

Reproductive Maturity of Siamese Mud Carp (*Henicorhynchus siamensis*) in Culture-Based Fisheries Ponds: A Strategy for Climate Resilience in the Ing River, Thailand

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Abstract

The study was conducted over a one-year monitoring period (June 2023 – June 2024) at two target community sites along the Ing River: Pa Kha Village and Wang Sila Village. A total of Five individual ponds were established at each site (total 10 ponds). These ponds utilized an enhanced natural food base by incorporating cow dung and rice straw to promote the growth of natural feed for the released indigenous fish. Biological data (e.g., length and weight) and water quality parameters were monitored regularly. The primary assessment involved measuring and observing the gonad development (maturity stages) of the *H. siamensis* population to determine the timing and condition of sexual maturity.

Results indicated successful growth and gonad development of *H. siamensis* within the CBF ponds. The morphology of gonad maturity peaked during June 2024 was determined to be approximately 11.44 cm SL. in males, 11.88 cm SL. in females. Overall, 89.36% of the sampled population achieved reproductive maturity within the culture period. These findings demonstrate that the management protocols (including the organic fertilization) effectively supported the reproductive capacity of the species.

This study confirms that small ponds managed through culture-based fisheries can successfully support the reproductive maturation of the Siamese Mud Carp. This not only provides a reliable source of protein for local communities but also contributes to the ecological resilience of the Ing River system by potentially supplementing wild populations. The established protocols offer a viable and sustainable model for enhancing fisheries productivity and climate adaptation for communities reliant on the Ing River.

Keywords

Reproductive system development, CBF, Replace, FCZ, *H. siamensis*

Introduction

The Global Annual to Decadal Climate Update (2022–2026) published by the World Meteorological Organization (WMO, 2022) indicates an increasing probability that global annual mean temperatures will exceed the 1.5°C threshold. The resulting impacts are expected to cause extensive damage to environments and biological life worldwide. These consequences include alterations in the hydrological cycle, shifts in wetland ecosystems, outbreaks of invasive alien species, deterioration of water quality, and increased water scarcity for agriculture, leading to the loss of food sources (Sam-ang, 2010). As ectothermic organisms, fish possess body temperatures that fluctuate in accordance with their environment. Consequently, rising and highly volatile global temperatures directly influence fish metabolic rates (Neuheimer *et al.*, 2011), which may impede reproductive success and foraging capabilities. Failure to adapt to these thermal changes can result in increased mortality. Furthermore, warmer water temperatures can lead to a decline in zooplankton—a vital food source for fish—thereby creating a cascading effect throughout the food web (Seub Nakhasathien Foundation, 2019). Collectively, these factors contribute to the contraction of community-based fisheries along riverbanks, reduced catch yields for local residents, food insecurity, and a significant decline in fishery-based income.

The Ing River is a primary tributary of the Mekong River, originating from Kwan Pha Yao in Pha Yao Province. It flows northward through rural communities in Chiang Rai Province before discharging into the Mekong River at Ban Pak Ing, spanning a total length of 260 kilometers with a catchment area of 7,238 square kilometers. The basin is geographically categorized into three sections: the Upper, Middle, and Lower Ing River Basins. The Ing River serves as a critical spawning ground for migratory fish from the Mekong, attributed to its relatively warmer temperatures. It is also vital to local agricultural and artisanal fishing communities. The peak fishing season occurs from May to July during the flood period when fish market values are highest. Fishing activities typically decrease between April and June. During the receding water levels and the onset of winter (October to November), fish that have matured and reproduced in the wetlands migrate back to the Mekong River. This diverse ecosystem and its riparian forests provide essential foraging grounds, which are crucial for the growth and dispersal of fish populations (Srimuang, 2016).

To mitigate and adapt to the impacts of climate variability while ensuring food security and replenishing declining natural fish populations, experimental nature-simulated aquaculture is required. Raising native fish in earthen ponds integrated into agricultural fields offers a semi-natural environment that demonstrates superior resilience to climatic fluctuations compared to other aquaculture systems. According to a study by Lebel *et al.* (2018), earthen pond systems can effectively implement up to 32 out of 34 identified adaptation strategies. This capacity significantly exceeds that of indoor systems, reservoirs, and cage culture systems.

Modern earthen pond aquaculture increasingly adopts Nature-Based Solutions (NbS) as a core framework. In this context, Culture-Based Fisheries (CBF) is implemented as a strategy to replenish fish populations in water bodies where natural recruitment is insufficient to sustain fishery demands. CBF is typically applied in small-scale communal water resources, such as irrigation reservoirs, where fish growth relies entirely on the primary productivity of the ecosystem. In these systems, external feeding is generally avoided; instead, fish forage on naturally occurring organisms. The operation of CBF is characterized by its simplicity and cost-effectiveness, utilizing agricultural by-products such as rice straw and bovine manure, which are readily available in agrarian societies (De Silva, 2015).

To stimulate the production of natural feed, a ‘straw-manure sandwich’ technique is employed. This involves constructing enclosures at the four corners of the pond and layering

rice straw with bovine manure at a 3:1 ratio for 3–4 layers. Microbial decomposition of these materials occurs over approximately one week, releasing nutrients that trigger the proliferation of phytoplankton, zooplankton, and water fleas, subsequently turning the water a greenish hue. This method ensures an adequate and sustainable supply of natural live feed within the pond ecosystem (Nan Freshwater Aquaculture Research and Development Center, 2018)

The ‘Tiny Pond’ project (locally known as Bo Jiew) is an initiative by the Department of Land Development (DLD) designed to assist farmers outside irrigation zones by providing on-farm water storage to mitigate drought and enhance agricultural productivity. Established in 2005, the department excavates ponds with a capacity of approximately 1,260 cubic meters. Participating farmers are required to contribute a co-payment of 2,500 Baht per pond and must satisfy specific criteria, such as holding legal land title deeds. From an engineering perspective, pond excavation must ensure structural stability to prevent embankment failure or landslides. For excavations not exceeding a depth of 3 meters, side slopes of 1:1, 1:1.5, or 1:2 are permissible. However, for depths reaching 5 meters, the slope must be restricted to 1:1.5 or 1:2 to ensure safety. Within Chiang Rai Province, 800 ponds were implemented under this project, including 23 experimental ponds in San Ma Kha Sub-district (Pa Daed District) and 8 experimental ponds in Pa Tan Sub-district (Khun Tan District) (Department of Land Development, 2022)

A Fish Conservation Zone (FCZ) is a specialized type of freshwater protected area established to safeguard aquatic ecosystems and restore fish populations. Typically, these zones prohibit or restrict fishing activities and other interventions that may adversely impact aquatic life. FCZs serve to protect critical habitats, such as spawning grounds and deep-pool refugia where fish aggregate. The primary objective is to allow fish to reproduce and mature, thereby replenishing depleted stocks and conserving aquatic biodiversity. Sustainable management of FCZs contributes to local food security and household income. These zones are often established and managed through a participatory approach involving local communities, government agencies, and non-governmental organizations (NGOs), empowering residents to take ownership of their natural resources. This collaborative process strengthens community resilience and mitigates conflicts over resource utilization. The FCZ model is a widely recognized and effective fisheries management strategy, particularly in the Lower Mekong Basin and other regions highly dependent on inland fisheries. It is regarded as a long-term strategy that necessitates continuous community engagement and systematic monitoring

The *Henicorhynchus siamensis* or Siamese mud carp is a small freshwater fish characterized by an elongated, slender body and a relatively large, rounded head. The mouth is small and subterminal, located near the tip of the snout, with a distinct symphyseal knob at the center of the lower lip; barbels are absent. The scales are large, and the body exhibits a bluish-grey coloration. A dark spot is typically present above the pectoral fin. The dorsal fin is small, while the caudal fin is deeply forked and marked with dark stippling. Mature individuals typically reach a total length of 15–20 cm. It is omnivorous and relatively easy to cultivate. In aquaculture, For fingerlings measuring 5–7 cm TL in length, the optimal stocking density is 3–4 individuals per square meter, or approximately 4,000 individuals per 1,600 Sq.m (Freshwater Fisheries Research and Development Center, 2021). The reproductive season coincides with the monsoon, typically from June to September. Adequate rainfall triggers the upstream migration of brood stock to spawning grounds. Fecundity ranges from 23,550 to 90,500 eggs per female, with an incubation period of 12–16 hours. The eggs are semi-buoyant (semi-pelagic), necessitating flowing water conditions to prevent them from sinking and accumulating on the substrate (Watanadilokkul et al., 1987). This species holds significant economic importance, particularly in the Northeastern region. For instance, in

Amnat Charoen Province, it is a primary raw material for processed fish products such as fermented fish (Pla ra) and pickled fish (Pla som), which are highly popular and serve as a vital source of community income (Amnat Charoen Freshwater Aquaculture Research and Development Center, 2017).

This research was conducted to compare the reproductive system development of Siamese carp raised in a simulated natural pond (Culture Based Fisheries: CBF) to replace wild-caught (Fish Conservation Zones: FCZ) fish, which are declining. The aim was to determine if this is feasible and what differences exist, in order to provide guidance for developing alternative Siamese carp farming methods.

Materials and Methods

Study Area

Fish Conservation Zones (FCZ)

Kwan Phayao, Mueang Phayao District, Phayao Province Station name: San Klaeb Dam (SKD), large-scale freshwater reservoir covering an area of approximately 16,960,000–24,000,000 Sq.m. (Phayao Provincial Fisheries Office). This site serves multiple functions, including as a primary source for domestic water consumption, a freshwater aquaculture hub, and a central location for community-based fisheries around the lake. Sampling location at Wang Pla Community, Wat Bun Yuen. Figure 3

Ban Wang Si La, Pa Daed District, Chiang Rai Province Station name: Wang Si La (WSL), This riverine site is characterized by the main river channel flowing beneath a bridge. The riverbanks exhibit contrasting features: one side is populated with dense riparian vegetation and trees, while the opposite side, adjacent to Wat Pha Silaram, features a developed concrete landing and access point to the water. Sampling location at Wat Wang Pha Silaram. Figure 4

Ban Pa Kha, Khun Tan District, Chiang Rai Province Station name: Pa Kha (PK), A public communal wetland containing natural fish populations that migrate from the Ing River. The area is enclosed by large perennial trees, with the water surface partially covered by aquatic plants, including water lettuce and water hyacinth. Sampling location at Nongmon, community forest. Figure 5

Ban Pak Ing, Chiang Khong District, Chiang Rai Province Station name: Pak Ing (PI), The river winds around the village perimeter, serving as the final reach before joining the Mekong River. Both riverbanks are utilized for riparian agriculture and are characterized by the presence of large, mature trees. Sampling location at Wat Pak Ing. Figure 6

Culture Based Fisheries (CBF)

Ban Wang Si la (WSL) The topography of the WSL site primarily consists of upland areas flanked by high mountain ranges. Situated far from the Ing River, this area remains unaffected by seasonal flooding. The experimental ponds in this cluster are characterized by substrates ranging from large rocks to heavy clay. A total of five experimental ponds were utilized: WSL2, WSL4, WSL5, WSL6, and WSL7. As shown in the Figure 1.

WSL2: Located on a lowland plain with silty clay loam soil. The water is characterized by high turbidity (brownish hue). The pond contains submerged woody debris and an earthen dike extending into the center of the basin. Figure 7

WSL4: Situated on a hillside with a depth of 2 meters. The water exhibits high turbidity with a distinct brown coloration. Figure 8

WSL5: Situated on a hillside with a depth of 1.5 meters. The water exhibits high turbidity with a distinct brown coloration. There are plants floating on the water's surface (Water mimosa). Figure 9

WSL6: Positioned on a hillside with clear, greenish water. The pond substrate is composed of rocky sediment and sandy soil. Figure 10

WSL7: Located on a residential plain within the community. The pond is relatively

shallow with clear, greenish water. The substrate consists of large boulders, and the site is utilized for integrated duck farming. Figure 11

Ban Pa Kha (PK) is situated within a floodplain, making it highly susceptible to seasonal flooding due to its close proximity to the Ing River. The pond substrates primarily consist of clay and loam. Most experimental ponds are densely surrounded by large trees, leading to a significant accumulation of organic detritus (leaf litter) on the pond floor. A total of four experimental ponds were monitored: PK1, PK4, PK5, PK6 and PK7. As shown in the Figure 2

PK1: a 1.5-meter-deep pond, The pond is enclosed by large perennial trees. Characterized by a high diversity of aquatic macrophytes and a significant amount of submerged woody debris. Figure 12

PK4: a 2-meter-deep pond with clear water. It exhibits distinct brownish films or patches, indicating high concentrations of plankton. Figure 13

PK5: a 2-meter-deep pond with clear, dark-tinted water. It is surrounded by Eucalyptus trees, resulting in a substantial layer of decomposed leaf litter on the substrate. Figure 14

PK6: a 1.5-meter-deep pond. The water is clear but cloudy. The pond has many aquatic plants (Giant Sensitive) and floating vegetation (Water mimosa). Figure 15

PK7: a 1.5-meter-deep pond with turbid greenish water. The site features various riparian plants along the edges, and the substrate is predominantly soil. Figure 16

Sampling Methodology

Conservation Zone (FCZ)

The sampling was carried out bimonthly from September 2023 to July 2023, September 2023, November 23, January 24, March 24, May 24 and July 24 totaling six sampling events. Fish samples were collected using gillnets of six different mesh sizes: 2, 3, 4, 5.5, 7, and 9 cm. Each net measured 50 meters in length and 2 meters in depth. Sampling was conducted across four stations representing the river's gradient: Ban San Klaeb Dam, Phayao Province (upstream); Ban Wang Sila, Chiang Rai Province; Ban Pa Kha, Chiang Rai Province; and Ban Pak Ing, Chiang Rai Province (downstream). Upon collection, fish specimens were initially preserved in a 10% formalin solution to maintain structural integrity. Subsequently, the specimens were transferred to 70% ethanol for long-term preservation and further laboratory analysis.

Culture Based Fisheries (CBF)

Sampling was carried out for the first four months after the fish were released: July 2023, August 2023, September 2023, October 2023, and at the end of the experiment in June 2024. Fish samples were collected using gillnets size below 2 cm and the efficiency of the blue 20-mesh net was tested by dragging it 3 times, checking the entire experimental pond. Randomly select fish, 5 people per experimental pond. Measure the time taken before preservation, using 10% formalin, fermenting for 2 weeks before ethanol to 70%.

Table 1. Information of ponds ban Wang Si La.

No.	Name	Coordinates	Pond
1	Tonglee Paerada	19°26'50.37"N100° 3'7.51"E	WSL2
2	Muan Sairach	19°28'15.53"N100° 1'8.86"E	WSL4
3	Weerawat Sritagron	19°26'48.25"N100° 3'7.54"E	WSL5
4	Supachai Vichit	19°27'33.39"N100° 1'39.88"E	WSL6
5	Songkran	19°26'56.25"N100° 3'13.92"E	WSL7



Figure 1. Show the location of the WSL experiment pond.

Table 2. Information of ponds ban Pa Kha.

No.	Name	Coordinates	Pond
1	Wan Kamsai	19°52'10.71"N100°14'58.04"E	PK1
2	Sombut Panthisong	19°52'18.20"N100°14'35.26"E	PK4
3	Buontha Guntakeaw	19°52'47.06"N100°14'48.20"E	PK5
4	Me Janphingean	19°52'22.21"N100°14'37.36"E	PK6
5	Sakron Saichana	19°52'7.79"N 100°14'36.74"E	PK7



Figure 2. Show the location of the PK experiment pond.



Figure 3. Phayao Lake or Kwan Phayao.



Figur 4 .Wang Si La.



Figure 5. Pa Kha.



Figure 6. Pak Ing.



Figure 7. WSL2.



Figure 8. WSL4.



Figure 9. WSL5.



Figure 10. WSL6.



Figure 11. WSL7.



Figure 12. PK1.



Figure 13. PK4.



Figure 14. PK5.

**Figure 15.** PK6**Figure 16.** PK7.**Emission rate.**

The optimal stocking density for Siamese Mud Carp is recommended at 5,000–10,000 individuals per 1,600 Sq. m (Department of Fisheries, 2019) or 4,800–6,400 individuals per 1,600 Sq. m (Freshwater Fisheries Research and Development Center, 2021). This study will release 1 individual per Sq. m because it is a natural rearing process. The specific rearing densities are shown in Table 3.

Natural Feed Production

To stimulate the production of natural live feed, a layering technique using rice straw and bovine manure was implemented. The materials were layered 3–4 times in a ‘sandwich’ fashion within bamboo enclosures constructed at the four corners of each experimental pond. The application rate was maintained at 100–120 kg per 1,600 Sq. m. (Kamphaeng Phet Provincial Office of Agriculture and Cooperatives, 2023). This method facilitates microbial decomposition, which subsequently triggers the proliferation of natural food organisms. This study used rice straw to cow manure in a ratio of 3:1 all 120 kg/1,600 Sq. m. The detailed quantities used are shown in Table 3.

Table 3. Showing information of Ban Pa Kha and Ban Wang Si La Experimental Pond.

No.	Ponds	Scale (m ²)	Rice straw: Cow dung (kg)	Quantity (1-3 Indiv./Sq. m.)
1	PK1	791	45:15	500
2	PK4	1,422	80:27	1,300
3	PK5	1,696	95:32	1,500
4	PK6	1,952	110:37	1,700
5	PK7	585	33:11	1,500
6	WSL2	833	47:16	800

Table 3. Continue.

No.	Ponds	Scale (m ²)	Rice straw: Cow dung (kg)	Quantity (1-3 Indiv./Sq. m.)
7	WSL4	765	43:14	800
8	WSL5	791	45:15	1,500
9	WSL6	639	36:12	800
10	WSL7	492	28:9	800

Water Quality

Water quality parameters were monitored using standardized test kits of Monitor Thailand, compliant with the standards established follow by the American Water Works Association (AWWA). The following parameters were measured: Ammonia-nitrogen and pH, both determined via the Colorimetric method, and Dissolved Oxygen (DO), analyzed through the Modified Winkler Titration method.

The Gonadal Maturity

The gonadal maturity was examined in a total of 230 specimens, comprising 131 individuals from the Culture-Based Fisheries (CBF) experimental ponds and 99 individuals from the Fishery Conservation Zones (FCZ) in the Ing River. The maturity stages were determined through macroscopic observation following the criteria established by Mathialagan and Rajangam (2017), which classifies gonadal development into five distinct stages: Immature, Maturing, Mature, Ripe, and Spent as shown in table 4.

Anatomical Procedure and Data Collection:

Dissection: A longitudinal incision was made using a scalpel along the ventral midline, extending from the urogenital pore to the pectoral girdle. Lateral cuts were performed to fully expose the abdominal cavity.

Organ Removal: The gill apparatus, including the gill arches, was detached from the cranium. Subsequently, the entire digestive tract—from the esophagus to the distal end of the intestine—was carefully removed to reveal the gonads.

Gonadal Examination: The gonads (testes or ovaries) were examined in situ and after removal to assess their size, color, and texture relative to the abdominal cavity.

Data Recording and Analysis: Morphometric data and maturity stages were systematically recorded for further statistical comparison between the CBF and FCZ populations.

Results and Discussion

Water Quality

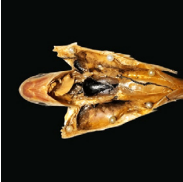
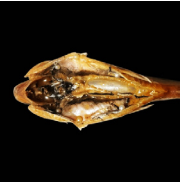
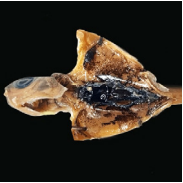
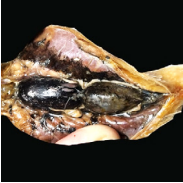
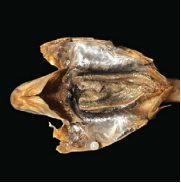
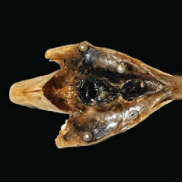
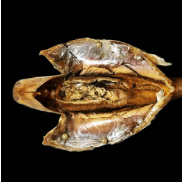
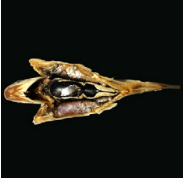
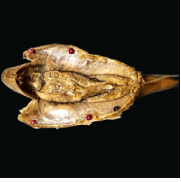
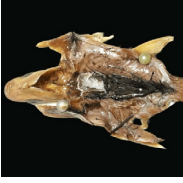
Dissolved Oxygen (DO): According to the Department of Fisheries (2021), Dissolved Oxygen (DO) levels should not fall below 3 mg/L, as levels lower than this threshold can cause critical stress or mortality in fish. For fish carrying eggs should receive more than 5 mg/L of oxygen. The analysis revealed that all ten experimental ponds maintained DO levels above 3 mg/L, providing a sufficient environment for fish respiration. Hydrogen-ion Concentration (pH): The pH levels across all experimental ponds were found to be within the optimal range for aquaculture, fluctuating between 6.5 and 9.0. This range is conducive to healthy physiological functions and nutrient cycling within the pond ecosystem. Ammonia: Ideal ammonia levels for fish cultivation should be maintained below 0.05 mg/L (Smart Farm, 2024). High ammonia concentrations, specifically reaching 1 mg/L, severely inhibit the gas exchange process. This occurs because un-ionized ammonia interferes with the binding affinity between oxygen and hemoglobin in the fish’s blood. In this study, only ponds WSL2

and WSL6 maintained ammonia levels strictly within the recommended threshold. While the remaining ponds slightly exceeded these standard values, the fish populations demonstrated resilience and were able to tolerate the conditions throughout the experimental period. as shown in Table 5.

Sample data for *H. siamensis*

Total number of CBF *H. Siamese* fighting fish 131. Maximum length 15.75 cm SL, minimum 3.35 cm SL, average length 8.36 cm SL maximum weight 99.00 g, minimum 1.00 g, average weight 19.27 g. Total number of FCZ Siamese fighting fish 99. Maximum length 26.01 cm SL, minimum 5.92 cm SL, average length 11.87 cm SL maximum weight 214.00 g, minimum 4.00 g, average weight 47.53 g.

Table 4. Showing the development of the reproductive organs of a *H. siamensis*.

Stage	FCZ		CBF	
	Testis	Ovary	Testis	Ovary
Immature				
				
Maturing				
				
Mature				
				
Ripe				
Spent				

The Gonadal Maturity

The gonadal development of *H. siamensis* sampled from the (FCZ) in the Ing River reached the Ripe stage starting in May (11%) and September (34%), with a peak frequency observed in July (50%). This was followed by a high prevalence of individuals in the Spent stage in November, indicating the completion of the spawning cycle. Please refer to Figure 17 for illustration. In comparison, fish from the (CBF) experimental ponds showed advanced reproductive development, with 84% of the population reaching the Ripe stage by June 2024. Please refer to Figure 18 for illustration. These findings align with several previous studies on the spawning seasonality of *H. siamensis* across various Thai water bodies. For instance, spawning was reported from May to August in the Krasiao Reservoir, Suphan Buri, and from April to June in the Mae Klong River (Duangsawasdi *et al.*, 1990, 1993). Similarly, in the Pasak Jolasid Reservoir, Lop Buri, spawning occurred between July and August, with peak fry abundance in July (Poungcharean and Meksumpun, 2006). In the UbolRat Reservoir, Khon Kaen, the season spanned from June to September (Watanadilokkul and Nabandit, 1987), while in the Kaeng Lerg Charn Reservoir, Maha Sarakham, spawning took place from May to August, peaking in June (Rungpiboonsophit and Watanamahatmat, 1984). Furthermore, research at the Mae Ngat Somboon Chol Dam, Chiang Mai, indicated a spawning period from June to August, with peak gonadal development in July, showing Gonadosomatic Index (GSI) values of 1.40 for males and 21.20 for females (Chitmanat *et al.*, 2004). In Kwan Phayao, the GSI remained high from May to August, with a maximum value of 20.1 ± 6.2 recorded in June (Tuncharoen *et al.*, 2018). The high percentage of ripe individuals in the CBF ponds in June (84%) confirms that the nature-simulated pond environment effectively supports the natural reproductive rhythm of this species.

The analysis of *H. siamensis* size relative to gonadal maturity revealed distinct patterns between the two study groups. In the FCZ, individuals within the 3–10 cm length class exhibited initial signs of sexual maturity (25%), which increased slightly to 26% in the 11–13 cm class. The highest prevalence of sexual maturity (49%) was recorded in the 14–16 cm size class. In contrast, the CBF experimental group showed that sexual maturity initiated at smaller sizes; the 3–6 cm class showed 2% maturity, while the 7–10 cm class already reached the Ripe stage at a frequency of 30%. The peak Ripe frequency (68%) was observed in the 11–16 cm size class. During the initial stocking phase in 2023, the fish were in the juvenile stage, with an average weight and length of 8 g and 6.8 cm, respectively, showing minimal gonadal development. However, after a one-year rearing period, the average size significantly increased to 68 g and 11.1 cm by June 2024, coinciding with a marked increase in reproductive maturity. These results are consistent with the findings of Rungpiboonsophit and Watanamahatmat (1984), who stated that female Siamese Mud Carp reach reproductive age at a length of 13 cm and weight of 51 g, with peak maturity observed at 15–18 cm (80 g). For males, reproductive size starts at 12 cm (30 g), peaking at 15–18 cm (60 g). Furthermore, our results align with studies from the Krasiao Reservoir and the Mae Klong River, which reported maturity at lengths of 13 cm and 11 cm, respectively (Duangsawasdi *et al.*, 1990, 1993). The findings confirm that the CBF system effectively facilitates the growth and maturation of *H. siamensis* within a single annual cycle.

A spatial analysis of gonadal development reveals that the highest frequency of individuals in the Ripe stage was recorded in Ban Pa Kha, followed by Ban San Klaeb Dam. Both sites are characterized as closed or semi—closed lentic systems (large wetlands/marshes). In contrast, lower frequencies of ripe individuals were observed in the riverine habitats of Ban Pak Ing and Ban Wang Sila. According to Watanadilokkul and Nabandit (1987), Siamese Mud Carp typically spawn in flowing water. The species exhibits potamodromous behavior, migrating

upstream in large schools to spawn in headwaters. This migratory instinct is triggered by river currents, ensuring that their semi-buoyant (semi—pelagic) eggs remain suspended in the water column rather than sinking and accumulating on the substrate. Therefore, it can be inferred that the ripe individuals may have migrated from the main river channels toward upstream reaches or specific spawning grounds characterized by dense riparian vegetation. Such habitats provide essential refugia from natural predators and offer optimal environmental conditions for spawning, compared to the open river stretches.

Statistical analysis was performed to compare the gonadal development of *H. siamensis* between the Culture—Based Fisheries (CBF) ponds and the Fishery Conservation Zones (FCZ) in the natural river. The results indicated no significant difference in the reproductive development between the two groups at a 95% confidence level ($p > 0.05$).

Although the data is not complete, but number of experiment points each month was determined to be consistent for both FCZ and CBF. Because, due to differences in the ecosystems, it was not possible to collect fish samples from every survey point. For example, in the FCZ, some periods of shallow river water caused fish migration, resulting in fish not being found at certain times or survey points. This may lead to some data loss, but it will not affect the analysis because the trends in the reproductive organ development of the Siamese carp can still be observed for comparison in the FCZ and CBF.

Table 5. Shown water quality in pond.

WQ	PK1	PK4	PK5	PK6	PK7	WSL2	WSL4	WSL5	WSL6	WSL7
DO (mg/L)	4.50 ± 0.71	6.00 ± 1.91	4.88 ± 0.48	7.50 ± 1.35	7.75 ± 0.29	4.63 ± 0.75	4.25 ± 0.29	6.00 ± 2.18	5.88 ± 0.85	4.88 ± 1.70
pH	7.13 ± 0.25	7.25 ± 0.29	7.13 ± 0.25	7.38 ± 0.25	7.25 ± 0.50	7.63 ± 0.25	7.00 ± 0	7.38 ± 0.48	7.50 ± 0.41	7.38 ± 0.25
Total Ammonia (mg/L)	0.13 ± 0.14	0.06 ± 0.13	0.06 ± 0.13	0.13 ± 0.14	0.13 ± 0.14	0.00	0.13 ± 0.14	0.13 ± 0.14	0.00	0.13 ± 0.14

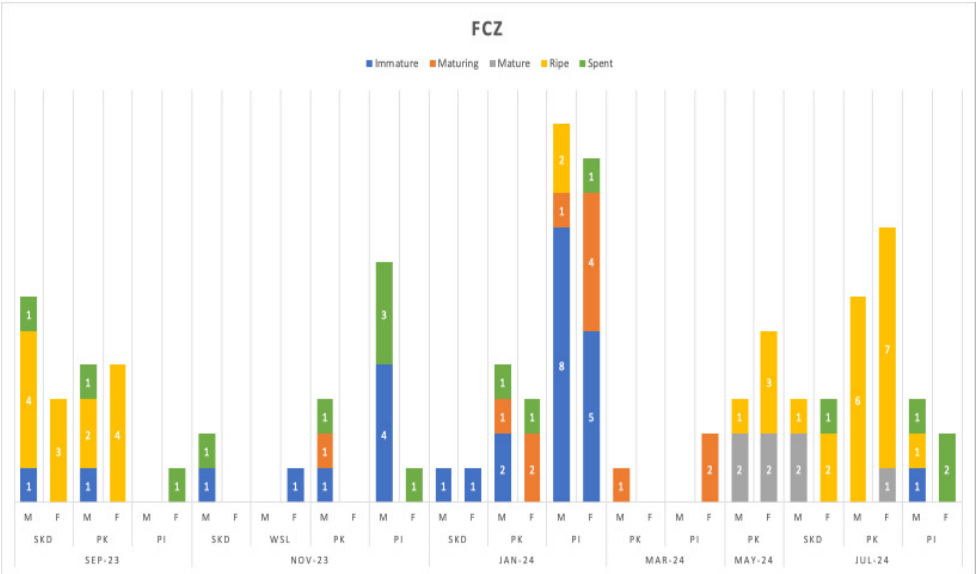


Figure 17. Showing the development stages of the reproductive organs of the *H. siamensis* in Fish Conservation Zone. M: Male, F: Female, SKD: San Klaeb Dam, WSL: Wang Si La, PK: Pa Kha, PI: Pak Ing.

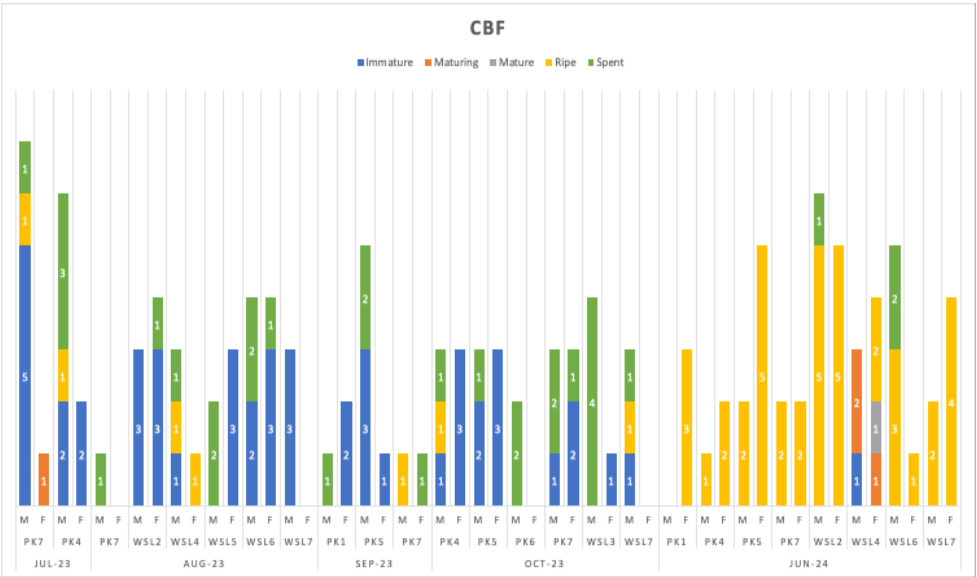


Figure 18. Showing the development stages of the reproductive organs of the *H. siamensis* in Culture Based Fisheries. M: Male, F: Female, PK: Pa Kha, WSL: Wang Si La.

Summary

The gonadal maturation of *Henicorhynchus siamensis* sampled from natural habitats in the Ing River (FCZ) was observed from May to September. Sexual maturity began at a body length of 8.8 cm, with peak maturation (46%) occurring in the 14–16 cm size class. In

comparison, fish from the nature—simulated experimental ponds (CBF) exhibited advanced gonadal development by June 2024, with 84% reaching maturity. Within the CBF group, sexual maturity initiated at a smaller size of 7.3 cm, and the 11–16 cm size class showed a significantly higher maturation rate of 88%.

Statistical analysis indicates that fish in the CBF system possess reproductive potential comparable to those in the FCZ. These findings confirm that small—scale, nature—simulated management systems can successfully enhance the reproductive development of *H. siamensis*. This model not only provides a reliable protein source for local communities but also strengthens the ecological integrity of the Ing River system by replenishing natural fish stocks. Consequently, it serves as an efficient and sustainable model for increasing fishery productivity and fostering climate resilience for communities dependent on the Ing River.

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