Food habits, growth pattern and condition factor of snakehead (*Channa striata*) from Danau Bangkau, Indonesia

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Abstract. The current research aims to provide valuable information on the food habits of snakehead (*Channa striata*) collected from Danau Bangkau, Indonesia. 220 snakeheads (265-439 mm total length and 207-950 g weight) consisting of 102 males (46%) and 118 females (54%), with the sex ratio of 1:1.2, were directly obtained from local fishermen. This study was conducted from July to September 2022. The food habits of snakehead adults were analyzed using the index of preponderance, while the larvae and fry food were determined with the plankton habitat analytical approach. The results showed that the snakehead adults consumed almost 90% small fish as main food, while the larvae and fry preferred the zooplankton (92.81%) 13 times better than phytoplankton (7.19%). The abundance of plankton categorized the water in the moderated fertility level, affecting the growth pattern of snakehead as a whole. Biologically, the fish grows negatively allometric with the condition factor value close to 1. Corrective actions to the snakehead fishery are also discussed.

Key Words: allometry, Index of Preponderance, plankton abundance, stomach samples, water quality.

Introduction. Snakehead (*Channa striata*) is one of endemic fish species commonly found in Asian and African countries (Kumolu-Johnson & Ndimele 2010; Osho & Usman 2019; Ahmadi & Ansyari 2021). It is considered a commercial freshwater fish species, which supports the global fisheries and aquaculture sectors, as well as considerably improves the welfare of local communities by different marketing channels (Haiwen et al 2014; Quyen et al 2016; Nadia et al 2022). It contains high albumin levels, useful for the recovery of wounds, and for malnutrition sufferers (Fitriliyani & Deviarnil 2013; Ramadhanti et al 2021). Advancements in fishing and bioeconomics of snakehead are needed for policy makers, conservationists, consumers and all other stakeholders interested in sustainable fisheries and aquaculture (Jumawan & Seronay 2017; Helkianson et al 2020; Ansyari et al 2020). On the other side, eradication programs for the wild snakehead populations are also required to protect native aquatic species from its predation (Love & Newhard 2012; Lapointe et al 2013; Guerrero III 2014).

Valuable information on biological aspects of snakehead is needed for sustainable fisheries management and effective conservation. Thus, there are many studies on the growth and survival rates (Rahman et al 2013), breeding features (Roy et al 2016), morphometry and condition factor (Ahmadi 2018), gonad maturation (Anwar et al 2018), stocking density (Saputra et al 2018), population genetic structure (Robert et al 2018), fecundity (Osho & Usman 2019), sex ratio, GML and GSI (Ahmadi & Ansyari 2021) of snakehead. These studies cannot be separated from ecological aspects such as food habits and biolimnology (Ansyari et al 2020), migration patterns (Lapointe et al 2013), population dynamics (Sofarini et al 2018), eutrophication effect (Sofarini et al 2020), restocking models (Bijaksana et al 2015) and domestication programs (Ndobe et al 2019). Other researchers concentrated on artificial feed formulation and development (He et al 2015; Hien et al 2016), investigations of parasites characteristics (Chowdhury & Hossain 2015), respiratory metabolism (Xie et al 2017), chitinase characteristics (Baehaki et al 2018) and immunostimulatory response (Norhayati et al 2019).

It was reported by the BPS - Statistics of Banjar Regency, Indonesia (2022), that the snakehead production in 2021 reached 37.55 tons, or 8.6% of the total fish production. In South Kalimantan Province, 95% of the marketed fish was supplied from the wild catch and the rest was produced from aquaculture with the price of 0.22 USD per kg (Ansyari et al 2020). In other words, high market demand has triggered an increase of its exploitation rate with no possession limits, catch time and size-barrier arising out of open access commercial fishing throughout the year. Although in North America, Europe and the Philippines there are eradication programs of the species, the snakehead population in our region is protected from illegal fishing practices (electrofishing and poisoning) due to ecological and socio-economic reasons. Therefore, it is necessary to monitor fishing areas regularly and enforce the law. Meanwhile, the main constraint recently faced in snakehead aquaculture is the high mortality of larvae and juveniles due to lack of nutritional information and cannibalism (Saputra et al 2018). Therefore, improvement of a proper nursery is important for fish farmers.

Due to the economic importance of snakehead worldwide, it is essential to learn more about its food habits and growth pattern. Understanding its food habits would help in assessing the growth pattern and survival rates of the fish (Rahman et al 2013; Ansyari et al 2020). The length-weight relationship data are useful for any assessment of fisheries and aquaculture related to the growth pattern, survival, maturity and reproduction of various species from different geographical areas (Islam et al 2013; Anwar et al 2018; Ahmadi 2018). Length-weight regression is an instrument for an easier estimation of weight from the length compared to a direct weight measurement in the field, in term of time efficiency. The condition factor is used to quantify physical wellbeing of fish. A higher the condition factor value shows a healthier fish. The reproductive cycle in fish is influenced by this condition factor (Welcome 1979).

The current research focuses on food habits, growth pattern and condition factor of snakehead in Danau Bangkau, in the continuation of our previous study to support sustainable fisheries (Ahmadi & Ansyari 2021).

Material and Method

Study site. The research was carried out from July to September 2022, in Danau Bangkau of South Kalimantan Province, Indonesia (Figure 1). The investigated area was purposively chosen to characterize the original habitat of the snakehead. It was generally represented by wetland areas with 0.5 to 2 m depths. The local people use the wetland for fishing, irrigation and household purposes. When the rainy season comes (September-April), the wetland is entirely flooded, while during the dry season (May-August), the wetland is covered by dense aquatic vegetation such as *Mimosa pudica*, *Pistia stratiotes*, *Eleocharis dulcis*, and *Ipomoea aquatica*. This regular seasonal change generates high biomass production and natural foods for freshwater fish species inhabiting the area (Ansyari et al 2020).

Sampling method. 220 individual snakeheads (265-439 mm total length and 207-950 g weight) consisting of 102 males (46%) and 118 females (54%), with the sex ratio of 1:1.2, were directly obtained from local fishermen. The sex ratio was evaluated by comparing the number of males to females monthly and tested with the chi-square test. The fish samples were sexed and measured, determining total length (TL) and weight (W), and were grouped by collection date. Total length and body weight were determined using a ruler (1 mm precision) and a digital balance SF-400 (0.01 g accuracy), respectively. Each individual fish was ventrally dissected using a scalpel. The stomach was removed, preserved in 5% formalin and transferred to 70% alcohol prior to content identification. The type and composition of stomach contents were further analyzed in the Biology Laboratory of the Faculty of Marine and Fisheries, Lambung Mangkurat University, Indonesia. The food items were identified based on Sachlan (1982) and Hutabarat & Evans (1986). In addition, the food items (i.e., phytoplankton and zooplankton) from the snakehead larvae and fry were also identified and analyzed in the Laboratory of Water Quality of the same faculty.

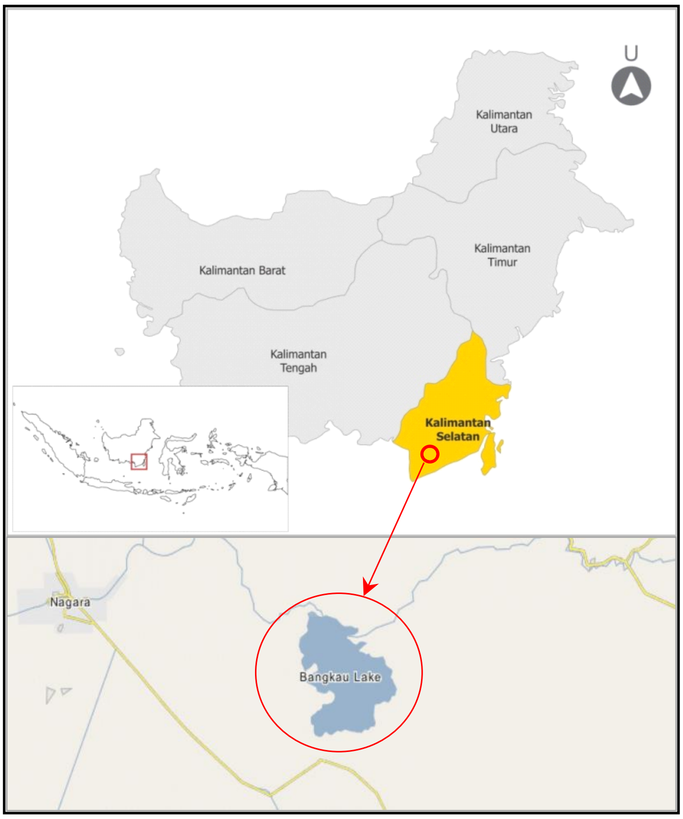


Figure 1. The map showing the location of Danau Bangkau in South Kalimantan Province, Indonesia.

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

Table 1

Equipment and materials used for Snakehead sampling periods

Equipment and materials	*Description*
Digital balance (SF-400)	Used for measuring the weight of fish samples.
Digital electronic scale (Camry-EHA401)	Used for measuring the weight of stomach samples.
Ruler	Used for measuring the total length of fish samples.
Scalpels	Used for dissecting the fish samples.
Measuring glass and pipettes	Used for measuring the volume of stomach samples.
Plankton net	Filters plankton samples.
Ekman Grab	Collects benthos samples.
Sample bottles	Depositary of water and plankton.
Secchi disc	Measures water transparency.
Roll meter	Measures the depth of waters.
DO meter	Measures dissolve oxygen.
pH meter	Measures pH.
Thermometer	Measures water temperature.
NH_3 test kits	Measures NH_3 content.
Digital camera	Documentation
GPS	Measures the site coordinates.
Stationary	Records measurement results.
Formalin	Preserved gonad samples.
Snakehead	Fish sample
Small boat (5.5x1.0x0.7 m)	Field operation support

Food habits. The food habits of snakehead adults were analyzed using the index of preponderance (IP), which is a combined method between the volumetric method and the probability frequency method. The formulation of this method can be expressed as (Natarajan & Jhingran 1961):

$$Ip = \frac{Vi\ x\ Oi}{\sum(Vi\ x\ Oi)}\ x\,100\ \%$$

Where: Ip - index of preponderance (%); Vi - the percentage of one food type (%); Oi - the percentage of one food type frequency; $\sum$(Vi x Oi) - the amount of food types. If Ip>40%, the item is regarded as a main food; if Ip is between 4-40%, it is considered as supplementary food; when Ip<4%, it is an additional food.

The food habits of larvae and fry were determined with the plankton habitat analytical approach. It was impossible to obtain the stomach contents because its size was very small. Plankton abundance was counted using a Sedgwick-Rafter Counting Cell (SRC) on a sample fraction and the results were stated in cells m^{-3}. According to Nurhaniah (1998), a water where the abundance of plankton is over 40 million cells m^{-3} (40000 cells L^{-1}) is categorized as fertile; an abundance 0.1–40 million cells m^{-3} (100–40000 cells L^{-1}) indicates a moderate fertility of waters; an abundance under 0.1 million cells m^{-3} (<100 cells L^{-1}) indicates an infertile water, poor in nutrients.

Morphometric measurements. A total of 23 characters in snakehead adults were measured individually: total length (TL), standard length (SL), head length (HL), head width (HW), head depth (HD), eye diameter (ED), snout length (SNL), interorbital width (IW), pre anal length (PAL), body depth (BD), body width (BW), ventral length (PVL), caudal peduncle depth (CPD), caudal peduncle length (CPL), dorsal basic length (DBL), dorsal fin height (DFH), pre caudal length (PCL), pre pelvic length (PPL), anal basic length (ABL), pre dorsal length (PDL), upper caudal length (LUCL), middle caudal length (LMCL), and lower caudal length (LCLL).

Length-weight relationship. The length-weight relationship of fish was individually estimated for males and females using the standard formula (Froese 2006):

$$W = aL^b$$

Where: W - weight (g); L - total length (mm); a - the constant as an index of growth; b - the slope of the curve as a coefficient of growth. The b value is usually used to define the growth pattern of fish, varying between 2.5 and 3.5 (Bagenal 1978). The significance of the isometric exponent (b) value was tested using the following formula (Pauly 1984):

$$t = \left(\frac{\mathrm{SD\ (x)}}{\mathrm{SD\ (y)}}\right)\left(\frac{|\mathrm{b}-3|}{\sqrt{1-\mathrm{R}^2}}\right)\left(\sqrt{\mathrm{n}-2}\right)$$

Where: *t* - the *t* student statistic test value; SD (x) - the standard deviation of log L; SD (y) - the standard deviation of log W; b - the slope of the curve; R^2 - the determination coefficient; n - the number of fish samples. The *t*-value is compared with the *t*-table value for degrees of freedom at a 95% significance level. If the *t*-value is less than the *t*-table value, the fish grows isometrically (b=3). If the *t*-value is greater than the *t*-table value, the fish grows allometrically (b≠3). Biologically, the b value has necessary implication for growth performance in fish. When b>3, it means that weight increases more than the length (positively allometric). When b<3, the length increases more than weight (negatively allometric). The regression coefficient (r) was also presented to show the strength of the relationship between the length and weight of fish for both sexes.

Condition factor. The condition factor (K) of fish was determined by the following formula (Weatherley & Gill 1987):
$K = 100(W/L^3)$

Where: K is Fulton's condition factor; L is the total length (cm); W is the body weight (g). The K value is used to determine the health condition of the fish. Relative condition factor (K_n) was predicted by following formula (Le Cren 1951):

$$Kn = \frac{W}{\hat{}W}$$

Where: K_n reflects "fatness" or well-being of fish; W is the observed weight; ^W is the calculated weight derived from the length-weight relationship. A higher K_n value shows a better condition of the fish. Thus, the K_n value is expected to be equal to or close to 1.

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

Results and Discussion

Food habits. The analysis results of food habits for snakehead adults using both volumetric and occurrence frequency methods are presented in Tables 2 and 3.

Table 2
Foods eaten by snakehead (*Channa striata*) adults analyzed with the volumetric method

Food types	*Monthly period*			*Average*	*%*
	July	*August*	*September*		
Fish	4.45	5.98	6.94	5.79	83.31
Amphibia	0.57	0.95	0.38	0.63	9.06
Crustacea	0.21	0.08	0.24	0.18	2,.59
Mollusca	0.32	0.30	0.12	0.25	3.60
Algae	0.04	0.03	0.05	0.04	0.58
Unidentified	0.08	0.04	0.06	0.06	0.86
Total	5.67	7.38	7.79	6.95	100

Table 3
Foods consumed by snakehead (*Channa striata*) adults analyzed with the occurrence frequency method

Food types	*Monthly period*			*Average*	*%*
	July	*August*	*September*		
Fish	10	10	10	10.00	27.78
Amphibia	6	7	6	6.30	17.50
Crustacea	5	4	5	4.70	13.06
Mollusca	9	7	5	7.00	19.44
Algae	4	3	5	4.00	11.11
Unidentified	5	2	5	4.00	11.11
Total	39	33	36	36	100

The index of preponderance values obtained from this combination method are summarized in Table 4. Fish was the largest portion (89.26%) of stomach contents as main food, followed by frogs (6.12%) as supplementary food, while mollusks (2.7%), crustaceans (1.3%), algae (0.25%) and others (0.37%) were considered additional food. This is reasonable because the snakehead is a top-level predator and a voracious carnivore feeding mainly on live prey. The high occurrence of fish as feed in the present study is in agreement with previous studies (Olasunkanmi & Ipinmoroti 2014; Hatta et al 2019; Ansyari et al 2020).

Table 4

The estimated index of preponderance of natural diets for snakehead (*Channa striata*) adults

Food types	*Index of preponderance (%)*		*Category*
	Estimated	*Criteria*	
Fish	89.26	>40	Main food
Amphibia	6.12	4-40	Supplementary food
Crustacea	1.30	<4	Additional food
Mollusca	2.70	<4	Additional food
Algae	0.25	<4	Additional food
Unidentified	0.37	<4	Additional food

In the present study, 6 families (14 genera) of plankton were recorded as natural diets for larvae and fry of snakehead (Table 5). They were comprised of 4 families of phytoplankton (7.19%) consisting of Chloropyceae (2.27%), Cyanophyceae (1.89%), Chrysophyceae (1.62%) and Bacillarohyceae (1.39%), and 2 families of zooplankton (92.81%) comprised of Crustacea (91.08%) and Protozoa (1.73%). The identified crustaceans like daphnia, rotifers and copepods were part of the main food, while protozoa and several types of phytoplankton were only additional food. Amin et al (2014) reported that copepods were the most preferable food item for snakehead fry in a lotic system. However, the African snakehead in the Upper River Ogun of Nigeria consumes diatoms and detritus instead of the above food items (Olasunkanmi & Ipinmoroti 2014). Variation in diet items may depend on the fish species, size, age, habitat and season (Lapointe et al 2013; Hatta et al 2019). The use of daphnia, rotifers or copepods as live food is more beneficial than artificial feed for successful rearing of fish larvae (Mehrajuddin et al 2009; Akbary et al 2010; Rasdi & Qin 2018). The most critical time is the first month, from the larval to the fingerling stage. Marimuthu & Haniffa (2006) reported that the larvae of spotted snakehead fed with solid food alone showed a high mortality during the first 7 days. According to Amornsakun et al (2011), the mortality of snakehead larvae becomes pronounced after the yolk was completely absorbed, particularly at 10.2 days. Thus, a lack of live food supply will lead to mass mortality. The food size should be suitable to the mouth size of the larvae. If food particles are larger, it can lead to high mortality rates in this stage (Singh et al 2015).

Phytoplankton can be used as a biological indicator for evaluating the quality and fertility of aquatic environments (Rochelle-Newall et al 2011). Meanwhile, the abundance of zooplankton depends on the abundance of phytoplankton and it is positively correlated with the emergence and distribution of pelagic fish (Hastuti et al 2018). From available data, it is known that the average abundance of phytoplankton and zooplankton estimated for a three-month period was 678 cells L^{-1} and 8752 ind L^{-1}. According to Nurhaniah (1998), Danau Bangkau swamp is categorized with a moderate fertility of waters (100–40000 cells L^{-1}). A negatively allometric growth pattern of snakehead in the present study is also likely affected by the abundance of plankton in the waters. The potential problems of aquatic environmental degradation are still being studied.

Table 5

The identified food types of snakehead (*Channa striata*) larvae and fry from Danau Bangkau, from July to September 2022

Food types	Monthly period			Average	%
	July	August	September		
Phytoplankton					
Chloropyceae	90	182	372	214	2.27
- *Chlorella*	60	182	372	204	
- *Chara*	30	-	-	10	
Cyanophyceae	182	100	256	178	1.89
- *Spirulina*	-	40	124	54	
- *Anabaenopsis*	182	60	132	124	
Chrysophyceae	144	190	125	153	1.62
- *Nitzschia*	68	190	65	108	
- *Synedra*	76	-	60	45	
Bacillarohyceae	152	130	114	131	1.39
- *Melanosira*	42	-	22	22	
- *Navicula*	82	40	92	72	
- *Diatoms*	28	88	-	37	
Sub-total (cells L^{-1})	568	602	867	678	7.19
Zooplankton					
Crustacea	7620	7872	10276	8589	91.08
- *Daphnia*	3004	2643	4646	3431	
- *Rotifers*	2972	3028	4302	3434	
- *Copepod*	1644	2201	1328	1724	
Protozoa	198	206	84	163	1.73
- *Sprirostonum*	-	206	84	97	
- *Euglena deses*	198	-	-	66	
Sub-total (ind L^{-1})	7818	8078	10360	8752	92.81
Total	8386	8680	11227	9430	100

Length-weight relationship. Overall estimated values of length-weight relationship (LWR) parameters, the body sizes, and condition factor of snakehead males and females are summarized in Table 6. Both males and females grew negatively allometric with the b values of 2.49 and 2.65, respectively. The LWR for males and females were individually expressed as $W = 2 \times 10^{-4}TL^{2.4852}$ and $W = 7 \times 10^{-5}TL^{2.6511}$ (Figure 2). The R^2 values ranged from 0.7435–0.8352, indicating that 74 to 83.5% of the variability of the weight was explained by the length. The r values varied between 0.8623–0.9139, showing that the length-weight relationship was positively correlated. A negative allometric growth pattern was also indicated by the pooled samples. It was also similarly reported in *C. striata*, *C. punctata, C. diplogramma* and *C. marulius* collected from different geographical areas (Table 7). Otherwise, *Parachanna obscura* from Buyo reservoir, West Africa (Tah et al 2012), *C. striatus* and *C. punctata* from Uttar Pradesh and Gomti River, India (Dayal et al 2012; Singh & Serajuddin 2017) grew positively allometric. Meanwhile, *C. punctatus* from Gomti River, India was reported to have an isometric growth pattern (Kashyap et al 2014).

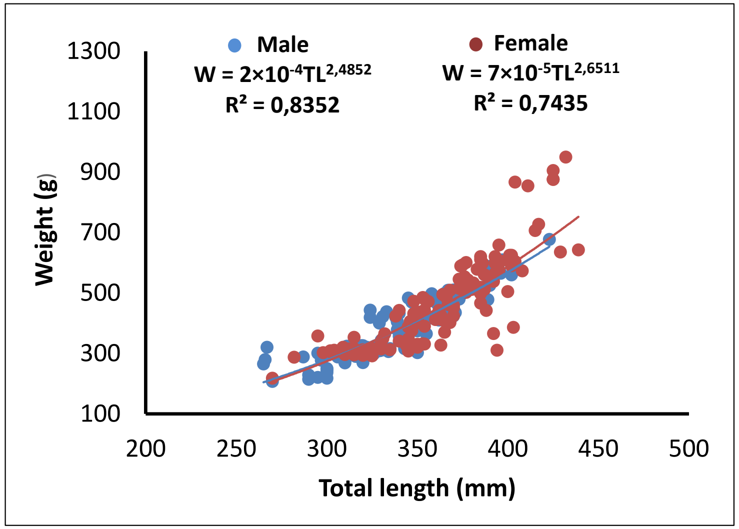
Considering variation in the b values and its significant differences for males and females, Ahmadi & Ansyari (2021) suggested to separately divide fish samples not only based on sex, but also on the size group (sexual maturity), because the coefficient of fitness between the sexes may also change with the increase in the length-weight of the fish body. Variation in the b value was attributable to life cycles and environmental factors such as the availability of food and space, water temperature, water current, and fish behavior (Jumawan & Seronay 2017; Khomsab & Wannasri 2017; Ansyari et al 2020).

Table 6

Length-weight relationship and condition factor of snakehead (*Channa striata*) from Danau Bangkau

Sex	*n*	*Total length (mm)*			*Weight (g)*			*a*	*b*	R^2	*r*	*Growth pattern*	*K*	K_n
		Min	*Max*	*Mean±SD*	*Min*	*Max*	*Mean±SD*							
Male	102	265	423	341±33	207	677	393±104	0.0002	2.4852	0.8352	0.9139	A⁻	0.98±0.14	0.98±0.12
Female	118	270	439	362±36	218	950	467±150	0.00007	2.6511	0.7435	0.8623	A⁻	0.96±0.14	0.90±0.21
Pooled	120	265	439	352±36	207	950	432±136	0.0001	2.5895	0.7835	0.8852	A⁻	0.97±0.14	0.94±0.18

Note: n - number of fish samples; a - constant; b - exponent; R^2 - determination coefficient; r - correlation coefficient; A– - negative allometric; K - Fulton's condition factor; Kn - relative condition factor.



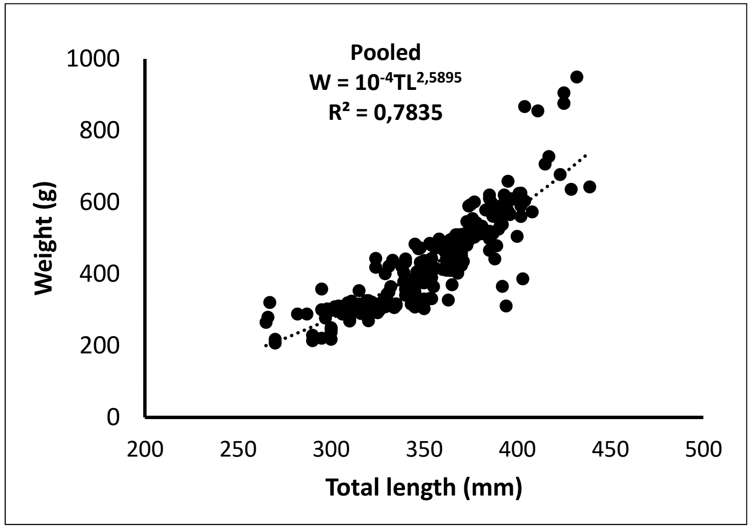


Figure 2. Length-weight relationship of males and females of snakehead (*Channa striata*) from Danau Bangkau.

Table 7

Comparative length-weight relationship and factor condition of the Channidae family from different geographical areas

Species	*n*	*Ratio of W/TL*	*a*	*b*	*R^2*	*Growth pattern*	*K*	*Locations*	*Country*	*References*
Channa striata	220	1.206	0.0001	2.589	0.7835	A^-	0.969	Danau Bangkau	Indonesia	Present study
C. striata	330	0.859	0.0000	2.922	0.972	A^-	0.842	Sungai Batang	Indonesia	Ahmadi 2018
C. striata	144	0.372	0.0140	2.812	0.952	A^-	0.839	Sekayu swamp	Indonesia	Muthmainnah 2013
C. striata	144	0.392	0.0350	2.543	0,881	A^-	0.880	Mariana swamp	Indonesia	Muthmainnah 2013
C. striatus	89	0.720	3.2800	3.685	0.933	A^+	-	Uttar Pradesh	India	Dayal et al 2012
C. punctata	150	0.103	0.0060	3.579	0.810	A^+	1.193	Fish farm	India	Datta et al 2013
C. punctatus	127	0.249	0.006	3.156	0.953	A^+	1.722	Gomti River	India	Singh & Serajuddin 2017
C. marulius	32	1.159	1.1670	1.450	0.935	A^-	-	Godavari River	India	Rathod et al 2011
C. diplogramma	67	-	1.0330	1.284	0.873	A^-	-	Lake Vembanad	India	Ali et al 2013
C. limbata	346	0.145	0.2060	1.850	0.900	A^-	1.510	Ta Bo – Huai Yai Wildlife Sanctuary	Thailand	Khomsab & Wannasri 2017
C. obscura	49	0.559	0.0160	2.663	0.706	A^-	5.230	Ologe Lagoon	Nigeria	Kumolu-Johnson & Ndimele 2010
P. obscura	408	0.143	0.0186	2.697	0.755	A^-	-	Enyong Creek	Nigeria	Bolaji et al 2011
P. obscura	85	1.198	0.0040	3.208	0.917	A^+	-	Buyo reservoir	West Africa	Tah et al 2012

Note: n - number of fish samples; W - weight (g); TL - total length (mm); a - constant; b - exponent; R^2 - coefficient of determination; A^- - negative allometric; A^+ - positive allometric; I - isometric; K - Fulton's condition factor.

There were significant differences in total length (TL), body weight (W) and the W/TL ratio between males and females ($p<0.001$). Females had the mean TL (362±36 mm) and W (467±150 g) greater than males (341±33 mm and 393±104 g). Females also had the mean ratio of W/TL (1.27±0.31) higher than males (1.21±0.21). The length weight relationship was $W/TL = 0.7 \times 10^{-5}TL^{1.6597}$ ($R^2 = 0.5529$) for females and $W/TL = 0.2 \times 10^{-4}TL^{1.5008}$ ($R^2 = 0.5887$) for males (Figure 3). Females had a ratio of W/TL 1.12 times higher than males.

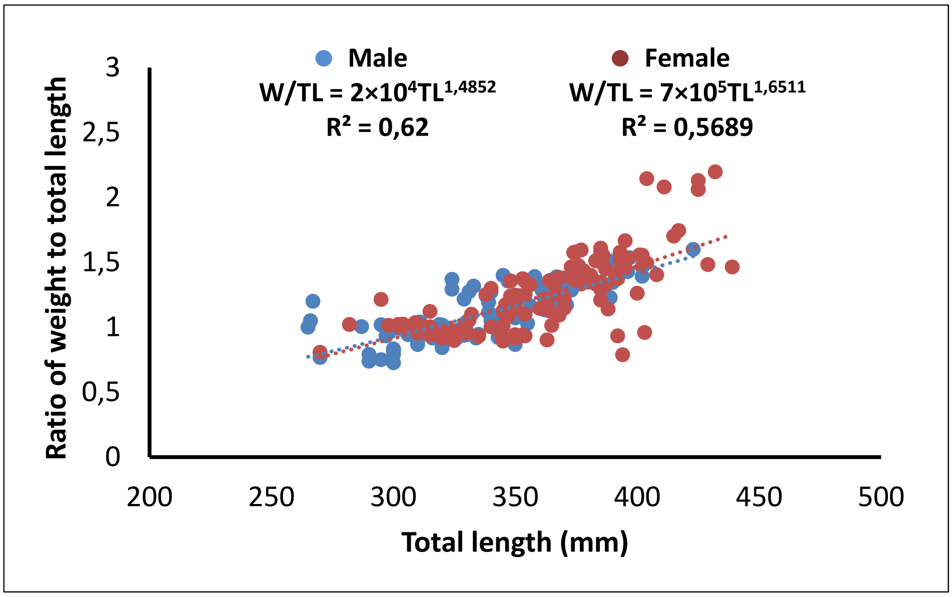


Figure 3. The relationship of total length (TL) and ratio of weight to total length (W/TL) of snakehead (*Channa striata*) males and females.

There was a variability of the ratio of W to TL in the family Channidae from different geographical areas (Table 7). The W/TL ratio of *C. striata* in the present study (1.208) was relatively higher than that of other members of the genera *Channa* and *Parachanna* (0.103-1.198), but lower compared to that of *C. striata* in Agusan Marsh, Philippines (1.340) (Jumawan & Seronay 2017).

A total of 23 morphometric characters of snakehead sampled from Danau Bangkau are presented in Table 8.

Condition factor. There was no significant differences in the values of Fulton's condition factor (K) between males and females (Table 6). The K values obtained for males and females were 0.98±0.14 and 0.96±0.14, respectively. Nevertheless, the initial growth index of females was greater than that of males. The increase in the ratio of W/TL was corresponding to the condition factor. The relationship was expressed as $W/TL=1.1324K^{0.4401}$ for males and $W/TL=1.2783K^{0.7049}$ for females (Figure 4).

In the present study, the K value was close to 1. According to Nash et al (2006), snakehead in Danau Bangkau was in favorable condition with a negative allometric growth pattern. According Barnham & Baxter (1998), a good and well-proportioned fish would have the K value around 1.4. A good condition was found in *C. obscura* from Ologe Lagoon, Nigeria (Kumolu-Johnson & Ndimele 2010), *C. punctatus* from Gomti River, India (Singh & Serajuddin 2017), and *C. limbata* from Ta Bo – Huai Yai Wildlife Sanctuary, Thailand (Khomsab & Wannasri 2017). Variation in the K values is closely related to biological interaction involving intraspecific competition for food and space between species including sex, maturity level, state of stomach contents and food availability (Singh & Serajuddin 2017; Khomsab & Wannasri 2017; Ansyari et al 2020).

Table 8

Descriptive morphometric of Snakehead sampled from Danau Bangkau

Characters observed	*Code*	*Mean value (mm)*	*Body size ratio to the total length*
Total length	TL	351±36.42	0.00
Standard length	SL	325±30.74	0.84
Head length	HL	95±8.99	0.25
Head width	HW	65±6.15	0.17
Head depth	HD	43±4.07	0.11
Eye diameter	ED	12±1.14	0.03
Snout length	SNL	35±3.31	0.09
Interorbital width	IW	26±2.46	0.07
Pre anal length	PAL	175±16.55	0.45
Body depth	BD	41±3.88	0.11
Body width	BW	55±5.20	0.14
Ventral length	PVL	38±3.59	0.10
Caudal pundacle depth	CPD	35±3.31	0.09
Caudal pundacle length	CPL	32±3.03	0.08
Dorsal basic length	DBL	197±18.64	0.51
Dorsal fin height	DFH	29±2.74	0.08
Pre caudal length	PCL	52±4.92	0.14
Pre pelvic length	PPL	112±10.59	0.29
Anal basic length	ABL	120±11.35	0.31
Pre dorsal length	PDL	110±40.41	0.29
Upper caudal length	LUCL	26±2.46	0.07
Middle caudal length	LMCL	60±5.68	0.16
Lower caudal length	LCLL	25±2.36	0.06

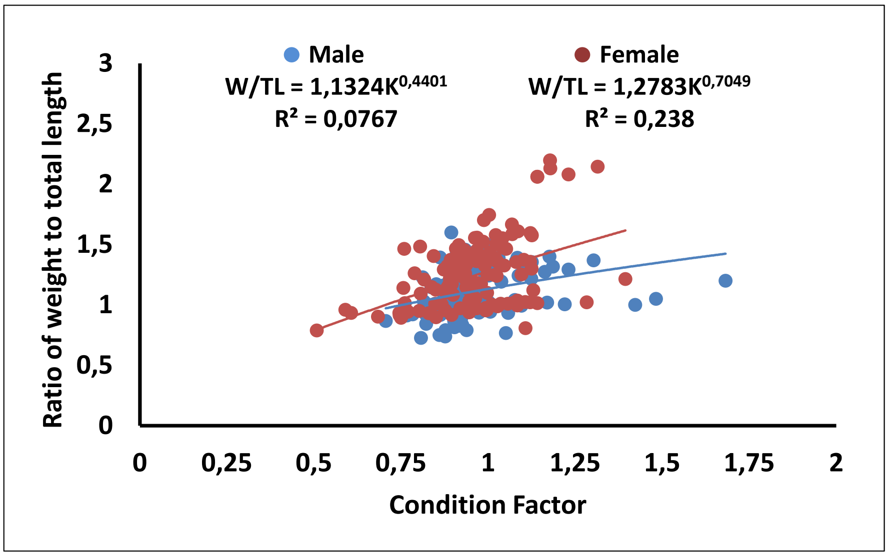


Figure 4. The relationship of condition factor and the ratio of weight to total length of snakehead (*Channa striata*) males and females.

No significant differences in the relative condition factor (K_n) between the sexes was observed (Table 6). The K_n values calculated for males, females and pooled were 0.98±0.12, 0.9±0.21 and 0.94±0.18, respectively. These values were close to the expected value. In term of 'fatness', females grew in a better condition compared to males, indicated by the ratio of W/TL, 1.12 times higher than in males. According to Bagenal & Tesch (1978), the heavier fish for a given length were in better condition. The healthy condition of an aquatic ecosystem along with the efforts to limit fishing activities are expected to increase the rate of fish growth in this swamp.

From the gear selectivity point of view, the use of hand-lines ("pancing pair") with live baits (frogs) is more preferable than other fishing gears such as fish traps ("lukah") or electrofishing because it only captures the larger fish. However, the catch usually does not survive due to the hook damage (Ahmadi 2018). "Lukah" is considered less selective because of its narrow bamboo laths, resulted in many small fish remaining trapped (Irhamsyah et al 2017). Electrofishing practices are totally prohibited by the law. Thus, the conservation planning for snakehead is required to reduce overfishing (Song et al 2013).

In Sungai Batang fishing village, the local fishermen sometimes directly sell fish to the traders or end-consumers without any records of snakehead catch (e.g. number, length and weight), resulting in unpredictable exploitation rates (Ahmadi 2018). Therefore, improvement of the quality of inland fisheries statistic data should also be prioritized, and research-based evidence should be encouraged for more effective fisheries management.

Water quality. Table 9 presents data on water quality parameters recorded during the three-month period. Water temperature was in the optimal range of 30.2-33.6ºC for swamps (KKP 2014). Snakehead has a varying thermal metabolic sensitivity dependent on temperature (Xie et al 2017). Tantarpale et al (2012) reported that the respiratory rate of snakehead increased at 35^{o}C and it decreased towards 15^{o}C. The pH concentration varied from 5.98 to 6.62, similarly reported by Sofarini et al (2020), indicating that the water was relatively acid. The optimum pH is usually between 7.5 and 8.5 (Boyd 1990). The DO concentration ranged between 0.63-1.4 ppm, which was far below the optimum DO range of 4-8 ppm required for the fish (Norhayati et al 2019). However, the snakehead can survive even in mud, due to its air-breathing capability (Xie et al 2017). According to Herliwati & Rahman (2011), DO levels fluctuate daily and seasonally, depending on the mixture and movement of water masses, photosynthetic activity, waste entering water bodies, and others. It is also closely related to eutrophication and decomposition of organic matter (Sofarini et al 2020). The ammonia content varied between 0.11-0.23 ppm and it is in tolerable condition (He et al 2015). The average transparency and the depth of waters were 1.45 and 2.16 m, respectively.

Table 9

Water quality parameters in Danau Bangkau, measured from July to September 2022

Parameters observed	*Monthly period*		
	July	*August*	*September*
Temperature (ºC)	30.2-31.0	32.5-33.6	32.4-33.3
pH	5.98-6.54	6.15-6.62	6.29-6.42
Dissolved oxygen (ppm)	0.70-1.14	0.63-1.40	0.74-1.13
NH_3 (ppm)	0.16-0.23	0.11-0.12	0.11-0.12
Transparency (m)	1.70-1.93	1.39-1.40	1.10-1.15
Depth (m)	2.60-2.95	1.82-1.86	1.82-1.90

Conclusions. Based on the index of preponderance, fish represented the highest portion of natural foods for snakehead adults. Crustaceans (e.g. daphnia, rotifera or copepod) were the most preferable food item for snakehead larvae and fry. Snakehead grew negatively allometric and the growth was highly correlated with the current environmental conditions of Danau Bangkau swamp, which was categorized in the "moderate fertility" group of waters.

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

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