet mature)	9
	1.398±0.081	Early IV (almost ripe)	20
	3.212±0.170	Initial V (mature)	16
Middle September	0.308±0.098	Final II (immature)	2
	1.680±0.013	Early III (immature)	8
	1.673±0.156	Early IV (immature)	20
	4.143±0.065	Initial V (mature)	20
End of September	0.295±0.011	Final II (immature)	1
	1.584±0.008	Final III (immature)	2
	1.873±0.152	Early IV (immature)	20
	3.182±0.089	Initial V (mature)	27

Note: GSI - gonadosomatic index; increased significantly from July to September (ANOVA, $p < 0.001$).

The proportion of vitellogenic oocytes increased significantly from late July to September (ANOVA, $p < 0.001$), indicating progressive ovarian maturation. During late May and June, *C. striata* gonads remained immature. Mean GSI increased from 0.066±0.011% in mid-July to 0.295±0.011% (GML II) and 3.182±0.089% (GML V) by late September (Figure 1), confirming a significant seasonal increase in reproductive development.

Rainfall swamp waters. GSI values differed significantly among sampling periods (ANOVA, $p < 0.001$). Gonadal development of *C. striata* in rainfall swamp waters was monitored from late May to the end of September. No significant gonadal development was observed from the end of May to the end of July. Gonads began developing at middle August, with GSI increasing steadily and reaching peak values by late September (Table 3). Statistical comparisons were performed only for GSI values, whereas changes in GML distribution were evaluated descriptively based on monthly frequencies.

The proportion of vitellogenic oocytes increased significantly from late August to September (ANOVA, $p < 0.001$), indicating progressive ovarian maturation. In rainfed swamps, *C. striata* gonads remained immature from late May to July. Mean GSI increased from 0.211±0.007% in mid-August to 0.267±0.006% (GML II) and 3.465±0.242% (GML V) by late September (Figure 1), confirming significant seasonal reproductive development.

The reproductive cycle in rainfed swamps was closely associated with the onset of seasonal rainfall. Mature females (GML IV-V) increased markedly in late August, reaching 46% of the population (Figure 2). However, the proportion of mature individuals fluctuated thereafter, suggesting that gonadal development was less stable than in tidal marshes.

Table 3

Gonadosomatic index and gonadal maturity stages of *Channa striata* from Rainfell Swamp waters during the reproductive season

Period	Average gonadosomatic index (%)	Gonado maturity level	Specimen (N)
Middle August	0.000	Not developed	39
	0.211±0.007	III	11
End of August	0.266±0.006	Final III (immature)	27
	1.490±0.559	Early IV (immature)	20
	2.944±0.091	Initial V (mature)	3
Middle September	0.543±0.049	Early II (immature)	19
	1.570±0.025	Final II	11
	1.590±0.013	Early IV (almost ripe)	20
End of September	0.267±0.006	Final II (immature)	5
	0.540±0.022	Early III (immature)	30
	1.020±0.096	III late early IV (immature)	5
	3.465±0.242	Initial V (mature)	10

Note: GSI - gonadosomatic index; increased significantly from August to September (ANOVA, $p < 0.001$).

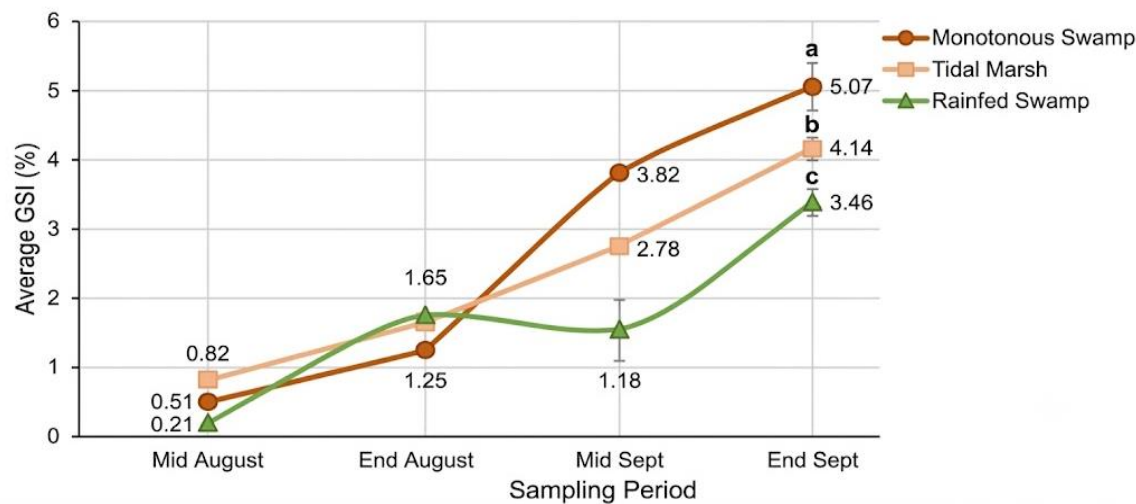


Figure 1. Monthly variation of gonadosomatic index of *Channa striata* across different swamp habitats.

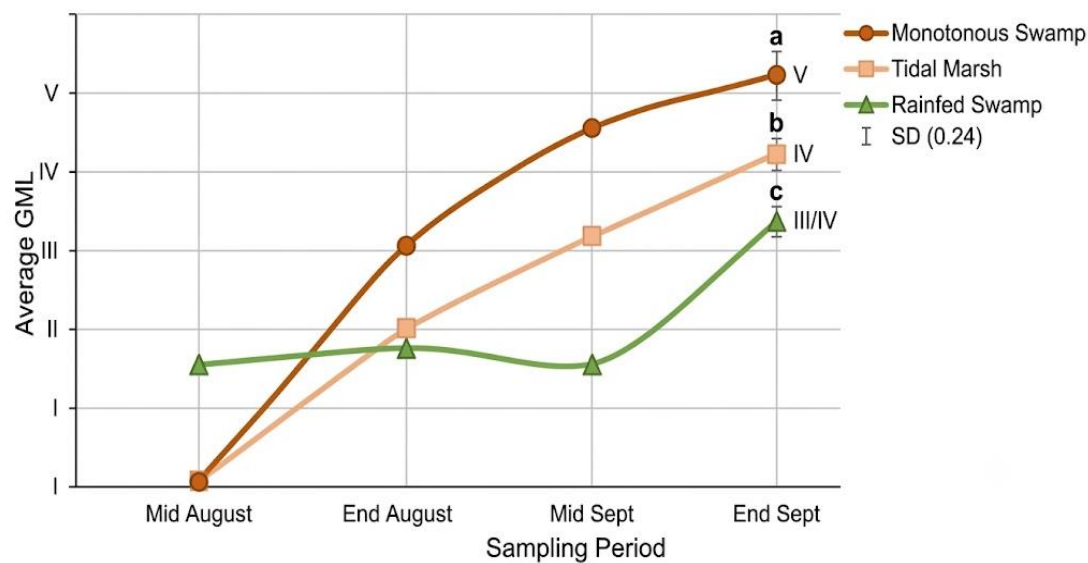


Figure 2. Monthly distribution of gonadal maturity levels of *Channa striata* across different swamp habitats.

Statistical comparison of GSI among habitats at GML V. ANOVA revealed significant differences in peak GSI among habitats ($F = 185.22$, $p < 0.001$), with Tukey HSD indicating that all habitats differ significantly (Table 4).

Table 4

One-way ANOVA and Tukey HSD comparison of GSI values at gonadal maturity stage V among habitats

Habitat type	Peak gonadosomatic index Mean $\pm$ SD (%)	F-value	P-value	Significance (Tukey HSD)
Monotonous Swamp	5.076 $\pm$ 0.076 ^a	185.22	< 0.001	a
Tidal Marsh	4.143 $\pm$ 0.065 ^b			b
Rainfed Swamp	3.465 $\pm$ 0.242 ^c			c

Note: values are mean $\pm$ SD; different superscript letters indicate significant differences among habitats (a, b, c) indicate significant differences among habitats (Tukey HSD, $p < 0.001$).

The results indicated that the GSI data were normally distributed ($p > 0.05$) and met the assumption of homogeneity ($p > 0.05$). Consequently, parametric analysis using One-way ANOVA followed by Tukey's HSD post hoc test was performed to identify significant differences ($p < 0.05$) among maturity stages and habitat types.

Gonadosomatic index (GSI) variation. Level V GSI was highest in the monotonous swamp, suggesting higher reproductive investment per individual, while tidal marsh fish matured earlier but with slightly lower GSI.

Morphology of snakehead fish gonads. Macroscopic examination showed progressive changes in gonadal development from GML II to GML V. The gonads increased in size and exhibited greater vascularization and more visible oocyte development with advancing maturity stages (Figure 3). These morphological characteristics were used to classify gonadal maturity levels according to Effendie's (2002) criteria.

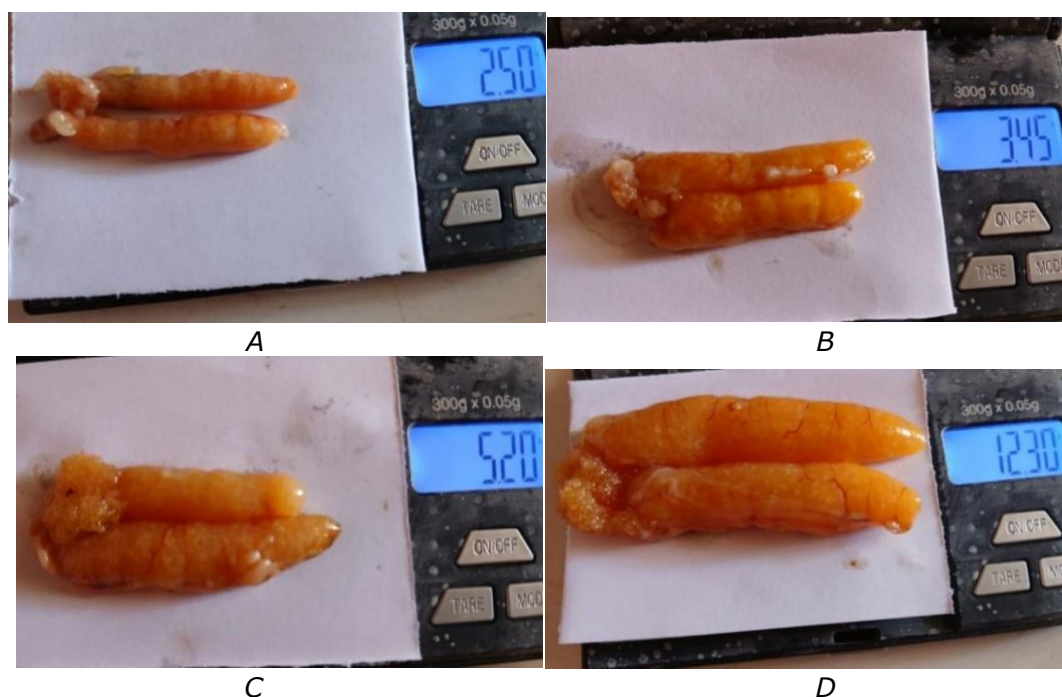


Figure 3. Representative macroscopic appearance of female gonads of *Channa striata* at different gonadal maturity levels (GML II-V). Gonadal maturity levels were determined based on gonad size, color, vascularization, elasticity, and macroscopic visibility of oocytes according to Effendie's (2002) criteria. (A) GML II, ovaries are relatively small, slender, and pale yellow. (B) GML III, ovaries increase in size, become yellowish, and blood vessels begin to be visible. (C) GML IV, ovaries are enlarged, bright yellow to orange, occupying most of the abdominal cavity, with distinct vascularization. (D) GML V, ovaries are fully developed, bright orange, turgid, and filled with mature oocytes, indicating readiness for spawning.

Discussion

General comparison between habitats. A comparison across the three habitat types, monotonous swamp waters, tidal marsh waters, and rainfall swamp waters, reveals distinct reproductive strategies reflected in GSI values at Stage V (mature phase) and the timing of gonadal development. These variations are strongly linked to environmental stability, hydrological regimes, and energy allocation patterns in fish reproduction (Rideout & Tomkiewicz, 2011; Lowerre-Barbieri et al., 2017).

Monotonous swamp waters, the temporal distribution of gonadal maturity stages demonstrates a gradual transition from GML I-II during July-August to a reproductive peak in mid-September, when 39.5% of individuals reached GML IV-V. This seasonal pattern coincided with the onset of flooding in the swamp ecosystem (Bijaksana, 2012). Such synchronization is consistent with a "wait-and-see" reproductive strategy, whereby maturation is delayed until environmental conditions become favorable, rather than occurring continuously throughout the year.

The delayed maturation observed during the early sampling period is likely associated with the relatively stable but nutrient-limited conditions characteristic of the swamp ecosystem. The onset of the rainy season increases water levels, habitat connectivity, and nutrient availability, thereby stimulating final gonadal maturation and spawning readiness. Similar seasonal synchronization has been reported for many tropical freshwater fishes, in which reproduction is timed to maximize larval survival under conditions of high food availability (Lowe-McConnell, 1987; Welcomme, 2001).

These findings also have practical implications for broodstock management. Mid-to-late September represents the most suitable period for broodstock collection, as females at GML IV-V with GSI values exceeding 4% exhibit advanced reproductive development. Knowledge of this seasonal "wait-and-see" reproductive strategy may also support hatchery management by enabling the manipulation of environmental cues, such as increasing water level or adjusting temperature, to synchronize spawning and improve seed production efficiency (Yaron, 1995; Bromage et al., 2001).

Tidal marsh waters, exhibited the most rapid gonadal development among the three habitats. The proportion of mature females (GML IV-V) increased from 55.5% in late July to 97.9% in late September. These differences were statistically significant (ANOVA, $p < 0.001$), indicating that tidal habitats promoted earlier reproductive maturation than the other swamp types.

This rapid maturation is likely associated with regular tidal fluctuations, which function as predictable environmental cues for reproduction (Makmur et al., 2014). Periodic flood pulses enhance habitat connectivity and nutrient availability, thereby accelerating gonadal development and synchronizing spawning with favorable environmental conditions (Junk et al., 1989; Humphries et al., 1999).

From an aquaculture perspective, tidal marsh populations provide an opportunity for earlier broodstock selection, beginning in late July. Replicating tidal water-level fluctuations or controlled water exchange in hatchery systems may help maintain reproductive readiness, synchronize spawning, and improve seed production efficiency.

Rainfall swamp waters, this variability is likely driven by irregular rainfall, which causes unpredictable changes in water level, habitat connectivity, nutrient availability, and temperature. Consequently, reproductive development becomes less synchronized, reflecting the environmental uncertainty characteristic of rainfall-driven flood pulses (Castello et al., 2015; Mosepele et al., 2017; Hutagalung et al., 2026).

From a management perspective, broodstock collection should be synchronized with peak rainfall, particularly during late August and September. Maintaining stable water levels or simulating natural flood conditions in hatchery systems may improve gonadal maturation, spawning synchronization, and seed production.

Comparative reproductive strategies. The three habitats demonstrate a clear trade-off between maturation timing, environmental stability, and energy investment:

- Monotonous Swamps (Delayed High-Investment): Reached the highest GSI (5.0%) but matured late (mid-late September). This reflects a "wait-and-see" strategy,

where energy is allocated for a single, synchronized when conditions become optimal (Winemiller & Rose, 1992).

- Tidal Marshes (Early Continuous-Investment): Matured earliest (late July) with moderate GSI (3.0-4.1%). Driven by regular tidal cycles, this population employs a batch-spawning strategy, prioritizing reproductive resilience and a prolonged spawning window over a single massive peak (Brown-Peterson et al., 2011; Ganas, 2018). Rainfed Swamps (Opportunistic Plasticity): Exhibited intermediate GSI (3.5%) with highly asynchronous and fluctuating maturation. This opportunistic strategy allows fish to respond rapidly to unpredictable rainfall, showing high life-history plasticity in unstable hydrological systems (Humphries et al., 1999).

The delayed maturation observed in monotonous swamps compared to tidal marshes reflects a "wait-and-see" reproductive strategy. In monotonous systems, the water level is relatively stable until the peak of the rainy season. Consequently, *C. striata* in these waters appears to synchronize its peak spawning with the onset of seasonal flooding in September to ensure higher survival rates for the larvae in the inundated floodplains (Welcomme 1985; Mahmud et al., 2016; Laboni et al., 2024). Interestingly, while the monotonous swamp population matures later, its Stage V GSI (5.07 ± 0.07) was the highest among all sites.

Management and aquaculture implications. Understanding these habitat-specific ecologies is vital for optimizing broodstock management:

1. Selection Criteria: Monotonous swamp broodstock are ideal for high-fecundity programs requiring superior gamete quality (Ingram & Nguyen, 2015), whereas tidal marsh sources are superior for early-season and continuous seed production.
2. Environmental Manipulation: Rainfed broodstock require precise captive control (e.g., simulated rainfall and water level regulation) to synchronize maturation and reduce output variability (Migaud et al., 2013).
3. Efficiency: Aligning hatchery protocols with these natural reproductive cycles enhances spawning efficiency, seed availability, and long-term production sustainability (Lowerre-Barbieri et al., 2017, Raizada S. et al. 2021)

Environmental drivers of gonad maturation. Habitat type significantly dictates the reproductive phenology of *C. striata*. The accelerated maturation in tidal marshes—with Stage IV and V individuals present as early as July—highlights water level fluctuations as primary environmental cues. This "flood pulse" effect facilitates nutrient transport and natural feed production, supplying the high energy required for vitellogenesis (Junk et al., 1989).

Abiotic factors and hypothalamic-pituitary-gonadal axis. External signals like photoperiod and temperature are critical regulators of the teleost reproductive cycle. While extended photoperiods stimulate gonadotropin secretion and development, extreme temperatures can suppress gonadal activity (Okuzawa et al., 1989). Seasonal shifts in these parameters regulate steroidogenesis and gene expression related to GnRH and LH, as observed across diverse taxa including *Fundulus heteroclitus*, *Trichogaster trichopterus*, and rainbow trout (Shimizu, 2003; Bhat et al., 2025). Collectively, these abiotic factors act through the hypothalamic-pituitary-gonadal (HPG) axis to synchronize oocyte maturation with optimal ecological conditions (David et al., 2011).

Domestication and breeding optimization. To enhance the reproductive performance of *C. striata* in captivity, domestication strategies must look beyond hydrological cues to include broader environmental manipulation. Stable water quality, specifically dissolved oxygen, pH, and ammonia control, is vital for maintaining endocrine balance. Chronic stress from poor water conditions elevates cortisol, which suppresses gonadal development in teleosts. Therefore, utilizing Recirculating Aquaculture Systems (RAS) to ensure environmental stability can effectively mitigate reproductive inhibition and improve spawning consistency.

Strategic hatchery protocols. Future hatchery protocols should integrate the controlled regulation of photoperiod and temperature alongside precision broodstock nutrition and water quality management. By simulating these environmental triggers, aquaculture practitioners can synchronize gonadal maturation and overcome breeding unpredictability. Such integrated management is essential for establishing sustainable, large-scale seed production for the snakehead industry.

Conclusions. This study demonstrates that reproductive development of *Channa striata* differs among swamp habitats and is closely associated with seasonal hydrological characteristics. Gonadal development occurred progressively from July to September, with the highest reproductive activity observed during September. Among the evaluated habitats, monotonous swamp waters showed the highest GSI at maturity stage V ($5.07 \pm 0.07\%$), indicating a higher reproductive investment at the final maturation stage. In contrast, tidal swamp habitats promoted earlier gonadal maturation, with mature individuals appearing earlier during the reproductive season, suggesting that regular water-level fluctuations may provide more predictable environmental cues for reproduction. Rainfed swamps exhibited an intermediate reproductive pattern, characterized by less synchronized gonadal development, which may be related to greater variability in rainfall-driven environmental conditions.

The differences observed among habitats highlight the importance of considering habitat-specific reproductive strategies when developing management and domestication programs for *C. striata*. Monotonous swamp populations may represent valuable broodstock sources for high reproductive output, whereas tidal swamp populations may provide opportunities for earlier broodstock collection and extended seed production periods. Understanding the relationship between habitat conditions and reproductive timing can support improved broodstock management, spawning synchronization, and sustainable aquaculture development of striped snakehead. Further studies incorporating environmental parameters and reproductive performance under controlled hatchery conditions are recommended to optimize domestication protocols for this species.

Recommendations. Broodstock of *C. striata* from monotonous swamp waters should be collected at the end of September, when GSI values indicate peak reproductive maturity. Collection during earlier periods (May-July) is not recommended due to immature gonadal conditions.

Aquaculture practices should incorporate environmental manipulation (e.g., water level and rainfall simulation) to accelerate or synchronize gonadal development, reducing reliance on seasonal cycles. The late July phase, marking the onset of maturation, is critical for broodstock conditioning through improved nutrition to enhance reproductive output.

Further research on hormonal regulation and comparative studies across different swamp types is recommended to support the development of more efficient, habitat-specific broodstock management strategies.

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Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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