Sex ratio, gonad maturity level and gonado-somatic index of snakehead (*Channa striata*) from Danau Bangkau, Indonesia

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Abstract. The current research provides valuable information on the sex ratio, gonad maturity level (GML) and gonad somatic index (GSI) of snakehead (*Channa striata*) collected from Danau Bangkau, Indonesia. 150 individual snakeheads (265-432 mm total length and 264.8-949.6 g weight) were directly bought from local fishermen. This study was conducted from July to September 2021. The sex determination and measurement of fish samples were procedurally performed following standard criteria. The results showed that the sex ratio of males to females was 1:1.1. The most frequent GML was level II (48%), found in July (48%). The following were GML III (42%) in August and GML IV (40%) in September. GML V was also recognizable, proving that snakehead can be considered a partial spawner. The highest GSI value obtained was 2.77% for males and 7.43% for females in September. Water quality parameters were in the tolerance range for the growth and survival of snakehead in the investigated area.

Key Words: gonadal development, monotonous swamp, partial spawner, sex differentiation, spawning season.

Introduction. Like in other Asian and African countries, snakehead (*Channa striata*) has become one of the commercially important freshwater fish species and positively increases local community incomes in Indonesia (Ahmadi 2018). It is an essential food source due to its nutritional content, organoleptic properties and even medicinal properties (Fitriliyani & Deviarnil 2013; Norhayati et al 2019; Ansyari et al 2020). Biologically, it is categorized as an air-breathing fish species, adaptable to low oxygen levels and tolerant to temperature changes (Al Mahmud et al 2016; Xie et al 2017). It plays an important role in the food chain in its natural habitat (Jumawan & Seronay 2017; Ahmadi 2018; Norhayati et al 2019). As a predatory species, its presence can potentially threaten the survival of native aquatic species (Love & Newhard 2012; Lapointe et al 2013; Guerrero III 2014). From an economical point of view, however, many fish farmers have successfully cultivated them in earthen ponds, net-cages or fish farms with different culture methods (Haiwen et al 2014; He et al 2015; Quyen et al 2016) to obtain benefit from this species.

Numerous fundamental studies on ecological and biological characteristics of snakehead have been conducted in recent years, on growth and survival rates (Rahman et al 2013), growth pattern and condition factor (Ahmadi 2018), gonad maturation (Anwar et al 2018), fecundity (Osho & Usman 2019), maturity level and somatic index of gonads (Widodo et al 2013), feeding habits (Akbar & Iriadenta 2019), breeding techniques (Roy et al 2016), migration patterns (Lapointe et al 2013), population dynamics (Sofarini et al 2018), population genetic structure (Robert et al 2018), eutrophication effect (Sofarini et al 2020), lead content analysis (Zarina et al 2020), respiratory metabolism (Xie et al 2017), parasites characteristics (Chowdhury & Hossain 2015), chitinase characteristics (Baehaki et al 2018), immunostimulatory response (Norhayati et al 2019), restocking models (Bijaksana et al 2015) and domestication programs (Ndobe et al 2019). At the same time, technology engineering of aquaculture (Samidjan & Rachmawati 2016) and its related aspects such as extruded feed development (Haiwen et al 2014), feeding frequency (He et al 2015), artificial feed formulation (Hien et al 2016) and stocking density (Saputra et al 2018) are also being studied to support fish farming business.

In South Kalimantan Province of Indonesia, snakehead is locally called "haruan". For the time being, supply and demand of snakehead are highly dependent on the catch from the wild, resulting in an increase of fish price in the market up to 8.5 USD per kg in December 2020. In 2019, the average annual production reached over 700 tons, while aquaculture contributed with only 35 tons (5%) to the local fish markets (Ansyari et al 2020). Fishing activity increases periodically to fulfill the targets of fish production (Norhayati et al 2019). Fishing activities for snakehead are permitted throughout the year. There is no season, no size limit, and no possession limit for snakehead. Therefore, strict monitoring by the Fisheries Department and law enforcement institutions is still needed to ensure that there is no drastic decline in fish populations.

Scientific information on fish reproductive biology is essential for fishery management and policy making of capture fishery. For this reason, the aim of this paper was to investigate the sex ratio, gonad maturity level and gonad maturity index of snakehead from the swamp of Danau Bangkau, Indonesia.

Material and Method

Study site. The research study was conducted in the swamp of Danau Bangkau, Hulu Sungai Utara District, South Kalimantan Province, Indonesia. This swamp is categorized as a peatland with a total area of 17000 ha, while the area for fisheries alone is 6 ha. It was purposively selected to represent the typical habitats of snakehead. This site is generally represented by wetland areas with 0.5 to 2 m depths, seasonally influenced by rainfall, especially between September and April, when wetlands are entirely flooded. During the dry season (May-August), the wetland is covered by dense vegetation. According to Ansyari et al (2020), a high production of freshwater fish species in this area occurs particularly because of this regular seasonal change linked with biomass production and nutrient generation in the waters. The research activities were performed for 3 months, from July to September 2021.

Sampling method. 150 snakeheads (265-432 mm total length and 264.8-949.6 g weight) were directly bought from local fishermen. They were 70 males (46.7%) and 80 females (53.3%), with the sex ratio of 1:1.1. Snakehead was mostly caught by using stage-lines with live bait (frogs) and fish traps. The fish samples were grouped by collection date. All fish were individually sexed and total length (TL) and weight (W) were determined. Total length was determined with a ruler (1 mm precision), while the body weight was determined using a digital balance (0.01 g accuracy) (SF-400). The fish were humanly killed by beheading and ventrally dissected using a knife. Each gonad was removed and weighed using a digital electronic scale (Camry-EHA401), coded, preserved in 4% formalin and stored in sample bottles, then analyzed in the Waters Biology Laboratory, Faculty of Marine and Fisheries, Lambung Mangkurat University.

Equipment and materials. Table 1 presents the materials and equipment used in this study.

Sex ratio. Sex differentiation and gonad development of snakehead can be seen macroscopically through the shape and color of the body and reproductive organs (Table 2). The sex ratio was determined by comparing the number of males on females monthly and tested with the chi-square test. If sex determination was done microscopically, then surgery was performed and the gonads were removed and observed. A microscope was used when fish were not matured.

Table 1

Equipment and materials used for snakehead sampling periods

No	*Equipment and materials*	*Description*
1	Digital balance (SF-400)	Measures weight of fish samples
2	Digital electronic scale (Camry-EHA401)	Measures weight of gonad samples
3	Ruler	Measures total length of fish
4	Knifes	Dissects the fish
5	Measuring glass and pipettes	Measures volume of gonad
6	Secchi disc	Measures water transparency
7	Roll meter	Measures the depth of waters
8	DO meter	Measures dissolve oxygen
9	pH meter	Measures pH
10	Thermometer	Measures water temperature
11	Microscope	Eggs observation
12	NH_3 test kits	Measures NH_3 content
13	Digital camera	Documentation
14	GPS	Measures the coordinates of site locations
15	Stationary	Records measurement results
16	Fish trap (Lukah)	Caught snakeheads
17	Stage-lines (Banjur)	Caught snakeheads using frogs
18	Formalin	Preserved gonad sample
19	Snakehead	Fish sample
20	Small boat (5.5x1.0x0.7 m)	Field operation support

Table 2

Morphological differences between males and females of snakehead (*Channa striata*) with mature gonads

No	*Male*	*Female*
1	Body shape is smaller and slimmer	Body shape is fatter and rounder
2	Slim belly and a darker color	Big belly and brighter color
3	Rough skin, small and wild fin size	The skin of the body is smoother and the fins are larger and more docile
4	The genital secretes a milky white liquid (sperm) when it is stripped	The genital secretes an orange-red liquid (eggs) when it is stripped

Gonad Maturity Level (GML). The gonadal development can be determined both macroscopically (through body color and reproductive organs) and microscopically/ histologically. The Gonad Maturity Level (GML) can be seen from the changes in the structure of the eggs. These changes are divided into five levels, namely: levels I, II and III, which can be distinguished by changes in the size of the diameter of the eggs, while changes at levels IV and V can be recognized by the formation of the yolk vesiole and yolk globe in the cytoplasm (Effendie 2002). At level V, the egg cell wall thickens and the location of the nucleus shifts to the edge.

The GML of snakehead was determined morphologically, covering both ovaries and testes, including color, surface structure, filling of the abdominal cavity, length and weight of the gonads, and the presence or absence of eggs. Observation of gonadal morphology refers to the characteristics listed in Table 3.

Table 3
Criteria for determination of fish gonad maturity level (Effendie 2002)

GML	*Female*	*Male*
I Immature	The gonads are like a pair of threads that extend on the lateral sides of the anterior peritoneal cavity, reddish color	The gonads are a pair of threads, but are much shorter than the ovaries of the female, gray color
II Nearly mature	Gonads are larger, fill a quarter of the peritoneal cavity, yellowish white, the eggs cannot be seen individually with the eye	The gonads are milky white, fill a quarter of the peritoneal cavity and appear larger than the level I gonads
III Maturating	The gonads fill almost half of the peritoneal cavity, the eggs begin to be seen with the eye without tools in the form of fine granules, greenish yellow	The gonads fill almost half of the peritoneal cavity, milky white
IV Mature	Gonads fill three-quarters of the peritoneal cavity, yellow and darker in color; eggs are clearly visible with much larger granules than in level III	The gonads fill three-quarters of the peritoneal cavity and are solid milky white and fill most of the peritoneum
V Spent	The gonads are still as in level IV, some of the gonads are deflated because some of the eggs have ovulated (spawned)	The gonads are empty and softer

Note: GML - gonad maturity level.

Gonad Somatic Index (GSI). Gonad Somatic Index (GSI) can be determined by dividing the weight of gonads to the total body weight of the fish. The GSI value was estimated using the following formula:

GSI%=(weight of gonads/weight of fish) x 100

Water quality. Water quality parameters for the three-month sampling period included temperature, pH, dissolved oxygen (DO), ammonia (NH_3) content (Table 1). Depth and transparency of waters were also measured and recorded *in situ*.

Results and Discussion

Sex ratio. The overall sex ratios observed for 150 fish caught from July to September 2021 are presented in Table 4. The chi-square test showed that there was no significant difference in the sex ratios. Variations in the sex ratio of the fish could be closely related to food availability, water temperature, DO and migration cycle (Widodo et al 2013; Osho & Usman 2019; Jumanto et al 2019).

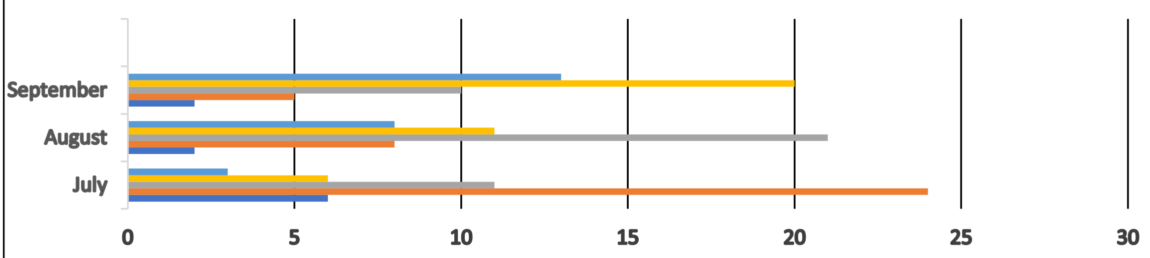
Table 4
The sex ratios of snakehead (*Channa striata*) sampled from Danau Bangkau, from July to September 2021

Month	*Fish samples from Danau Bangkau*			
	Male	*Female*	*Total*	*Sex ratio (M:F)*
July	19	31	50	1:1.6
August	24	26	50	1:1.1
September	27	23	50	1.2:1
Total	70	80	150	1:1.1

Table 3 illustrates that the sex ratios of snakehead males and females during the study period was close to a ratio of 1:1, indicating that the ratio within populations was balanced. Such condition can be used for the management of reproduction in snakehead hatcheries within controlled waters, with a ratio of 1 male to 1 female. In other words, the sex differentiation in aquaculture is very important to know, being directly related to broodstock management for the spawning process.

The differences in size and number of one sex may be attributable to the growth pattern of the fish itself and the differences in the age of the fish when the gonad matures for the first time, as well as due to high fishing pressure (Rahman et al 2013; Mian et al 2017). If males and females are balanced or there are more females, it can be interpreted that the population can maintain its originality (Saputra et al 2009). Information about the sex ratio can be used to estimate the spawning ability of a fish.

Gonad maturity level. The number of fish samples and GML (%) of snakehead collected from Danau Bangkau from July to September 2021 are presented in Figure 1.



	July	August	September
GML V	3 (6%)	8 (16%)	13 (26%)
GML IV	6 (12%)	11 (22%)	20 (40%)
GML III	11 (22%)	21 (42%)	10 (20%)
GML II	24 (48%)	8 (16%)	5 (10%)
GML I	6 (12%)	2 (4%)	2 (4%)

Number of Fish Samples and GML (%)

Figure 1. The number of fish samples and gonad maturity level (%) of snakeheads (*Channa striata*) from Danau Bangkau from July to September 2021; GML - gonad maturity level.

Figure 1 clearly shows that the GML of snakehead was the highest during July (GML II - 48%), then shifted to GML III (42%) in August and GML IV (40%) in September, indicating an increase of GML value that corresponds to its size group and spawning condition. Until September, GML I, II and III tended to decline, while GML V increased by 26%. At this time, many snakeheads began to spawn, coinciding with the rise in water levels when the rainy season began. The maturity pattern was characterized by the formation of numerous spermatozoa in the peritoneum and the oocyte in ovarian follicles (Jumanto et al 2019). Based on observations from these gonadal samples of snakehead, it can be said that the spawning of snakehead was not dependant on seasons, because its spawning is "partial", meaning that not all eggs were released, only matured ones. Hossain et al (2015) also reported that spotted snakehead (*Channa punctatus*) may spawn several times in a year under favorable environmental conditions. In the present study, the peak of spawning occurred in September and October, at the beginning of the rainy season. Such condition proves that gonad maturation and fish spawning are influenced by natural signals such as rain, water levels and changes in environmental temperature. In the tropic area with warmer water temperature, the gonads can mature faster. This gonadal maturation mechanism of fish is induced by the central nervous system and transmitted to the hypothalamus (Al Mahmud et al 2016).

Gonado-somatic index. The GSI value shows quantitative changes in the gonads. It expresses the relative change in gonad weight reported to the percentage of body weight and it would reach the maximum range when spawning would occur. It is the indicator of the status of gonadal development and maturity of individuals (Al Mahmud et al 2016). Sometimes, GSI is associated with GML to show that there is a close relationship between internal and external development of the gonads. According to Effendie (2002), the increase in gonad weight in female ranges between 10-25% of body weight, while for males it ranges between 5-10%. The GSI structure of snakehead collected from Danau Bangkau is presented in Figure 2.

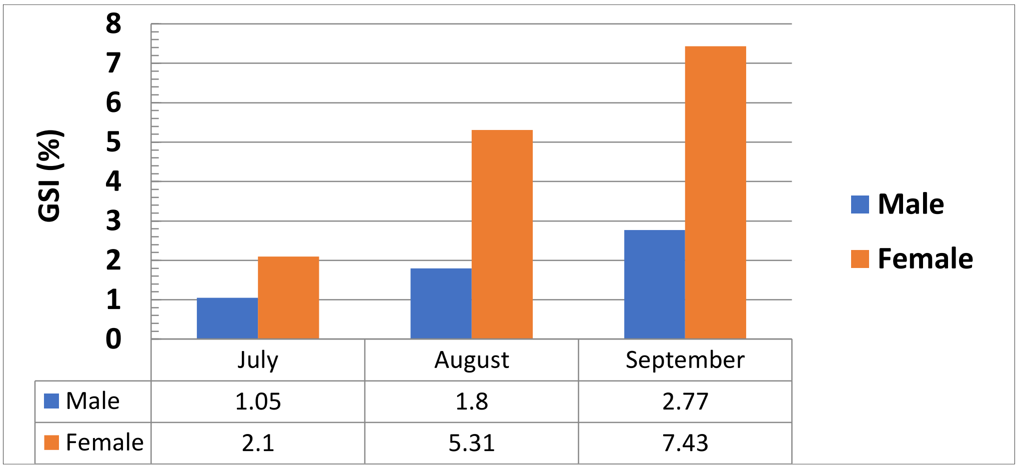


Figure 2. The gonado-somatic index (GSI) of snakehead (*Channa striata*) from Danau Bangkau, between July and September 2021

Within a three-month period, the GSI value increased linearly and corresponded with the development of the GML. The GSI value of males in September (2.77%) increased 2.6 times the GSI value in July (1.02%), while the GSI value of females in September (2.1%) increased 3.5 times the GSI value in July (7.43%). The GSI value of females tended to be higher than that of males at the same GML. This was due to the higher increase in ovarian weight than testicular weight. The GSI value decreases when fish spawn. Our observations during July and August showed that the GSI values were still relatively low (1.05-5.31%) compared to those found in September (7.43%), this is due to the absence of a trigger, swamp waters being still in low tide conditions (dry season). The peak in spawning season of snakehead started in September and October, simultaneously with the start of the rainy season. This was similarly reported for dwarf snakehead (*Channa gachua*) in Ta Bo, Huai Yai Wildlife Sanctuary, Thailand (Khomsab & Wannasri 2017). Al Mahmud et al (2016) and Mian et al (2017) found that the highest GSI for *Channa punctatus* in a lentic ecosystem was in July (rainy season). Ghanbahadur et al (2013) and Tiwari et al (2014) reported a peak in GSI value for *C. gachua* and *Channa marulius* in May, with a spawning period from June to August (Table 5).

Table 5

Comparative sex ratio, gonad maturity level and gonado-somatic index of family Channidae from different geographical areas

Species	n	Sex ratio (M:F)	GML (%)	GSI (%)	Month/Year	Locations	References
Channa striata	150	1: 1.1	4.0 - 48.0	1.05 - 7.43	July - Sep 2021	Sungai Batang, Indonesia	Present study
C. striata	545	1: 0.6	-	0.48 - 7.56	August 2016 - Jan 2017	Sebangau River, Indonesia	Selviana et al (2020)
C. striata	409	1.96: 1	15.6 - 20.0	1.52 - 3.54	Oct 2017 - August 2018	Lake Rawa Pening, Indonesia	Jumanto et al (2019)
C. striata	600	-	-	0.03 - 0.30	Nov 2017 - Oct 2018	Mae La River, Thailand	Boonkusol et al (2020)
C. striata	350	-	-	0.67 - 5.10	April - Sep 2014	Wetlands of Sylhet, Bangladesh	Ferdausi et al (2015)
C. striata	120	-	-	0.02 - 5.95	Dec 2012 - Nov 2013	Lentic and lotic ecosystem, Bangladesh	Al Mahmud et al (2016)
C. punctatus	342	1: 1.28	-	0.19 - 5.64	Dec 2012 - Nov 2013	Wetlands of Sylhet, Bangladesh	Hossain et al (2015)
C. punctatus	312	1: 1.16	-	0.13 - 5.34	March – Sep 2015	Lentic ecosystem, Bangladesh	Mian et al (2017)
C. gachua	-	-	-	5.0 - 47.29	Sep 2011 - August 2012	Godavari River, India	Ghanbahadur et al (2013)
C. marulius	-	-	-	7.76 - 35.76	June - Dec 2015	Sutlej River, India	Kaur et al (2018)
C. limbata	346	1: 0.7	-	0.21 - 3.74	Nov 2013 - Oct 2014	Ta Bo, Huai Yai Wildlife Sanctuary, Thailand	Khomsab & Wannasri (2017)
Parachanna obscura	408	1: 1.32	-	-	Oct 2000 - March 2001	Enyong Creek, Nigeria	Bolaji et al (2011)

Water quality. Water quality parameters were measured and recorded during sampling periods as presented in Table 6. In general, water samples collected during the dry season showed a poor water quality (Ansyari et al 2020). Water temperature in the investigated areas was in the optimal range of 26.1-30.3ºC for swamps (KKP 2014). According to Xie et al (2017), snakehead has a varying thermal metabolic sensitivity dependent on temperature. The pH in the swamps varied from 5 to 6, slightly lower than those reported by Sofarini et al (2020), indicating the water was relatively acid. The optimum pH is usually between 7.5 and 8.5 (Boyd 1990). The DO was between 2.1-4.3 ppm, below the optimum DO range required for the fish, which is 4-8 ppm (Norhayati et al 2019). During the dry season, the oxygen supply declined due to the decomposition processes of organic matter. However, the snakehead can survive even in mud, due to its air-breathing capability (Xie et al 2017). The ammonia content varied between 0.05-0.3 ppm and it was in tolerable condition (He et al 2015). The average transparency and the depth of waters were 62.33 cm and 98.55 cm, respectively. Conservation planning for snakehead is needed to reduce overfishing due to its high economic value (Song et al 2013).

Table 6

Water quality parameters inDanau Panggang, Indonesia, from July to September 2021

Parameters observed	*Monthly period*		
	July	*August*	*September*
Temperature (ºC)	27.5-30.3	26.7-28.2	26.1-27
pH	5.8-5.95	5-6	5.5-6
Dissolved oxygen (ppm)	2.5-2.9	2.1-4.3	2.2-2.6
NH3 (ppm)	0.14-0.15	0.05-0.16	0.15-0.3
Transparency (cm)	57-81	54-62	47-96
Depth (cm)	75-82	65-95	125-165

Conclusions. The sex ratio of snakeheads collected from Danau Bangkau was 1:1.1 (males to females). The highest GML was found in July, GML II (48%), then GML III (42%) in August and GML IV (40%) in September. In these periods, GML V was also recognized, which means that snakehead partially spawns throughout the year, and the peak of spawning season occurs in September and October when the rainy season starts. The GSI continues to increase in value over time, and the highest GSI obtained was 2.77% for males and 7.43% for females, in September.

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

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