Food habits and biolimnology of snakehead larvae and fingerlings from different habitats

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Food habits and biolimnology of snakehead larvae and fingerlings from different habitats

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Abstract. Snakehead (*Channa striata*) is widely distributed particularly in Asian and African countries, and has become one of the favorite freshwater fish commodities, which beneficially supports the aquaculture sector and fish processing industries. However, high mortality rate, slow growth and susceptibility to parasite attacks are serious problems. This study aims to investigate the food habits related to biolimnology parameters of snakehead larvae and fingerlings as a fundamental input for better aquaculture management. The study sites were located at Danau Bangkau Village (monotonous swamp), Anjir Muara Village (tidal swamp) and Sungai Batang Village (streams) of South Kalimantan Province, Indonesia. The food habits of the larvae were studied with the plankton habitat analytical approach, while those of the fingerlings (48-74 mm and 3.4-7.7 g) were analyzed using the Index of Preponderance. The results showed that the larvae mostly consumed chlorophyta (31.11%), followed by chrysophyta (19.11%), cyanophyta (14.67%), protozoa (14.67%), crustaceae (10.22%), rotifera (8.89%) and insecta (1.33%), while the fingerlings preferred small fish (61.05%) rather than frogs (15.06%), mollusks (11.47%), crustaceans (10.35%), and worms (1.67%). The fingerling males were more susceptible to parasites attacks compared to females. The parasite population was dominated by *Lernea* sp., *Argulus* sp., *Gyrodactylus* sp. and *Ichthyophthirius* sp. The abundance of plankton was categorized in the moderated fertility level, and water quality parameters were in the tolerant range for the growth and survival of the larvae and fingerlings.

Key Words: *Channa striata*, index of preponderance, monotonous swamp, stream, tidal swamp.

Introduction

Snakehead (*Channa striata*) is widely distributed particularly in Asian and African countries, and has become one of the favorite freshwater fish commodities. It beneficially supports the aquaculture sector and fish processing industries as an important food source. At least 25 species of the genus Channidae have been identified and documented, including *Channa striata* (Bloch 1793). The snakehead can withstand extreme environmental changes (Xie et al 2017). It is an air-breathing fish species and can survive for some extended periods out of water, having a labyrinth organ, similar to the climbing perch (*Anabas testudineus*) (Ahmadi 2019). The rivers, swamps, lakes, irrigation canals, and paddy fields are the most suitable habitats for snakehead (Amilhat & Lorenzen 2005; Ali et al 2013; Jumawan & Seronay 2017; Ahmadi 2018). It has been successfully cultivated in fish farms, earthen ponds or net cages with various culture techniques (Kumar et al 2011, Haiwen et al 2014; Quyen et al 2016). The use of rainwater is better than acid sulfate water in terms of a rearing medium for snakehead juveniles (Purnamawati et al 2017). In the Philippine, North America and Europe, it is categorized as a predatory or invasive species that outcompetes native aquatic species (Love & Newhard 2012; Lapointe et al 2013; Guerrero III 2014). Among snakehead species, *C. striata*, *C. gachua* and *C. melasoma* were reported to fed nocturnally (Lee & Ng 1994), while *C. argus* is thought to fed diurnally (Lapointe et al 2019).

Some fundamental studies linked to the biological and ecological aspects of snakehead were conducted, such as breeding techniques (Roy et al 2016), growth and survival rates (Rahman et al 2013), hybridization techniques (Samidjan & Rachmawati 2016), fecundity (Osho & Usman 2019), stocking density (Saputra et al 2018), gonad rematuration (Anwar et al 2018), respiratory metabolism (Xie et al 2017), parasites characteristics (Chowdhury & Hossain 2015), population genetic structure (Robert et al 2018), population dynamics (Sofarini et al 2018), migration pattern (Lapointe et al 2013), growth pattern and condition factor (Ahmadi 2018), feeding habits (Akbar & Iriadenta 2019), feeding frequency (He et al 2015), extruded feed development (Haiwen et al 2014), artificial feed formulation (Hien et al 2016), immunostimulatory effect of kelakai (*Stenochlaena palustris*) (Norhayati et al 2019), chitinase characteristics (Baehaki et al 2018), technology engineering of aquaculture (Samidjan & Rachmawati 2016), domestication programs (Ndobe et al 2019) and restocking models (Bijaksana et al 2015), among others.

In South Kalimantan Province of Indonesia, *Channa striata*, locally called "haruan", is one of marketable important fish species particularly in regional Kalimantan, Indonesia, due to its taste, high nutritional contents and availability throughout the year. It is usually served as a favorite food at restaurants, in different forms. For the time being, supply and demand of snakehead are highly dependent on the catch from the wild. In 2019, the average annual production reached over 700 tons, while aquaculture only contributed to 35 tons (5%) to the local fish markets. The selling price of snakehead is about 2-3 times higher than other freshwater fish species such as catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*), patin (*Pangasius hypophthalamus*) and carp (*Cyprinus carpio*) (BPS 2019). This is the main reason why fishing activity increases from time to time is to meet the target of production (Norhayati et al 2019). Fishing activity for snakehead is open throughout the year, regardless of seasonal periods. Many active and passive fishing gears are being used for catching snakehead from the wild (hook and line, stage lines, fish traps, cast nets, and others). Although electrofishing is prohibited by law, some people still use it because it is a fast and easy way to earn money. As a result, the larvae, fry and fingerlings that suffer from electric shock will possibly die, depleting the population.

Understanding well the food habits of snakehead larvae and fingerlings associated with appropriate culture methods would be a contributing factor that determines the success of fish farming business, particularly in increasing fish growth and survival. Other factors, such as high mortality rates, slow growth and parasitic infestations are still serious problems that need to be solved. In response to these obstacles, we comprehensively studied food habits related to biolimnology aspects, and identified the parasite types attacking the larvae and fingerlings of snakehead in their habitats. This information can help in developing proper culture strategies for administering natural live feed for snakehead in different stages.

Material and Methods

Study sites. The study was carried out in Bangkau Village of Hulu Sungai Utara District (monotonous swamp), Anjir Muara Village of Barito Kuala Districts (tidal swamp), and Sungai Batang Village of Banjar District (streams), as presented in Figure 1. These locations were selected purposively to represent the typical habitats of snakehead. The research activities were conducted for 6 months started from May to October 2018, while fish samples were collected from each location with the same procedure from July to September. These areas of study are generally wetlands with water depths ranging from 0.5 to 2 m. The wetlands are influenced seasonally mainly by rainfall resulting in two contrasting environmental conditions. The rainfall is highly seasonal, occurring between October and April, when wetlands are entirely flooded by water. On the other hand, in the dry season (May-September) the wetlands are covered by dense vegetation. A high production of freshwater fish in the wetland is mainly created from this regular seasonal change associated with biomass production and nutrient generation in the waters.

Sampling method. The snakehead fingerlings (48-74 mm total length and 3.4-7.7 g weight) were collected by using a scoop net, which was similarly used for catching snakehead fry from the lotic streams (Amin et al 2014). Individual fish were immediately killed after being caught and ventrally dissected (Ramli & Rifa'i 2010). 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, Faculty of Marine and Fisheries, Lambung Mangkurat University. The food items were identified to the phylum level using the keys given by Sachlan (1982) and Hutabarat & Evans (1986).

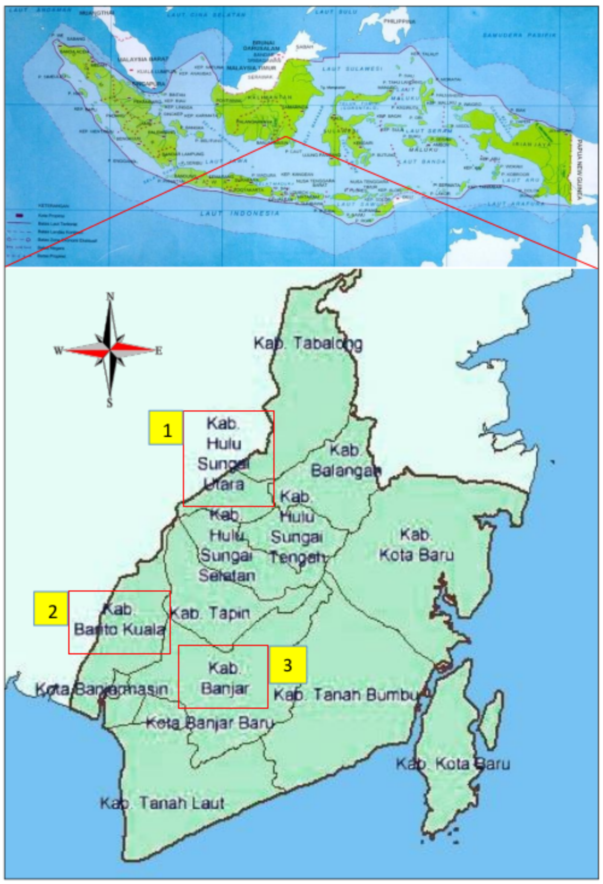

Figure 1. The sampling sites for snakehead (*Channa striata*) larvae and fingerlings. 1 - Bangkau Village of Hulu Sungai Utara District, Indonesia (monotonous swamp); 2 - Anjir Muara Village of Barito Kuala District, Indonesia (tidal swamp); 3 - Sungai Batang Village of Banjar District, Indonesia (streams).

Data collection and analysis. The food habits of snakehead larvae were determined with the plankton habitat analytical approach. It was impossible to get the stomach contents of the larvae because the size was very small. The food habits of the snakehead fingerlings were analyzed using the Index of Preponderance (IP), which was the combined method between volumetric method and 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; and $\sum(Vi \ x \ Oi)$ is 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 and when Ip<4%, it is an additional food.

Plankton abundance was counted using a Sedgwick-Rafter Counting Cell (SRC) on sample fraction and the results were stated in cell 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 water; and an abundance under 0.1 million cells m^{-3} (<100 cells L^{-1}) indicates an infertile water, poor in nutrients.

Parasite identification. Samples of body tissue (gills, fins, skin, mucous and digestive tract) of snakehead were observed under a light microscope. Identification of the parasites that attacked the snakehead in the wild was determined based on the keys of Duborow (2003), Patterson & Ruchstuhl (2013), Bhure & Nanware (2014). Morphological and anatomical observations were made.

Biolimnology habitat. The study of the biolimnology of the habitat covers the qualitative analysis (type identification) and quantitative analysis (abundance of plankton, macrobenthos and macrophyta). The water quality parameters throughout sampling periods such as temperature, pH, dissolved oxygen (DO) and ammonia (NH_3) content were also recorded and analyzed in the Laboratory of Water Quality. Prior to taking the sample, the sample container was rinsed 3 times with water. Water samples were collected 3 times, at the beginning, middle and end of sampling activities (totaling 9 sample units). The sample code and the sampling date were clearly marked. 1 L per sample was sent for analysis. Samples were cooled, arriving at the lab between 2-5^{o}C.

Results and Discussion

Food habits of larvae and fingerlings. Overall, a total of 7 phyla were identified as natural diets of snakehead larvae, comprising chlorophyta (31.11%), chrysophyta (19.11%), cyanophyta (14.67%), protozoa (14.67%), crustaceae (10.22%), rotifera (8.89%) and insect (1.33%).

Referring to the Index of preponderance criteria, the larvae consumed phytoplankton (64.89%) as a main food and zooplankton (35.11%) as a supplementary food (Table 1). Amin et al (2014) reported that the most preferable food item of snakehead fry were copepods (23.37%), followed by cladocerans (20.52%), insects (20.07%), mollusks (13.70%), worms (9.58%), shrimps (9.12%) and others (3.65%). Olasunkanmi & Ipinmoroti (2014) reported that African snakehead (*Parachanna obscura*) in the Upper River Ogun of Nigeria, consumed diatoms and detritus instead of the above food items. Such food items were also consumed by the kissing gourami (*Helostima temmincki*) in a freshwater marsh of Sri Lanka (Wickramaratne & Amarasinghe 2001).

Table 1. Index of preponderance of natural diets of snakehead (*Channa striata*) larvae

Food types	Index of preponderance (%)		Category
	Estimated	Criteria	
Phytoplankton (chlorophyta, chrysophyta, cyanophyta)	64.89	>40	Main food
Zooplankton (protozoa, crustaceae, rotifera, insect)	35.11	4-40	Supplementary food

Since snakehead is typically considered a carnivore species (Jumawan & Seronay 2017), zooplankton, insect, rotifera and crustacean could be cultured for the larval phase. Generally, the first external food for fish larvae is represented by small single-cell plankton (Amornsakun et al 2011). The food size should be appropriate with the mouth size of the larvae. If food particles are larger, it can lead to high mortality rates in this stage. Amornsakun et al (2004) stated that the mouth height of the larvae was linearly related to total length. Moreover, larvae with larger mouths will grow faster (Arumugum & Geddes 1987). The most critical time is the first month, from larval to fingerling stage. A lack of food supply will lead to mass mortality. According to Amornsakun et al (2011), the mortality of snakehead larvae becomes pronounced after the yolk was completely absorbed, particularly at 10.2 days. Therefore, it is necessary to better understand the food habits of larvae and fingerlings in order to reduce the mortality rate in the early life stages by improving the quality of feeding management. Through the Ip value, the proper food habits of larvae and fingerlings can be determined by quantifying the food composition of stomach contents. In this regard, Nikolsky (1963) divided food habits in 3 groups based on the amount of food type consumed: main food/basic food - the food is usually consumed by the fish and it is well-marked in the largest portion of stomach contents; secondary food/additional food - the food is frequently found in the fish stomach, but in small quantity; supplement food - the food is rarely found in the fish stomach. In addition, the snakehead is a top-level predator with fearsome teeth and a voracious carnivore feeding mainly on live prey.

Based on the estimated Ip value (Figure 2), fingerlings preferred small fish (61.05%) rather than frogs (15.06%), mollusks (11.47%), crustaceans (10.35%), worms (1.67%) and plankton (0.40%). The Ip values of each food item were summarized in Table 2. The high occurrence of fish in the present study was also in agreement with findings from different geographical areas (Saylor et al 2012; Olasunkanmi & Ipinmoroti 2014; Hatta et al 2019).

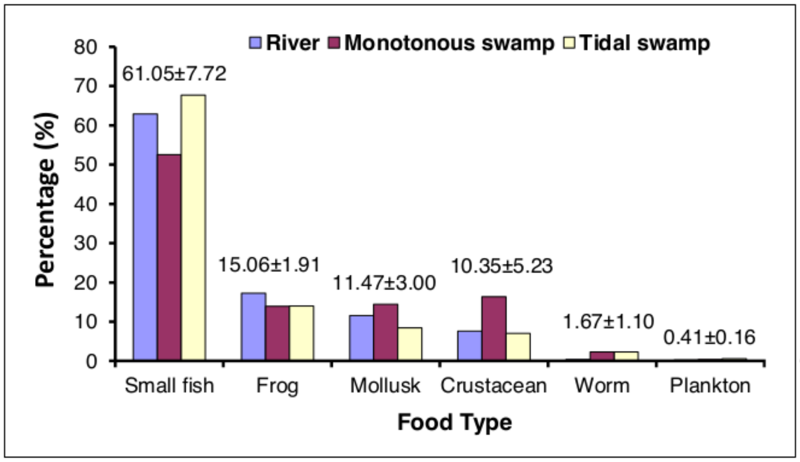

Figure 2. Comparative food habits of snakehead (*Channa striata*) fingerlings sampled from different habitats, stated in the mean ± standard deviation of the percentages.

Table 2. Index of preponderance of the food items in the stomach of snakehead (*Channa striata*) fingerlings investigated from different sampling sites

Food types	Index of preponderance (Ip %)				Category
	Bangkau	Anjir Muara	Sungai Batang	Mean± SD	
Fish fry	52.57	67.68	62.89	61.05±7.72	MF
Frogs	13.92	13.99	17.27	15.06±1.91	SF
Mollusks	14.42	8.42	11.56	11.47±3	SF
Crustaceans	16.38	7.05	7.62	10.35±5.23	SF
Worms	2.32	2.29	0.4	1.67±1.1	AF
Plankton	0.39	0.57	0.26	0.41±0.16	AF

Note: MF - main food (Ip>40%); SF - supplementary food (Ip between 4-40%); AF - additional food (Ip<4%).

In the stomach contents, many pieces of meat and bone of unidentified fish were found, most likely herbivore or omnivore species like fish fry of three spot-gourami (*Trichopodus trichopterus*), Snakeskin gourami

(*Trichopodus pectoralis*), kissing gourami (*H. temmincki*), Seluang fish (*Rasbora agrotynea*), Nile tilapia (*Oreochromis niloticus*), climbing perch (*A. testudineus*) and frog (*Rana cancrivora*). Such diet components were also similarly reported for African snakehead (*Ophiocephalus obscura*) (Uwem et al 2011). This implies that the fingerlings had the ability to ingest food corresponding to their mouth sizes. The food habits will change in line with age, growth pattern and seasons. Makmur & Prasetyo (2006) observed that the Ip value of snakehead in the dry season (91.52%) was higher than in the rainy season (88.74%), in term fish consumption. An explanation could be that fish are being concentrated on the sludge holes backwater or shallow water, in small areas with little chance of escaping snakeheads. The results differed from those of Uwem et al (2011) and Amin et al (2014), who reported that *O. obscura* or *C. striata* preferred polychaete worms or shrimp, respectively. Variation in diet items may depend on the fish species, size, age, habitat and season (Whenu & Fagade 2012; Hatta et al 2019; Lapointe et al 2019). Baehaki et al (2018) suggested that the stomach was better than the intestine in terms of digestivity. Ecologically, the existence of snakehead in their natural habitats plays an important role in the food chain, as a predator, by eating other small fish, frogs, crustaceans, worms and insects.

Parasites identified. During the sampling period, 8 parasite species were identified: *Lernea* sp., *Argulus* sp., *Gyrodactylus* sp., *Dactylogyrus* sp., *Ichthyophthirius* sp., *Trichodina* sp., *Aeromonas hydrophylla*, and

Psedomonas sp. (Table 3). Among these parasites, *Lernea* sp., *Argulus* sp. and *Gyrodactylus* sp. were frequently found in the investigated areas. *Ichthyophthirius* sp. was solely discovered in Sungai Batang River, while *A. hydrophylla* and *Psedomonas* sp. were found in the monotonous swamp. The results clearly showed that a preponderance of parasites occurred in September and October, especially in the tidal swamp. This is understandable, because these months coincide with the dry season, when parasites are more likely to grow. The parasites found in Sungai Batang River were fewer than in the two other habitats, because of water was flowing through this river, while the tidal swamp and monotonous swamp were stagnant. Many more males were infected by parasites than females, which may be attributable to the physiological stress of the fingerlings during dry season due to genetic material and diet changes over time. Snakehead infested by parasites showed a reduction in appetite resulting in slow growth and weak immune system in males. The similar condition was also reported for *Perca flavescens* (Zelmer & Arai 1998), *Channa punctatus* and *C. striata* (Gautam et al 2018). For aquaculture practices, male seed production must be minimized as they are indeed carriers of disease, so as not to interfere with female fish production.

Table 3. The parasite species and their presence at the study sites

Parasite types	*Monotonous swamp*			*Tidal swamp*			*Streams*		
	I	*II*	*III*	*I*	*II*	*III*	*I*	*II*	*III*
Lernea sp.	-	+	+	+	+	+	-	+	-
Argulus sp.	+	+		+	+	+	-	-	+
Gyrodactylus sp.	-	-	+	-	-	+	+	+	+
Dactylogyrus sp.	-	-	+	-	+	+	-	-	-
Ichthyophthirius sp.	-	-	-	-	-	-	-	+	+
Trichodina sp.	-	-	-	-	-	+	-	-	-
Aeromonas hydrophylla	-	-	-	+	+	-	-	-	-
Psedomonas sp.	-	-	-	-	+	-	-	-	-

Note: I - August; II - September; III - October; (+) - available; (-) - not available.

In open waters, there were various parasites with wide variations, but few in number. In aquaculture, the presence of parasites presents little variation, but is large in numbers (Salam & Hidayati 2017). The parasites of snakehead vary depending on species, age, sex, immunity, season and habitat (Harris et al 1992; Auta et al 1999; Chowdhury & Hossain 2015). It has been confirmed that the effect of parasites have caused adverse consequences both economically and ecologically in the form of lower fish production, high treatment costs, mass mortality, and disease spread (Noga 1996; Chai et al 2005). For aquaculture practices, the addition of probiotics in feed will reduce the population of some parasites of snakeheads (Agustin et al 2014).

Plankton. The highest abundance and diversity of plankton were sourced from the monotonous swamp (7060 cells L^{-1} and 36 species), followed by the tidal swamp (3696 cells L^{-1} and 18 species) and then streams (4253 cells L^{-1} and 16 species). The diversity of plankton is an expression of plankton community structure itself (Takarina et al 2019). Plankton can be an indicator of water fertility, and its abundance and diversity are highly correlated with the potential productivity of a fishing ground (Hemraj et al 2017). The abundance of plankton in the present study indicates moderately fertile water for all 3 habitats (Table 4). In this case, monotonous swamp was the most fertile among the locations, because the monotonous swamp was able to enrich the water by autochthonous materials derived from dead organisms, detritus or crushed organic matter. This condition was ideal for the growth and survival of larvae and fingerlings. Ecologically, the snakehead was part of the top-level consumers in tropic level of food items in their habitats (Hatta et al 2019).

Table 4. The abundance and spatial distribution of plankton in the research sites

Criteria	Plankton (cells L^{-1})			Category
	Monotonous swamp	Tidal swamp	Streams	
40000	-	-	-	Fertile waters
100 - 40000	7060	3696	4253	Moderate
<100	-	-	-	Poor in nutrients

Macrobenthos. Regarding food habits, it is necessary to determine whether snakehead fingerlings also feed on macrobenthos as a food item. In a previous study, *C. striata* was reported as a bottom feeder species (Das & Moitra 1956), but results from other studies differ and point out that snakehead mostly consumes fish, crustaceans, phytoplankton and zooplankton (Amin et al 2014; Olasunkanmi & Ipinmoroti 2014; Lapointe et al 2019). For African snakehead (*Ophiocephalus obscura*), detritus could also be empirically determined (Uwem et al 2011). In the present study, macrobenthos with empirical value was not found. Macrobenthos is usually used as a bioindicator for water quality or as a biomonitor to detect pollution or environmental changes in aquatic ecosystems (Pawhestri et al 2015; Sarker et al 2016). Since macrobenthos life is relatively motionless, it is the most susceptible to the contaminants (Soegianto 2004).

Water quality. Water temperature in the investigated areas was in optimal range (KKP 2014): 27.2-29.1ºC for monotonous swamp, 27-28.3ºC for tidal swamp, and 27-27.2ºC for streams (Table 5). In the Tempe lakes of South Sulawesi, snakehead lives at a higher water temperature (30.7-31.4ºC) (Hatta et al 2019). According to Jain & Garg (1984), *C. striata* is tolerant to a wide temperature range, between 2-40ºC. The pH in the streams was 5.74-6.15, in the tidal swamp it was 5.3-5.8 and in the monotonous swamp it was 5.72-6.4, indicating the water was relatively acid. Moreover, water samples collected during the dry season showed a poor water quality. The optimum pH is usually between 7.5 and 8.5 (Boyd 1990). Such conditions commonly occur in South Kalimantan’s waters or soils. The DO was 3.9-6 ppm, within the optimum DO range required for the fish in general (4-8 ppm) (Norhayati et al 2019). During the dry season, the oxygen supply declined particularly in tidal and monotonous swamps 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 ranged of 0.01 to 0.03 ppm, indicating that the snakehead's habitats are free of pollutants (He et al 2015).

Table 5. Water quality parameters measured from three different habitats

Water quality parameters	Sampling sites		
	Bangkau	Anjir Muara	Sungai Batang
Temperature (ºC)	27.2-29.1	27-28.3	27-27.2
pH	5.72-6.4	5.3-5.8	5.74-6.15
Dissolved oxygen (ppm)	3.9-5.6	3.97-5.7	4.6-6
NH_3 (ppm)	0.01-0.03	0.01-0.03	0.01-0.02

Conclusions. It can be concluded that snakehead at larva stage behaves like a herbivorous fish species, while fingerlings turn carnivore. From a biolimnology point of view, the snakehead's habitats were in the moderate fertile category and suitable for growth and survival. The most consumed diet component for the larvae and the fingerlings was chlorophyta (31.11%) and small fishes (61.05%). Among the parasites identified, *Lernea* sp., *Argulus* sp. and *Gyrodactylus* sp. were frequently found in the investigated areas.

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