Population dynamic and spawning potential ratio of Asian redtail catfish (*Hemibagrus nemurus*) in the flooded swamp of Tasik Giam Siak Kecil waters, Bengkalis, Riau Province, Indonesia

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Abstract. The high market demand for Asian redtail catfish (*Hemibagrus nemurus*) has caused intensive fishing for this resource, which may threaten its sustainability. Studies of population dynamics and spawning potential ratio (SPR) are the main foundations for formulating a management for sustainable utilization. The purpose of this study was to determine the stock status of Asian redtail catfish in the flooded waters around Tasik Giam Siak Kecil, Bengkalis Riau Province. The study was conducted from April to November 2019, using a survey method. The study results revealed that the Asian redtail catfish growth pattern was negatively allometric and that the ratio of males and females was unbalanced. The length at first capture (Lc) and length at first maturity (Lm) were 18.1 cm and 21.56 cm, respectively. The growth rate (K) and maximum total length (L∞) valued 0.61 per year and 37.8 cm, respectively. The estimated total mortality rate (Z) was 2.8 per year, the fishing mortality rate (F) and natural mortality rate (M) were 1.53 per year and 1.27 per year, respectively. Recruitment occurred throughout the year with one peak in June. The exploitation rate (E) was 0.55 per year and the spawning potential ratio (SPR) was 6.8%. Therefore, the stock status was categorized as overfished. In order to ensure the sustainability of the Asian redtail catfish, precautionary approaches such as reducing fishing effort are strongly needed.

Key Words: exploitation rate, growth pattern, length at first capture, mortality, sustainable utilization.

Introduction. Asian redtail catfish (*Hemibagrus nemurus*) is one of the important fisheries products with high economic value in public waters (Muflikhah et al 2006). The Asian redtail catfish is a member of the family Bagridae, from the Siluriformes order (Djajadiredja et al 1977). The barbels reach the eye and the upper jaw barbel can reach the anal fin. The distribution of Asian redtail catfish in the world is wide, covering Africa, southeast and eastern Asia (Kottelat et al 1993). In Indonesian waters, the catfish can be found in Sumatra, Borneo, and Java islands (Djajadiredja et al 1977). The catfish is able to live in Ranau Lake waters, as well as in the upstream and downstream of several rivers such as Musi, Batanghari, Kampar, and Barito (Gaffar 1983; Samuel & Said 1995; Husnah & Gautama 2003; Prasetyo et al 2004).

The habitat of the Asian redtail catfish is represented by fresh waters, rivers, lakes, and brackish waters, and flooded swamps such as Tasik Giam Siak, Kecil area (Sukendi 2001). The utilization of the Asian redtail catfish from the waters of Tasik Giam Siak Kecil has been intensive due to high market demand of the resource. A very high level of exploitation would threat to sustainability of the stock.

There is insufficient data about catch, effort, and biology of the Asian redtail catfish in Sumatra and Riau waters. Therefore, this research aims to identify some of the population dynamics parameters of Asian redtail catfish and bring information regarding the spawning potential ratio (SPR) of the fish. Hopefully, the information can be used to manage the sustainability of Asian redtail catfish stock in waters of Tasik Giam Siak Kecil, Bengkalis, Riau Province, Indonesia.

Material and Method

Description of the study sites. This research was carried out in the waters of Tasik Giam Siak Secil, Bengkalis, Indonesia (Figure 1) from April to November 2019, using several survey methods. Monthly data collection was done by placing several enumerators in research areas. The fishermen questioned used mainly gillnets and traditional traps named "lukah". Fishing activity assessment and Asian redtail catfish sample measurements were conducted in the main place of fishermen activity around Tasik Giam Siak Kecill areas.

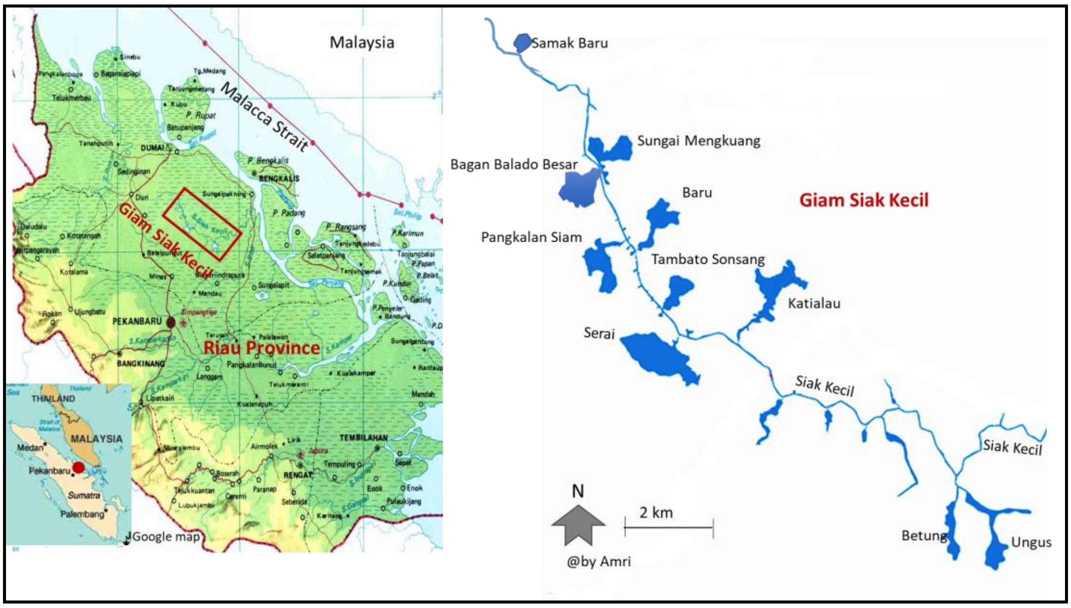

Figure 1. Fishing ground of Asian redtail fish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

Biological assessments. The biological aspects observed were total length, weight and sex. Sex was determined by dissection and observing the reproductive organs. Sex ratio was determined, and a comparative analysis of the observed sex ratio and expected sex ratio can be made by using the chi-square test, as follows (Wujdi et al 2015):

$$X^2 = \sum(Oi - Ei)^2 \; Ei$$

Where: X^2 - Chi-square value; Oi - the frequency of male/female fish observed; Ei - the expected frequency. The function of chi square test is to justify the balance of the sex ratio of females and males.

The relationship of total length and weight was characterized by the equation $W=aL^b$ (Ball & Rao 1984), where W is the fish body weight (g), L is the total length (cm), a is a constant value and b is the exponential value. The length at first capture (Lc) was obtained by logistical function approach with the equation of Sparre & Venema (1992):

$$S_{CL} = \frac{1}{1 + \exp\,(a - b * CL)}$$

Where: S_{CL} is the selectivity of the fishing gear; a and b are constants; CL is the fish length; Lc was obtained from a/b.

The length at first maturity (Lm) was determined based on the calculation method introduced by Udupe (1986):

$$m = X_k + \frac{X}{2} - \left\{X \sum p_i\right\}$$

$$anti\log\left[m \pm 1{,}96\sqrt{X^2 \sum\left(\frac{p_i x q_i}{n_i - 1}\right)}\right]$$

Where: m is the Lm logarithm value; X_k is the logarithm of the mean value when fish was 100% mature; X is the logarithm of the mean value; pi is the proportion of mature fish in class i, where $p_i = r_i/n_i$; r_i is the number of mature fish in class i; ni is the amount of samples in class i; qi=1-pi.

Growth patterns identification. The growth pattern was predicted by using the von Bertalanffy growth model (Sparre & Venema 1992):

$$L_t = L_\infty\left[1 - e^{-k(t-t_0)}\right]$$

Where: L_t is the total length of fish at age t; L_∞ is a theoretical maximum length; k is the growth rate; t_0 is a theoretical age at the zero length of fish.

The theoretical maximum length (L_∞) and growth rate (K) were analyzed by using ELEFAN I and FISAT II methods (Gayanilo et al 2005). The value of t_0 was predicted based on an equation introduced by Pauly (1983):

$$\text{Log}(-t_0) = (-0.3922) - 0.2752 \log L_\infty - 1.038 \log K$$

The value of natural mortality (M) was calculated using the Pauly equation based on average seawater temperature (T) (Pauly et al 1984):

$$\text{Log } M = (-0.0066) - 0.279 \log CL_\infty + 0.6543 \log K + 0.4634 \log T$$

The value of total mortality (Z) was determined based on length converted catch curve assessment with the FISAT II program (Pauly 1983; Gayanilo et al 2005). In addition, fishing mortality (F) and exploitation rate (E) were assessed with equations introduced by Sparre & Venema (1992):

$$F = Z - M$$

$$E = F/Z$$

Where: F - fishing mortality; Z - total mortality; M - natural mortality; E - exploitation rate.

The value of the spawning potential ratio (SPR) was estimated using fish length data (Hordyk et al 2014). Data input used in SPR analysis was the ratio of M/K, asymptotic length (L_∞), the proportion of 50% and 95% mature fish (L_{50}, and L_{95}), and fish length. Finally, the estimation of spawning potential ratio (SPR) was based on the comparison of mature potential between fished ($SSBR_{fished}$) and unfished ($SSBR_{unfished}$) catch according to the equation introduced of Goodyear (1993). Spawning potential ratio (SPR) determination was based on biological and growth parameters data. They were Lm, von Bertalanffy growth equation, length weight relationship, and early cohort.

$$SPR = \frac{SSBR_{fished}}{SSBR_{unfished}}$$

Results and Discussion. The catch composition obtained by gill nets consisted of several species of fish such as Asian redtail catfish, selais (*Kryptopterus schilbeides*), giant Malayan catfish (*Wallagonia leerii*), Indonesian snakehead (*Channa micropeltes*), lele catfish (*Clarias batrachus*), forest snakehead (*Channa lucius*), and kissing gourami (*Helostoma temminckii*). The catch was dominated by Asian redtail catfish (33%), followed by Indonesian snakehead (20%), selais (19%), and kissing gourami (15 %) (Figure 2).

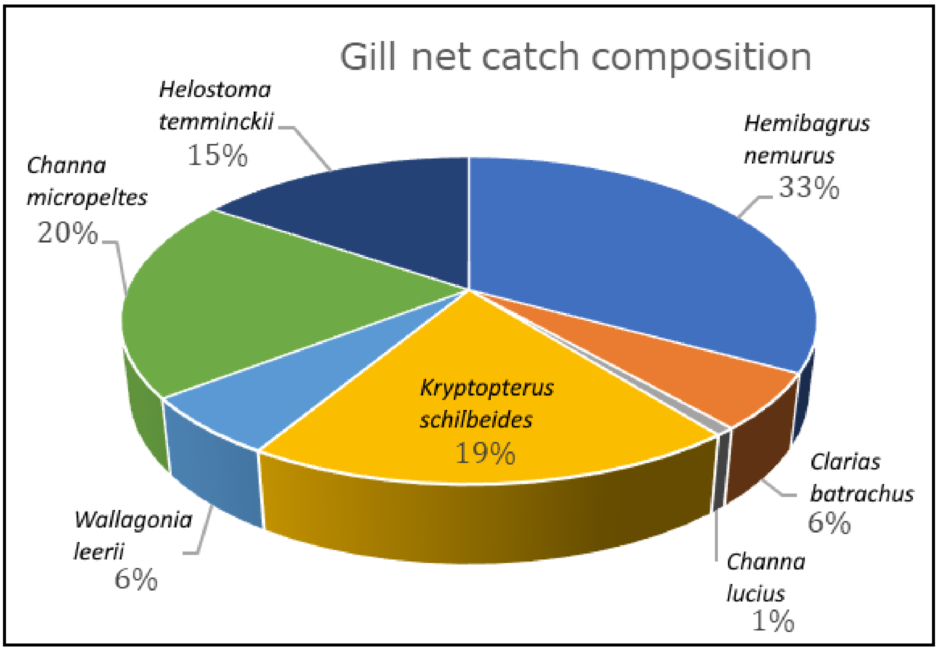

Figure 2. Gill net catch composition in Tasik Giam Siak Kecil, Bengkalis.

The trap catch was dominated by *W. leerii* (22.4%), followed by *C. micropeltes* (20.6%), *C. lucius* (17.8%), *K. schilbeides* (14.4%), and *H. nemurus* (13.2%). Other species caught, but in small number (less than 10%) were *H. temminckii*, Mullidae, *Trichopodus pectoralis*, *Parachela oxygastroides*, and *Ambassis kopsii* (Figure 3).

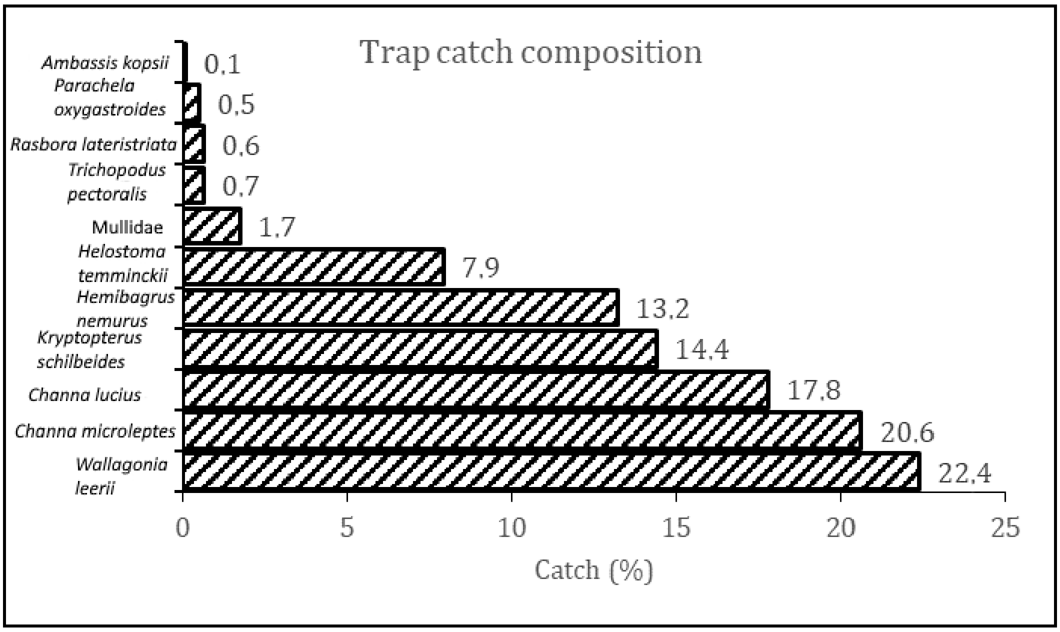

Figure 3. Traditional trap catch composition in Tasik Giam Siak Kecil, Bengkalis.

Length weight relationship and sex ratio of Asian redtail catfish. Asian redtail catfish captured during the survey had total length ranging from 8.7 cm to 37 cm, with the dominant number in the 16–20 cm interval (Figure 4).

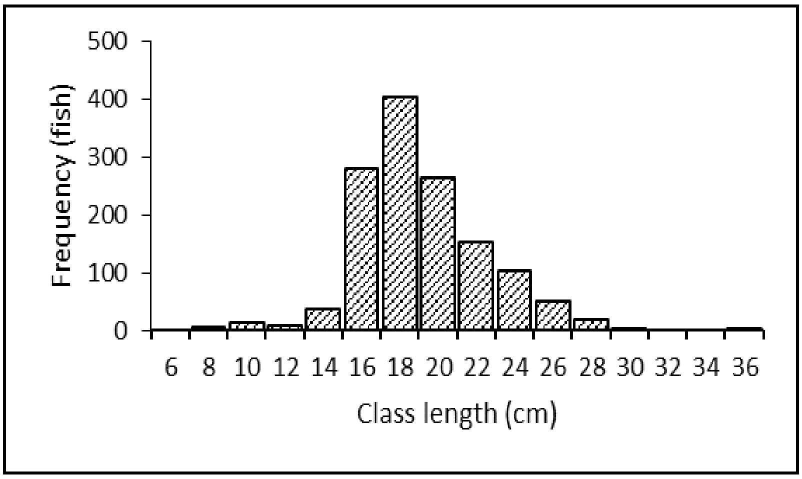

Figure 4. Length frequency of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

Length weight relationship analysis illustrated that the Asian redtail catfish had a negatively allometric growth (b=2.3986). This means that the increase in length is faster than the increase in weight (Figure 5). The sex ratio of males to females was 1:1.74. Based on the chi-square analysis, it was discovered that the sex ratio was unbalanced.

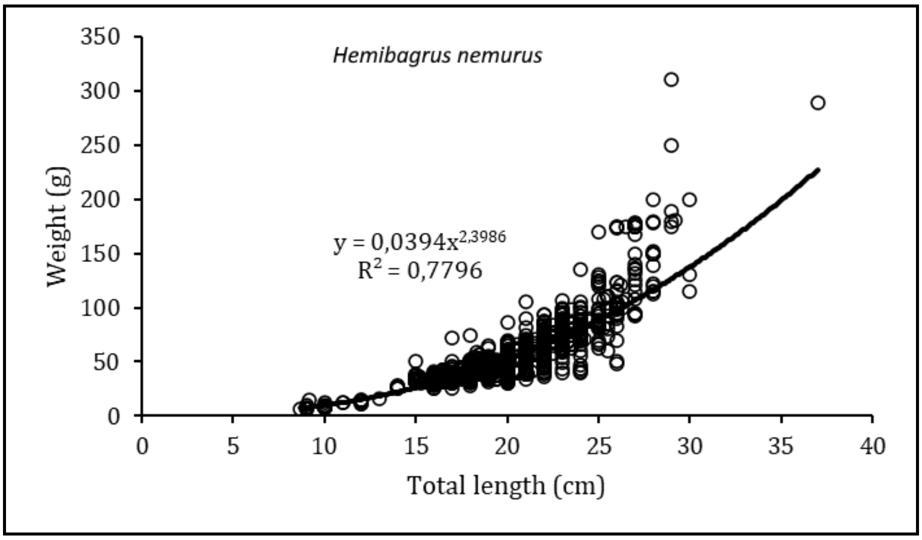

Figure 5. Length-weight relationship of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

Length at first capture (Lc) and length at first mature (Lm). Based on the results, it was observed that the average value of Lc of Asian redtail catfish in Tasik Giam Siak waters was 18.1 cm (Figure 6). The average value of Lm was 21.56 cm. This means that the value of Lc was smaller than that of Lm. This condition indicated that most of the Asian redtail catfish have been caught before spawning.

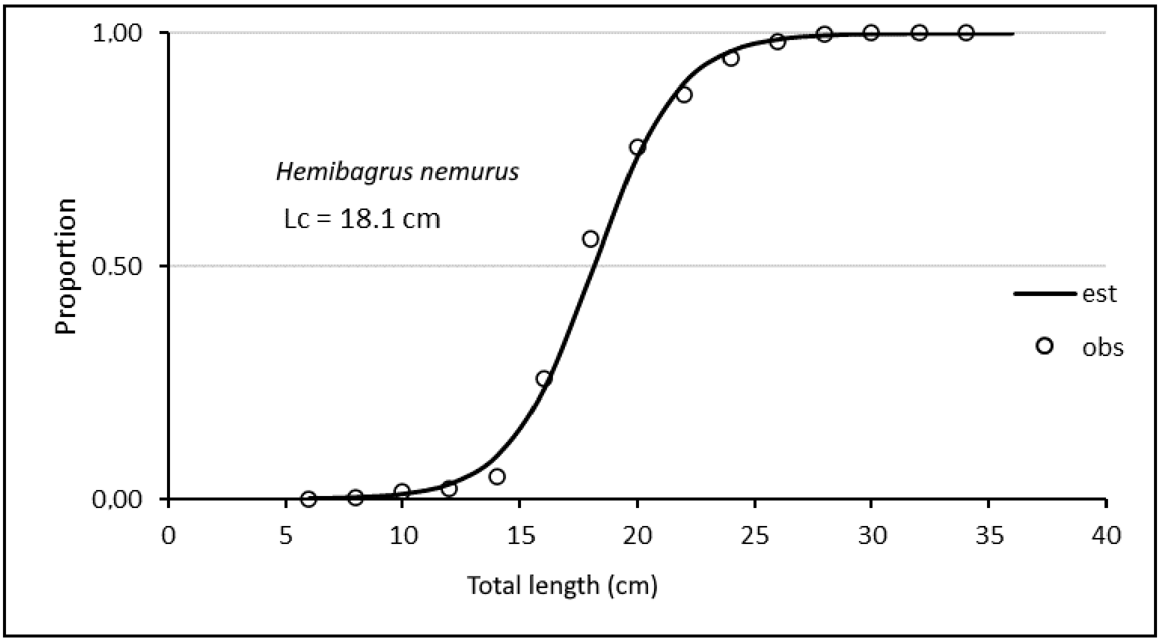

Figure 6. The length at first capture of Asian redtail fish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

Growth rate (k) and asymptotic length (L∞). Based on length frequency data, the growth rate (k) of Asian redtail catfish was 0.61 per year and L∞ reached 37.8 cm (Figure 7). Therefore, the equation of the von Bertalanffy growth curve was: $Lt=37.8\ [1\text{-}e^{-0.61(t\ +\ 0.25)}]$.

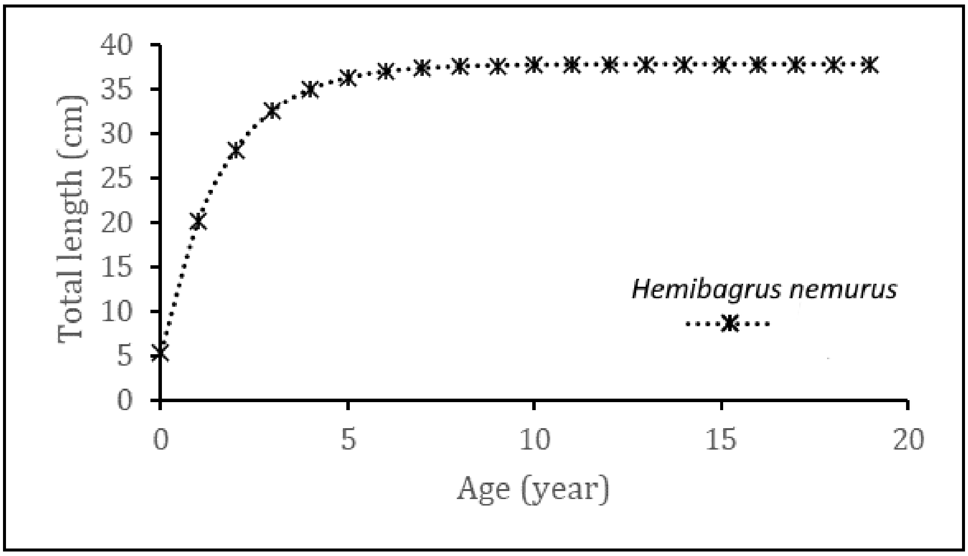

Figure 7. The von Bertalanffy growth curve of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

By using the Asian redtail catfish growth parameters calculation (K=0.61 per year, L∞=37.8 cm), the catch curve could be determined. The estimated values of Z, M, and F were 2.8, 1.27, and 1.53 per year, respectively (Figure 8). The exploitation rate (E) was estimated to be 0.55 per year. This condition showed that exploitation of the Asian redtail catfish reached overfishing levels. The recruitment pattern indicated that spawning activity took place throughout the year with a peak occurring in June (Figure 9).

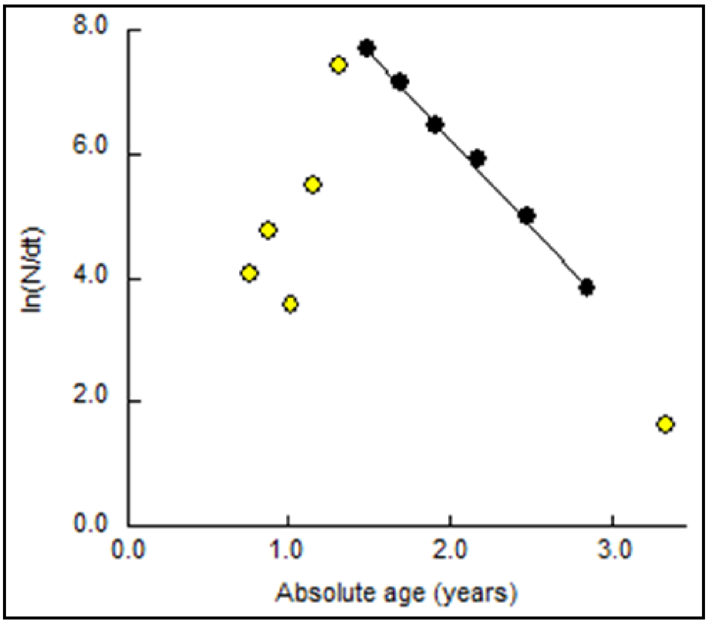

Figure 8. The catch curve of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

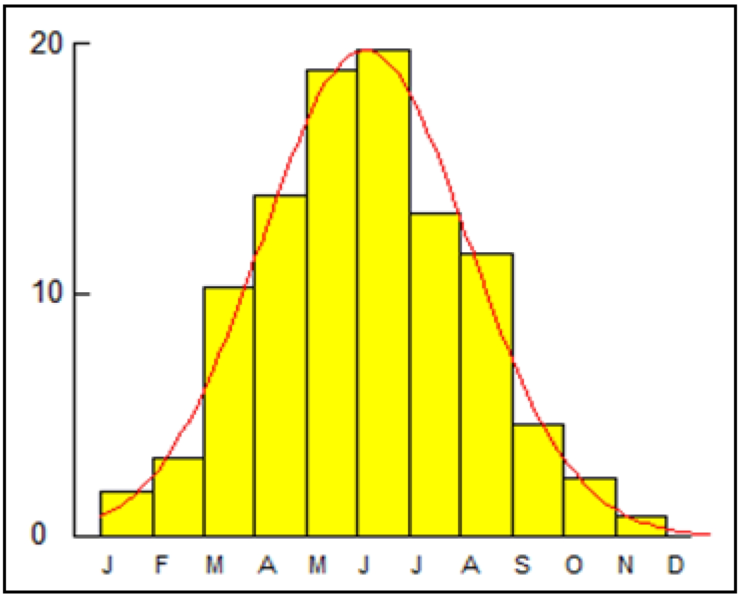

Figure 9. Recruitment pattern of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

Spawning Potential Ratio (SPR). It was found that the SPR of Asian redtail catfish was 6.8% (<20%) (Figure 10). This value was obtained from extrapolation between fish length and SPR below and above the Lm value. This result indicated that the Asian redtail catfish stock has been overfished.

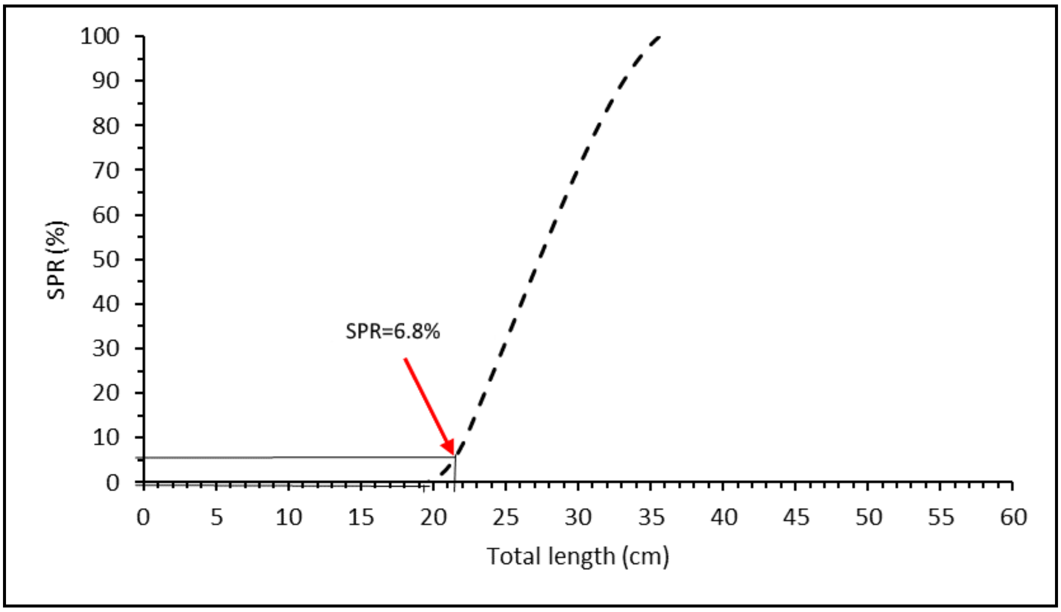

Figure 10. Spawning Potential Ratio (SPR) curve of Asian redtail catfish (*Hemibagrus nemurus*) in Tasik Giam Siak Kecil waters, Bengkalis.

The growth of the fish body length is faster than the growth of weight. This result is the same as that obtained in the waters of Batang Lembang and Batang Sumani (Wanda 2008), but different from results obtained in Batanghari River, Jambi Province, where the growth of the fish is isometric (Aida 2011). The existence of these differences is because individual growth models depend on food availability and water temperature. According to Effendie (2002), internal factors are factors that are generally difficult to control such as heredity, gender, age, and diseases. Meanwhile, the main external factors affecting fish growth are temperature and food.

The sex ratio of Asian redtail catfish in Tasik Giam Siak Kecil waters shows an unbalanced condition, where females of Asian redtail catfish are more dominant. The same phenomenon was also found in Lubuk Lampam waters, Ogan Komering Ilir (Prianto et al 2015). Meanwhile, a different status was observed in Binga River, Binjai, where the sex ratio between males and females was in a balanced state (Manurung et al 2013). According to Ball & Rao (1984), in normal waters, the sex ratio should be 1:1. The causes of differences in sex ratios can also occur due influence by arrest pressure and migration factors (Edrus & Syam 2004).

The size of Asian redtail catfish at maturity is important in fisheries management. The exploitation must allow a certain number of adult Asian redtail catfish reaching maturity to reproduce (Sudjastani 1974). The average Lm of Asian redtail catfish at Tasik Giam Siak Kecil is 21.56 cm is larger compared to Lc, which is 18.1 cm. The average Lm in various waters is influenced by food availability and other environmental conditions, such as temperature and salinity. According to Udupe (1986), Lm varies between species and within the same species. Lc differs depending on many factors, including water depth, exposure to floods, and others (Muflikhah et al 2006). A smaller Lc than Lm will disrupt the sustainability of Asian redtail catfish in the long term, because it does not allow spawning.

According to Sparre & Venema (1992), a lower growth coefficient (K) means a longer time for the species to approach the asymptotic length. Conversely, a higher growth coefficient means a shorter time to approach the asymptotic length. The value of K for Asian redtail catfish in Tasik Giam Siak Kecil waters was 0.61 per year, and L_∞ was 37.8 cm, indicating a relatively slow growth rate. This is different from what was observed in Kampar River, Riau, where K was 0.8 per year and L_∞ was 79 cm (Suman et al 2009), in the Wadas Lintang Reservoir, where K was 0.26 per year and L_∞ was 58.3 cm (Kartamihardja & Purnomo 2006), or in Rungan river, where K was 0.4 per year and L_∞ was 47.5 cm (Suraya & Haryuni 2013). Differences in growth parameters can be caused by differences in the maximum length of samples collected and differences in location of sampling (Widodo & Suadi 2006). Knaepkens et al (2002) and Effendie (2002) state that differences in the values of K and L_∞ are caused by both internal and external factors.

The M value of Asian redtail catfish in Tasik Giam Siak Kecil waters is smaller than the F value, showing that most of the fish in Tasik Giam Siak Kecil waters died due to capture. The E value, 0.55 per year, shows that the utilization level exceeded the optimal rate of 0.5 (Pauly et al 1984). This shows that the utilization rate of Asian redtail catfish has reached 110%, being overfished. Thus, the reduction of fishing efforts must be carried out.

In general, Asian redtail catfish spawn throughout the year, with a peak in July. In July, there is an increase in the population of Asian redtail catfish (Muflikhah et al 2006). By looking at the peak period of spawning, it appears that Asian redtail catfish spawn best in the transition season from the rainy season to the dry season. During this period, the water has a lower turbidity, and the temperature is lower (Marini & Husnah 2011).

The spawning potential ratio (SPR) is the relative reproductive index used to determine the fish stock status (Walters & Martell 2004; Prince et al 2015). SPR is also known as a measure of the level of reproductive capacity of a resource that has declined from its original condition (Smallwood et al 2013). The SPR of Asian redtail catfish in Tasik Giam Siak Kecil waters is 6.8%, indicating that the Asian redtail catfish stock is overfished. This is in accordance with fisheries stock status criteria based on SPR, which are classified into 3 groups, namely underexploited (SPR>40%), moderate (20<SPR<40%), and overexploited/overfishing (SPR<20%) (Walters & Martell 2004; Prince et al 2015).

Conclusions. The growth pattern of Asian redtail catfish in Tasik Giam Siak Kecil waters, Bengkalis, is negatively allometric. The length at first capture (Lc) is smaller than the length at first maturity (Lm) and, in the long run, will not guarantee the sustainability of resources. The growth rate and mortality rate of Asian redtail catfish are high, so care must be taken in the management options. The spawning pattern shows that spawning occurs throughout the year, with a peak in June. The rate of exploitation (E) of Asian redtail catfish is 0.55 per year and SPR is 6.8%. Thus, the status of Asian redtail catfish stocks in Tasik Giam Siak Kecil waters is overfished. To ensure the sustainability of Asian redtail catfish resources in the waters of Tasik Giam Siak Kecil, Bengkalis, the catch must be reduced. Measures like increasing the mesh size can be taken, so that Asian redtail catfish may have the chance to spawn.

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

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