Reproductive biology and dynamics of snakeskin gourami (*Trichopodus pectoralis*) larvae in Lubuk Lampam floodplain, Ogan Komering Ilir, Indonesia

[1]Eko Prianto, [2]Romie Jhonnerie, [3]Kamaluddin Kasim

[1] Aquatic Resources Management Department, Faculty of Fisheries and Marine Science, Universitas Riau, Indonesia; [2] Fisheries Resources Utilization Department, Faculty of Fisheries and Marine Science, Universitas Riau, Indonesia; [3] Fisheries Research Center, Ministry of Marine Affairs and Fisheries, Indonesia. Corresponding author: E. Prianto, eko.prianto@lecturer.unri.ac.id

Abstract. The snakeskin gourami (*Trichopodus pectoralis*) is one of the most popular commercial freshwater fish in Sumatera. This research was conducted from November 2012 until November 2013 in Lubuk Lampam, Ogan Komering Ilir district. It is aimed to studying the reproduction aspect and dynamics of snakeskin gourami in the floodplain of Lubuk Lampam, Indonesia. Fish and larvae samples were collected within a year from November 2012 to November 2013. Fish samples were collected using nets and traps, while a scope net, with a 500 μm mesh size, was used to gather larvae. 865 individual fish were observed, consisting of 566 females and 299 males. The body length of females and males ranged from 59 to 192 mm and 53 to186 mm, respectively. The sex ratio for the entire sample was 0.53 to 1, males to females. Both males and females have experienced gonad maturity level (GML) I from January to November 2013, while matured fish that experienced GML IV were predominantly found during two months, from November to December. Both females and males had ripe gonads at a length of 165 mm, and 173 mm, respectively, with an average fecundity of 17.885±16.056 eggs. The diameter of eggs ranged from 0.369 to 1.058 mm, and the spawning was simultaneous. In terms of spatial distribution, fish larvae were found in some stations such as Kumpai Kanan, Kumpai Kiri, Lebung Proyek, and Suak Buayo, mostly in August, November, and December, with abundance ranging between 0 and 500 ind. 100 m^{-3}.

Key Words: freshwater fish, reproduction aspect, spatial and temporal distribution of larvae.

Introduction. Snakeskin gourami (*Trichogaster pectoralis*), with the synonym *Trichophodus pectoralis* (Vann et al 2006; Paepke 2009; Low & Lim 2012) is a freshwater fish that has a high fecundity (Amornsakun et al 2004), and can live in acidic waters and in low oxygen waters (Moyle & Cech 1988; Arenas & Acero 1992). The genus *Trichogaster* consists of several species, but the most popular commercial species in trade is the snakeskin gourami. This fish is categorized as an economically important freshwater fish and it is mostly caught in floodplains (Baishya et al 2012) in Southeast Asia. Although the species is known to be an introduced species in Indonesian waters (Robison 1975; Welcome 1988; Hoggarth & Utomo 1994; Syaifuddin et al 2019), the fish has been widely distributed throughout Southeast Asia and are also found in the lakes of Papua (Umar & Makmur 2006; Boonanuntanasarn et al 2020). In some countries, the genus *Trichogaster* or *Trichophodus* is reported as alien (Pallewatta et al 2003; Firmat & Alibert 2011). In Indonesia, farming of snakeskin gourami rarely has been done due to the abundance of this fish in inland fisheries, while in Thailand, the farming of snakeskin gourami exists in rice fields (Little et al 1996).

Snakeskin gourami can live in acidic waters, and it is able to live its entire life in swampy areas. The Ostariophysi superorder and Labyrinthodontia generally live in swamps, including species like snakehead (*Channa striata*), carps (*Macrones nigriceps*), and pearl gourami (*Trichogaster leeri*) (De Graaf et al 1994; Sulistiyarto 2008). The fish is omnivorous, but can be herbivorous (Little et al 1996; Amornsakun et al 2004), when moss and algae are found in the waters. Snakeskin gourami spawns during the rainy season when the water rises. The fertilized eggs are placed on a froth until they hatch. Farmed snakeskin gourami have a maturation total length of 18.07±1.1 cm with a weight of 94.2±13.39 g (Amornsakun et al 2004). The size of snakeskin gourami larvae on day 0 is about 2.3 mm and on day 16 it is about 8.2 mm (Marioka et al 2010).

Snakeskin gourami production in Indonesia has decreased dramatically. According to FAO (2009), snakeskin gourami production was 30407 tonnes in 1996 and decreased substantially to 20075 tonnes in 2004. Snakeskin gourami is the main commodity of fishermen, together with climbing perch (*Anabas testudineus*) in Lubuk Lampam (Hoggarth & Utomo 1994). The capture of snakeskin gourami by various fishing gears such as sengkirai (traps), kilung (filtering nets), gill nets, tugok (filtering device), and pengilar (wire pot trap) is carried out when the water rises in November-December and when the water level decreases in April-November. The existence of fish in Lubuk Lampam, including snakeskin gourami, has decreased (Hoggarth & Utomo 1994). This condition was caused by a degradation of Lubuk Lampam and the overexploitation of fish. Management is needed in the sustainable use of water resources in the floodplain. Once the basic information about the species is explored in more depth and detail, it should help in the management efforts. One of the indispensable pieces of information are aspects of reproduction and dynamics of snakeskin gourami larvae.

Reproduction and the dynamics of fish larvae are fundamental aspects in fish biology and are essential for management purposes. Assessment of sex and gonadal maturity levels (GML) constitute basic knowledge regarding the reproductive biology and potential. Simultaneously, the dynamics of larvae can provide the location of spawning and nursery grounds. The development of gonad maturity and larvae dynamics can be associated with the fish size, the length at first maturity, as well as with the spatial and temporal distribution. This information can be used in selecting the fishing gear. In addition, this information can be used for habitat management to determine conservation areas (Makmur et al 2003). Based on the description above, the aim of this research is to explore the reproductive aspects, but also the dynamics of snakeskin gourami larvae in Lubuk Lampam floodplain.

Material and Method

Description of the study sites. The study was conducted in Lubuk Lampam floodplain, Ogan Komering Ilir Regency, South Sumatra Province, Indonesia (Figure 1). The larvae were collected from seven different sampling plots namely Belanti, Kumpi Kanan, Kumpai Kiri, Rawang Kanan, Rawang Kiri, Lebung Proyek, Suak Buayo, and Kapak Hulu. Observations were conducted from November 2012 to November 2013, when the water rised, when it inundated the floodplain, at maximum flood, and at its retreat. The number of sampling sites was based on habitat characteristics and dynamics of water: swamp forest (2 points), floodplain pools (2 points), flooded grassland (2 points) and the main river (2 points). Sampling of fish and fish larvae and environmental data/habitat observations were conducted every month.

The design of the study. Larvae of snakeskin gourami were collected using a scoop net with a mesh size of 500 µm. The scoop net had a size of 0.125 m^2, with a diameter of 30 cm and a length of 2 m with a cod-end length of about 0.4 m (De Graaf et al 1999). Larvae samples were collected from a depth of 30 cm. The scoop net was deployed for approximately 10 min and the captured samples were placed in a bottle for preservation, with formalin 4%. Identification of snakeskin gourami larvae was done according to the Mekong River Commission (2013) and Marioka et al (2010).

The fishermen collected fish samples once the water was level is high using various fishing gear such as gill nets and traps. Sampling was conducted monthly, starting when the water had risen and until it retreated and fish were finished spawning. The length and weight of individuals were determined. The gonadal maturity was recorded using visual observations through dissection. Gonadal observation was conducted to determine the sex, fecundity, reproductive potential, gonadal somatic index, and gonadal maturity level.

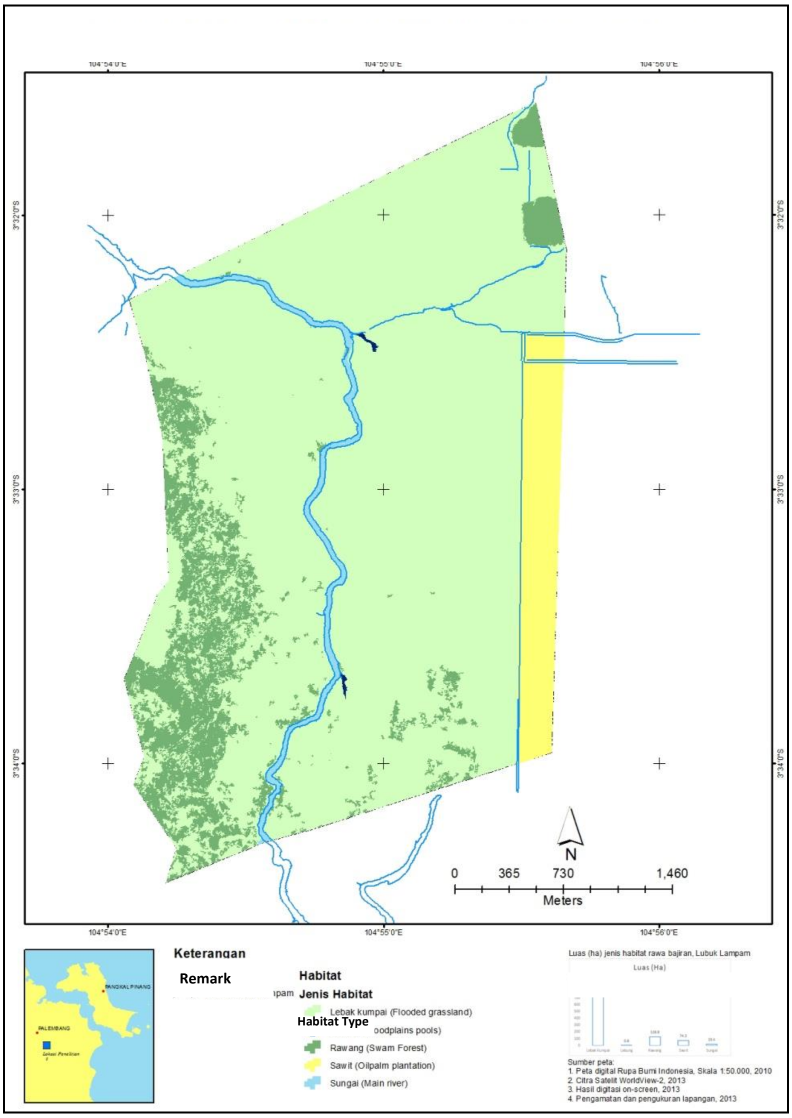

Figure 1. Sampling site.

Frequency distribution of snakeskin gourami. The number of length classes was determined using the Sturges formula (Sugiyono 2003):

$$K = 1 + (3.32 \times \log n)$$

Where: K is the number of length classes; n is the number of data observations. The length-weight relationship analysis was carried out to determine the patterns of fish growth:

$$W = aL^b$$

Where: W is the weight of fish (g), L is the total length (mm), and a and b are constants.

Reproductive biology. For the analysis of reproductive biology, the following parameters were determined: sex, gonadal maturity level (GML), gonad weight, and gonadal somatic index (GSI).

Sex ratio was calculated based on the number of males and females at each sampling site. Sex was determined after the dissection of each individual. To determine the sex ratio, we applied the Effendie (1997) formula as follow:

$$Nk = \frac{M}{F}$$

Where: N_k - sex ratio; M - total number of males; F - total number of females.

The chi-square test (Gaspersz 1991) was used to determine whether the data was normally distributed.

The gonadal maturity levels were determined morphologically by visual observations, including color, shape and size. Gonadal development was qualitatively determined by observing gonadal maturity levels (I-IV) based on a gonadal morphology guide (Effendie 1979).

The GSI can be calculated by the following formula (Effendie 1979):

$$GSI (\%) = (Bg/Bt) \times 100$$

Where: GSI - gonado-somatic index; B_g - gonad weight (g); B_t - body weight (g).

Prediction of the size at first maturity was calculated using the Sperman-Karber equation (King 1995). Criteria of gonadal maturity are GML III, IV, and V, with the formula:

$$LogM = X_k + \frac{\bar{x}}{2} - (\bar{x}\sum Pi)\ ;\ \mathrm{Pi = ri/ni}$$

Where: X_k - logarithm of middle value when the gonads mature at 100%; $\bar{x}$ - average of difference of logarithm middle value; ri - the number of mature gonads from class i^{th}; ni - the total number of fish, M – mean length of first time maturity size, Pi – proportion of mature fish in i-length class.

Reproduction potential can be predicted from the fecundity value, which is the number of eggs in the fish ovaries that reached GML IV. The eggs from females were extracted. The fecundity was calculated by the gravimetric method (Effendie 1979):

$$F = G/Q \times N$$

Where: F - fecundity (ova); G - gonad weight (g); Q - sample of gonad (g); N - number of eggs from the sample.

Reproductive patterns can be estimated by measuring the diameter and patterns of eggs distribution of the individual fish sample in the anterior, middle, and posterior of the fish using a Dinolite camera with magnification 100x. Once the patterns were observed, the spawning could be further investigated to determine whether it occurs in a long period, or it is released only partially, known as partial spawning.

Dynamic of fish larvae. The determination of larvae spatial and temporal distribution was based on the identification of larvae plotted on the sites under the recorded GPS coordinates and time of capture.

Abundance of larvae is defined as the number of larvae in each volume unit of the sampling site, and was calculated with the formula:

$$N = n/Vtsr$$

Where: N - fish larvae abundance (ind m^{-3}); n - the number of fish larvae (ind); Vtsr - the volume of water filtered.

$$Vtsr = l \times t \times v$$

Where: l - the width of the scoop net; t - the time of using the scoop net (minutes); v - the towing speed (m per minute).

Results and Discussion

Frequency distribution of snakeskin gourami. 865 snakeskin gourami were obtained during the sampling period, consisting of 566 females and 299 males. The data analysis shows that females had ten classes of total length, and the males had nine classes of total length. The female and male lengths varied from 59 to 192 mm and 53 to 186 mm, respectively. The highest female frequency was in the interval between 129 and 142 mm, 208 fish, while the highest frequency of males was in the interval between 133 and 148 mm, with 108 individuals. The chi-square test result ($p<0.05$) showed that the length data of snakeskin gourami was normally distributed.

Length-weight relationship. Length-weight relationship analysis for females follows the relationship $W=0.00002\ L^{2.94}$, where b is 2.94. For males, the length-weight relationship formula is $W=0.00002\ L^{2.928}$, where b is 2.928. The correlation coefficient (r) of the length-weight relationship of females and males was high, 0.93 and 0.95, respectively (Figure 2). T-test analysis shows that female and male growths follow a negative allometric pattern, meaning that the body's length grows faster than the bodyweight.

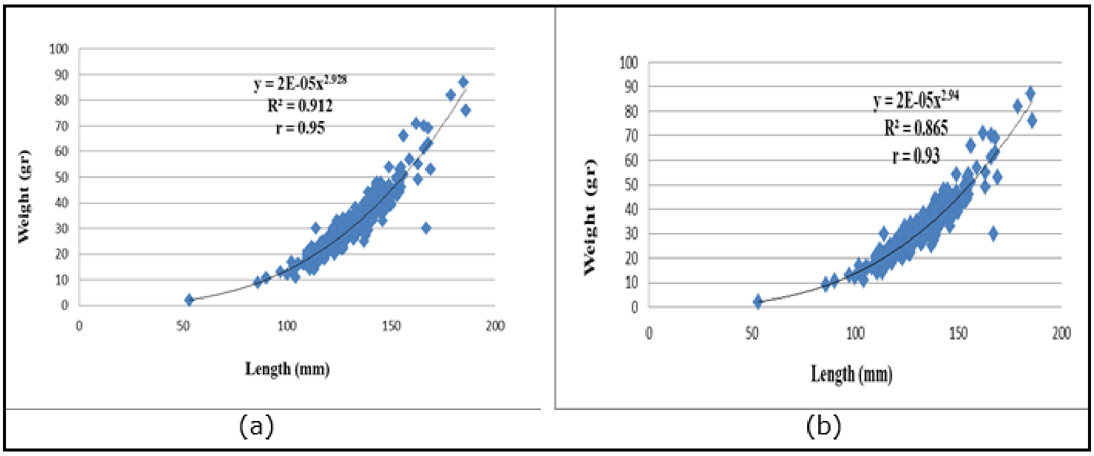

Figure 2. Length-weight relationship of snakeskin gourami (*Trichopodus pectoralis*): a - male; b - female.

Sex ratio. The sex ratio (females to males) was 1:0.53. According to the sampling period, the sex ratio ranges from 0.26 to 3.45. The highest sex ratio recorded in January, 3.45, and the lowest sex ratio (0.26) occurred in April (Figure 3).

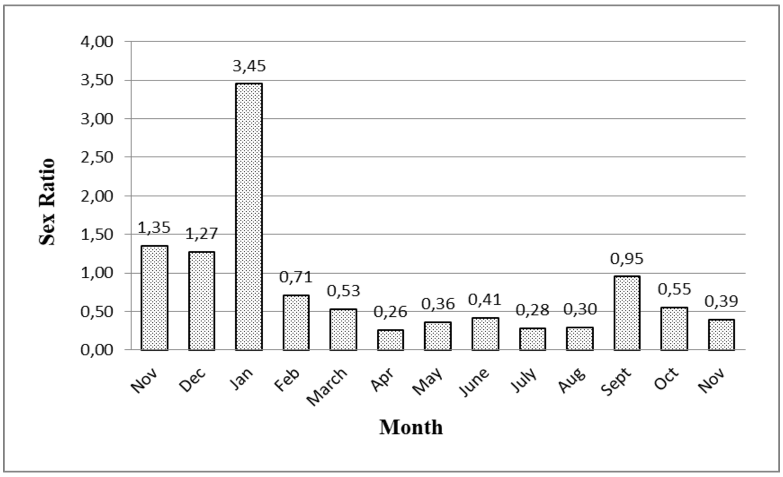

Figure 3. The sex ratio of snakeskin gourami (*Trichopodus pectoralis*).

Gonad maturity levels (GML). In males, GML I occurred from January to November, while GML IV was found in November and December, as well from August to November. For females, GML I occurred from January to November, while GML IV was found in November and December, as well from July to November. All the fish captured in November and December had GML IV (Figure 4).

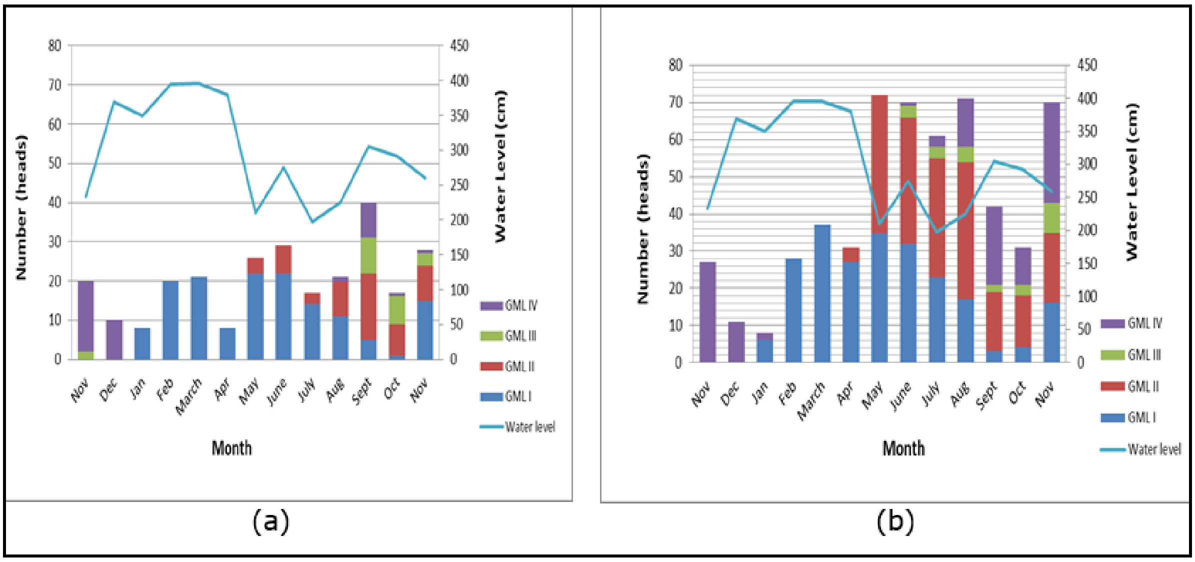

Figure 4. Percentage of gonadal maturity level (GML) of male (a) and female (b) *Trichopodus pectoralis* according to month.

Gonado-somatic index (GSI). For males, the lowest value of GSI found was in GML I, ranging from 0.076 to 0.1538%, with a mean of 0.1153±0.0769%, while the highest was in GML IV, ranging from 0.952 to 2.778%, with a mean of 1.865±0.913%. For females, the lowest value of GSI was found in GML I, ranging from 0.2988 to 1.6447%, with a mean of 0.6373±0.6716%. The highest GSI for females was found in GML IV, ranging from 5.66 to 38.93%, with a mean of 22.295±16.635%. The GSI of males and femals increased from GML I to GML IV, following the increase of the size of the gonads.

The size at first maturity. The snakeskin gourami females have first matured at 165 mm, and males matured at 173 mm total length. Therefore, females have experienced faster maturity than males.

Reproduction potential. The fecundity of snakeskin gourami was determined by analyzing over 39 matured individuals, with 17 gonads in GML III and 22 in GML IV. The total number of eggs varied from 1369 to 56053, with an average of 17885±16.056 eggs. The lowest number, 1369 eggs, was recorded from a sample in GML III and 128 mm total length. The highest frequency, 56053 eggs, was recorded from a sample with GML IV and a total length of 146 mm.

Reproduction pattern. The egg diameters from 39 gonad samples range from 0.369 to 1.058 mm. The diameter distribution varies in GML III and IV, showing that only one egg cohort curve was produced during the spawning season (Figure 5). This fact reflects that the eggs of snakeskin gourami have matured approximately at the same time. It is assumed that snakeskin gourami spawns only once a year, confirmed by the distribution of egg diameters.

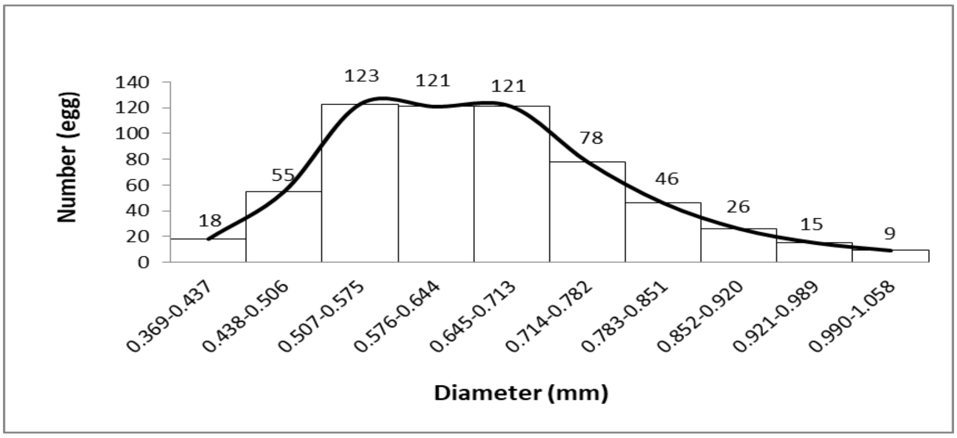

Figure 5. Eggs diameter distribution of snakeskin gourami (*Trichopodus pectoralis*).

Spatial and temporal distribution of larvae. 132 larvae were collected, widely distributed in Kumpai Kanan, Kumpai Kiri, Lebung Proyek, and Suak Buayo station (Figure 6). Kumpai Kanan and Kumpai Kiri stations are sub-ecosystems with floodplains dominated by Gramineae vegetation. Lebung Proyek and Suak Buayo are sub-ecosystems of a swamp, predominantly covered by aquatic vegetation such as water hyacinth (*Eichhornia crassipes*) and *Narcissus* sp. This vegetation plays an essential function as a shelter and food source for newly hatched larvae and also as a spawning ground. Periodically, the larvae could only be found in August, September, November, and December, when the water began to rise until the floodplain was flooded.

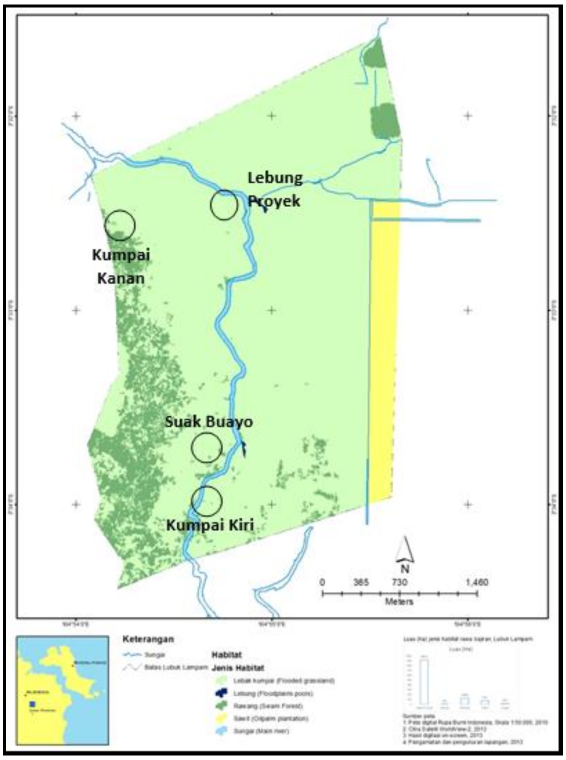

Figure 6. Map of distribution of snakeskin gourami larvae in the floodplain of Lubuk Lampam, Indonesia.

Abundance. A high water level influences the existence of snakeskin gourami larvae. The abundance of larvae also is affected by sub-ecosystems of their habitat. Based on the sampling station, the larva distribution shows the abundance of larvae ranged from 0-100 individual/ m^3 of fish. The highest abundance was found in Kumpai Kiri and Lebung

Proyek with 100 individuals per m^3, subsequently in Suak Buayo with 46 individual per m^3, and in Kumpai Kanan with 4 individuals per m^3. There were no larvae found in other stations (Figure 7).

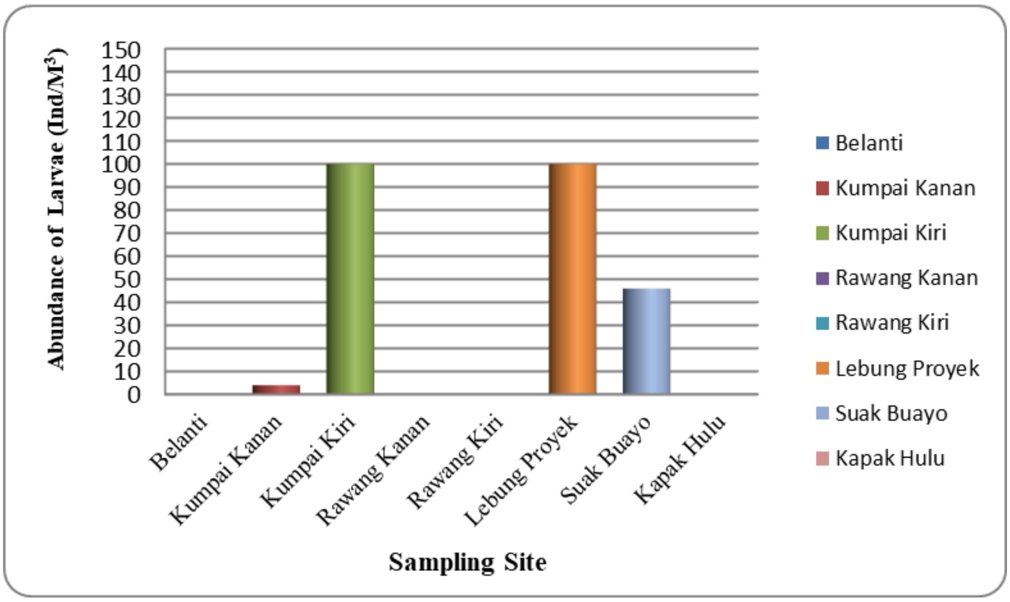

Figure 7. The abundance of snakeskin larvae according to the sampling site.

Snakeskin gourami is one of the freshwater fish widely distributed in Indonesia and has become the dominant species. The total length of snakeskin gourami is proportional to the total body weight. Walpole (1995) states that if the value of the correlation coefficient (r) is close to 1, then the total length and weight are highly correlated.

The sex ratio of the snakeskin gourami has fluctuated on a monthly basis in this study. The ratio reflects the higher number of females compared to males, with an exception in December. Like the sex ratio, the gonadal maturity stage (GMS) of snakeskin gourami also fluctuates monthly. The matured females with GMS III and IV were predominantly found from June to November, and in December, with a GMS ratio of 31 to 69% and 59 to 41%, respectively. Like the females, most of the matured males had a GMS of III and IV, which were recorded in November and December, showing a ratio of 50 to 44% and 69 to 23%, respectively. The immature males, with GMS I and II, were mostly found from January to July.

A visual observation during the research shows that the water level fluctuation might influence the spawning season. Weber (1976) stated that the spawning season of tropical fish is closely related to the region's hydrography factor.

The fact that mature females with GMS III and IV have been found from June to November during this research is uncommon, since studies show that floodplain fish, like snakeskin gourami, commonly spawn early in the rainy season. This phenomenon is arguable due to the high water level fluctuation during the season. Thus, this condition could trigger the fish to release their eggs. In Indonesia, the rainy season is caused by the negative impact of the Indian Ocean Dipole (IOD) against Indonesia, generally occurring from June to November (www.antaranews.com). During the time of study, the dry season was interspersed with rain and known as the wet-dry season. This phenomenon caused the water level in Lubuk Lampam to fluctuate, causing floods to occur throughout the year. The GSI of females was higher than the GSI of the same species reported by Amornsakun et al (2004), where it was 10.9% and 10.4% for females. Most of the freshwater fishes have GSI ranging from 8 to 10% (Prianto 2015). As a comparison, according to Rukdontri et al (2020), the GSI of snakeskin gourami ranged from 10.26±0.36%. Therefore, the GSI of snakeskin gourami in Lubuk Lampam has appropriate values, as can be seen from the large size of the gonad of the female fish samples. The large size of the gonads is presumably due to the availability of food.

In terms of size at first maturity, the females with the size of 165 mm have matured faster than males, which matured mostly when reaching 173 mm. This finding is different from the results of Tampubolon & Rahardjo (2011), where males of snakeskin gourami in Taliwang lake have matured faster than females. Tampubolon & Rahardjo (2011) reported that the sizes at the first maturity of males and females were 134 mm and 136 mm, respectively. Furthermore, they explained that most of the snakeskin gourami in Taliwang lake had matured gonads in July. The difference in size at first maturity and peak season of gonad maturity might be explained by the complex processes of the two different ecosystems. The Lubuk Lampam is a floodplain ecosystem influenced by season, where the water level rises at maximum levels during the rainy season, but recedes during the dry season. This extreme water level fluctuation in the Lubuk Lampam floodplain may trigger the snakeskin gourami to spawn in the early rainy season in November.

The fecundity of snakeskin gourami in Lubuk Lampam floodplain ranged from 1369 to 56053 eggs, with an average of 17885 eggs. Tampubolon & Rahardjo (2011) reported that the total fecundity of snakeskin gourami in Taliwang lake ranged from 1140 to 7986 eggs. Amornsakun et al (2004) recorded 26261-31476 eggs, while Rukdontri et al (2020) found that the fecundity of snakeskin gourami were at least 2318±262 eggs. Diana et al (1985) stated that, in Thailand, snakeskin gourami spawned generally during the rainy season (May to September), and fish fecundity ranged from 20000 to 40000 eggs. Djuhanda (1981) states that fecundity is affected by the quality of food, fish size, and environmental conditions.

The eggs of snakeskin gourami had a diameter between 0.6-1.07 mm. The diameter of eggs varied. Amornsakun et al (2004) showed that the diameter of eggs from snakeskin gourami was 0.908±0.39 mm. The egg looks similarly distributed in size, confirming that the spawning pattern can be categorized as simultaneous spawning. The larvae were found only in some stations, namely Kumpai Kanan, Kumpai Kiri, Lebung Proyek, and Suak Buayo. The four stations are characterized by several aquatic vegetation species and have a slow water current. At Kumpai Kiri and Kumpai Kanan stations, freshwater plants from the Gramineae family dominate the habitat and cover the floodplain areas almost entirely. In contrast, Lebung Project and Suak Buayo stations are flooded throughout the year and covered by aquatic vegetation such as water hyacinth (*Eichhornia crassipes*) and "kumpai" (*Huperzia serrata*). Snakeskin gourami can live easily in swamps or stagnant waters. According to the Mekong River Commission (2013), snakeskin gourami larvae (yolk-sac larvae) live in swamp and floodplain habitats, having a size of about 2.7 mm at hatching. Another study conducted by Holland (1986) stated that the highest concentration of fish larvae is mostly found in a floodplain ecosystem such as in Lebung area or in areas with slow water current, with aquatic vegetation.

In terms of spawning behavior, snakeskin gourami builds a nest that resembles bubbles or froth to lay their eggs. These bubbles stick on grass (Gramineae), being protected against currents, wind, and rain. The high density and extent of "kumpai" vegetation can provide enough space and food for the larvae to grow and thrive, since they are herbivorous. Ali et al (1988) stated that the distribution and composition of fish species in a habitat are closely connected with food availability, location of spawning, water flow, depth, topography, and water quality. Jurajda et al (2004) stated that the timing of flooding and water temperature are essential for reproducing in phytophilous and phytolithophilous fish. Flooded vegetation affects fish abundance by creating structurally complex habitats that provide more food and shelter (Jurajda et al 2004). High food availability and higher temperatures in flooded areas support many juveniles that could proliferate and have an increased survival rate. Larvae of snakeskin gourami in Lubuk Lampam could be found only in November, December, August, and September, with abundance ranging up to 500 individual per m^3.

The spawning of snakeskin gourami is closely related to the fluctuation of water level throughout the year. Snakeskin gourami spawned in the early rainy season due to the availability of high oxygen concentration, good water quality, neutral pH, and abundance of freshwater availability. The water level began to rise and enter through the canal, then overflowed in around the swamps. According to the observations during the research, the fish had stopped spawning in January, since rainwater gradually flooding the swamps reached maximum level from February to July. Hoggarth & Utomo (1994) stated that the spawning season occurs in November once the rainy season has started. Gogola et al (2010) and Wanner et al (2011) said that the density of larvae is influenced by the water's physical and chemical properties such as pH, temperature, conductivity, turbidity, dissolved oxygen, and rainfall. The snakeskin gourami was also found in Suak Buayo in August and September, with a small abundance, probably because of weather anomalies in the research location. August was a dry season, but the IOD can affect the dry season, interspersing it with rain. Thus, the water level fluctuated. Hence, these water fluctuations could trigger the spawning. Vilizzi (2012), Baumgartner et al (2003), and Gogola et al (2010) stated that spawning in the floodplain is influenced by water level fluctuations, which depend on season.

Conclusions. The sex ratio of snakeskin gourami in Lubuk Lampam was unbalanced, with more females than males. Females matured faster than males. According to egg diameter distribution, their spawning occurs in a single period, the species being classified as a total spawner. The spawning season of the species is influenced by water level fluctuation that reaches the peak in November. The spawning areas are mostly characterized by overgrown aquatic vegetation. The larvae were found only in the early rainy season, when water began to rise in the swamp.

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

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Authors:
Eko Prianto, Aquatic Resources Management Department, Faculty of Fisheries and Marine Science, Universitas Riau, Jl. Raya Pekanbaru-Bangkinang km. 12.5 Sp. Baru, Pekanbaru, 28293 Riau, Indonesia, e-mail: eko.prianto@lecturer.unri.ac.id
Romie Jhonnerie, Fisheries Resources Utilization Department, Faculty of Fisheries and Marine Science, Universitas Riau, Jl. Raya Pekanbaru-Bangkinang km. 12.5 Sp. Baru, Pekanbaru, 28293 Riau, Indonesia, e-mail: romie.jhonnerie@gmail.com
Kamaluddin Kasim, Fisheries Research Center, Ministry of Marine Affairs and Fisheries, BRSDMK II Building, 2nd Floor, Jl. Pasir Putih II Ancol Timur, 14430 Jakarta Utara, Indonesia, e-mail: kamaluddin.kasim@kkp.go.id

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