Borneo Journal of Resource Science and Technology (2021), 11(2): 10-18
DOI: https:doi.org/10.33736/bjrst.3700.2021

Length-Weight Relationship, Condition Factor and Feeding Habit of Fishes from Mangrove of Santubong Estuary, Sarawak, Malaysia

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Received: 29 July 2021 Accepted: 3 October 2021 Published: 31 December 2021

ABSTRACT

Length-weight relationship (LWR), condition factor (K) and feeding habits of *Coilia dussumieri, Nemapteryx nenga* and *Nibea soldado* from Santubong Estuary, Sarawak, Malaysia were reported in the present study. The sampling was conducted during the non-monsoon season and monsoon season from April to November 2017 at Buntal, Penambir and Demak rivers using three-layered gillnets. A total of 182 fish samples were caught and measured for the total length and body weight. Then, the data were analysed by the equations for LWR and K. The feeding behaviour analysis was carried out using Relative Gut Index (RGI) and Frequency of Food Occurrence method. The log-transformed regression showed that most of the fishes exhibited negative allometric. K showed a significant difference between seasons. The RGI values of the fishes showed that they were carnivorous. The highest frequency of food occurrence in both seasons was gastropods (94-95 %) and the food items were found to be more variable during monsoon season (gastropods insect, worms, fish, asteroidea, phytoplankton and bivalve). The b value is an exponent to measure the growth pattern of fish and in this study, the b values were in the expected range of 2.5-3.5 and not affected by seasonal variation. The K values suggesting that most of the species were surviving well in the river and was influenced by seasonal change. The RGI and frequency of food occurrence showed that all fish in this study species were carnivorous with more variability in food was observed during the monsoon season. The data of this study are important for a sustainable fisheries management in this area.

Keywords: Estuary, fish, fish diet, length and weight, seasonal

INTRODUCTION

Fishes from families of Engraulidae, Ariidae and Sciaenidae are widespread in tropical estuaries (Fauziyah *et al*., 2019). They are commercially important as they are delicacy in the diet of local communities. Length-Weight Relationship (LWR) provides information on the fish stock composition, life span, mortality, growth patterns, fish production, indications on the climate and environmental changes as well as human subsistence. LWR is widely used in planning a better management strategy fisheries resources (Huang *et al.,* 2018). Growth patterns of fish usually follow the cube laws but the actual relationship may differ due to environmental factors (Yosuva *et al*., 2018). Condition Factor (K) is used to measure the health and general well-being of a fish concerning to its environment. The K values reflect their gonadal development, degree of food supply availability and environmental conditions (Rodriguez *et al.,* 2017). The value K is required for effective fish management and exploitation as it suggests the life cycle and physiological state of the fish concerning to its welfare. In fisheries, both LWR and K are crucial in predicting the best length and time to harvest a specific species of fish (Abobi, 2015). The analysis of feeding habit of fish is important to provide information on the life history facilitating rational exploitation and management of commercial species (Kiran *et al.,* 2017). In this study, monsoon season refers to the Northeast and Southwest monsoon while the non-monsoon season refers to the Inter-monsoon. The monsoon season occurs between November to March and May to September which usually brings rainfall. The non-monsoon season is the transition period between monsoons, typically occur between April to May and September to October and the winds are generally light and variable (Malaysian Meteorological Department, 2017).

Coastal rivers and estuaries are known as productive ecosystems for fisheries resources worldwide and the turbid water of these ecosystems provides abundant food for juvenile fishes (Siddik *et al*., 2016). Santubong Estuary is a mangrove area which is near to an industrial park and human settlement. This area shows high productivity and it has the highest wintering population of water birds in Malaysia (Sarawak Forestry, 2017). Up to this date, there has been no evaluation on LWR, K and feeding behaviours in relation to seasons conducted in Santubong Estuary which is one a tropical mangrove area in Sarawak. Most of the previous studies (Kamal *et al*., 2017; Mahapatra *et al*., 2015; Ya *et al*., 2015) done on these fish species mainly focused on the study of LWR without conducting the study on K and their feeding habits. These studies are essential to be performed together because they can act as baseline data that can be useful for resource management and provide insights into the growth pattern and well-being of the fish species. The main research question is whether there is any seasonal variation in these fish species. Thus, this study was conducted to examine seasonal LWR and K of three fish species namely *Coilia dussumieri*, *Nemapteryx nenga* and *Nibea soldado* from Santubong Estuary, Sarawak in accordance to their feeding behaviours.

MATERIALS & METHODS

Description of the Study area

This study was carried out in Santubong Estuary, Sarawak. The location is situated at the North East of Kuching, the capital city of Sarawak. It opens into the South China Sea through the Buntal Esplanade which is one of the openings for the entire basin. Three rivers involved in this study were the Buntal, Penambir and Demak Rivers. These rivers serve as an important means of transportation, food source and aquaculture site for the locals. This area is nearby to Demak Laut Industrial Park that has more factories being set up. The primary occupation of the villagers in this area were fishermen. The coordinates for the sampling stations were 01°41’49.38' N, 110°22’20.04” E (Buntal River), 01°39’44.28” N, 110°22’58.62” E (Penambir River) and 01°35’51.30” N, 110°23’34.08” E (Demak River) (Figure 1).

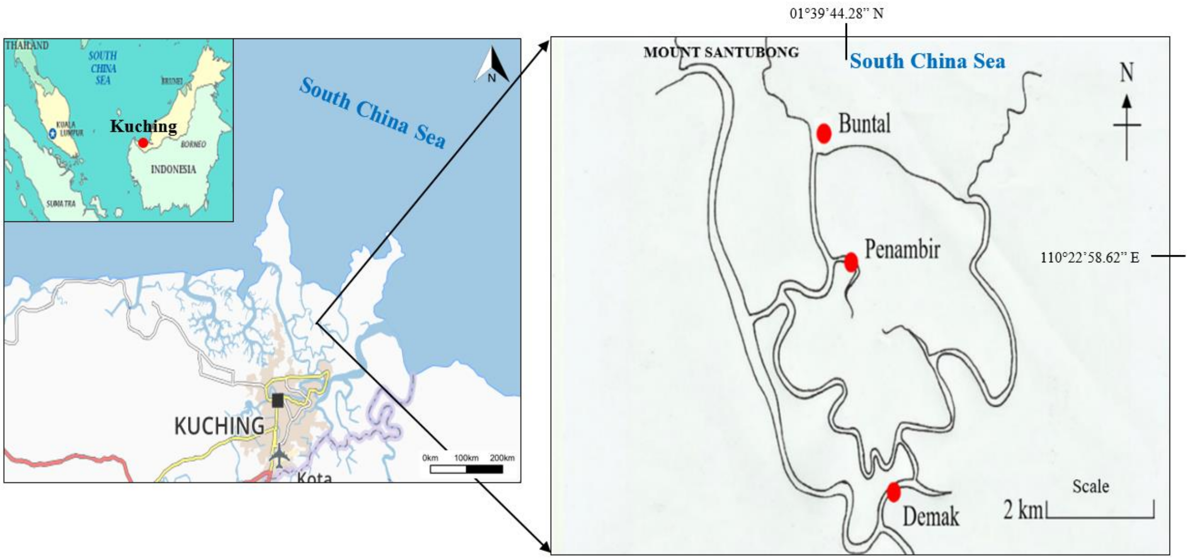

Figure 1. The map on the left shows the location of Santubong Estuary which situated in between Santubong Peninsula and Bako of Kuching, Malaysia, while the map on the right shows the Santubong Estuary with the selected stations (Buntal, Penambir and Demak)

Fish sampling

The sampling trips were conducted six times during non-monsoon season (1 April 2017, 2 April 2017 and 4 April 2017) and monsoon season (16 July 2017, 4 November 2017 and 21 November 2017). Three sets of three-layered gillnets (3.81 - 12.7 cm mesh sizes) were deployed at each sampling station. The three-layered gillnets were set in the morning and the catch was collected after 6 hours in the afternoon. Fishes captured were identified based on Froese and Pauly (2020a, 2020b, 2020c). The total length (TL) of each fish was measured from the tip of the snout to the extended tip of the caudal fin using a measuring board and the weight (W) was measured using an electronic balance (Shimadzu, TX3202L).

Length-weight relationship

The growth pattern (b) of the LWR was estimated using Equation (1) (Kahraman *et al.*, 2014) and the expression of the relationship was represented with Equation (2):

$$W = aL^b \qquad \textbf{(1)}$$

$$Log\, W = b\, log\, L + log\, a \qquad \textbf{(2)}$$

Where:
W = the weight of the fish (g),
L = the total length of the fish (cm)
a = exponent describing the rate of change of weight with length
b = weight at unit length

Condition factor

The condition factor for each fish species was calculated using Fulton condition factor (K) equation (Equation 3) (Kamelan *et al.*, 2014):

$$K = 100W/L^3 \qquad \textbf{(3)}$$

Where:
K = condition factor
W = the weight of the fish (g)
L = the standard length of the fish in (cm)
100 = factor in bringing the value of K near unity

Gut content analysis

The gut content was dissected and preserved in 10 % formalin and observed under both compound and stereo microscopes. The gut contents were analysed based on the relative gut index (RGI) method. The RGI is the percentage ratio of total gut length against the standard length (SL) of the fish (Equation 4) (Steinberg, 2018):

$$RGI = (X/Y)\, x\, 100\ \% \qquad \textbf{(4)}$$

Where:
X = total gut length of fish (cm)
Y = standard length of fish (cm)

The frequency of occurrence was expressed as the percentage of the occurrence of a particular prey item against the total number of fish examined with food in the stomach (Equation 5) (Sagar *et al.*, 2018):

$$\%\, Frequency\ of\ occurrence, Oi = (Ji/P) x\, 100\ \% \qquad \textbf{(5)}$$

Where:
Ji = the number of fish where prey occurs
P = the total number of fish examined with food in the stomach

Statistical Methods

Analysis of variance (ANOVA) was used to determine if there was a significant difference in the mean of b and K of the fish species between seasons. The Student’s t–test was performed to confirm whether the LWR was significantly different from the theoretical value of ‘3’ and whether the LWR differed between seasons. The regression coefficient was used to determine the degree of correlation between the variables. All statistical analysis was done using SPSS (Version 24) and Microsoft Office Excel software (Version 2016).

RESULTS

Length-Weight Relationship (LWR) and Condition Factor (K)

A total of 182 fish samples of three species were collected during the non-monsoon and monsoon seasons. The *b* values were 2.57 for *N. nenga*, 2.67 for *C. dussumieri* and 3.21 for *N. soldado* during the non-monsoon season. While the *b* values for monsoon season were 2.67 for *N. nenga*), 2.91 for *C. dussumieri* and 2.94 for *N. soldado* (Table 1). The mean K values of the fish species studied were ranged from 0.43 ± 0.14 (*C. dussumieri*) to 1.15 ± 0.20 (*N. soldado*) during the non-monsoon season. The mean K values during monsoon season were ranged from 0.39 ± 0.06 (*C. dussumieri*) to 1.04 ± 0.16 (*N. soldado*) (Table 1).

The regression coefficient, r^2 varied from 0.77 for *C. dussumieri* to 0.91 for *N. nenga* during non-monsoon season and from 0.88 for *N. nenga* to 0.98 for *C. dussumieri* during monsoon season. The r^2 of the fish species in this study was high ($r^2 \geq 0.7$) during both seasons indicating a proportional increase in weight and length (Figure 2).

Feeding Habits

In Table 2, the feeding habit of all fish species was found to be carnivorous in both seasons based on their RGI values. The RGI of *C. dussumieri* was ranged from 47.22 to 49.83, the RGI of *N. nenga* was ranged from 135.00-196.80 and the RGI of *N. soldado* was ranged from 81.61 to 88.68.

Table 1. Length-weight relationship and condition factor of fishes in Santubong Estuary during the non-monsoon and monsoon seasons.

Season	Species	N	TL (cm)	BW (g)	*b*	K
Non-monsoon	*C. dussumieri*	113	9.80 ± 1.31	3.94 ± 2.81	2.67	*0.43 ± 0.14
	N. nenga	11	13.67 ± 6.89	40.46 ± 82.87	2.57	*0.99 ± 0.29
	N. soldado	10	13.65 ± 1.99	30.88 ± 12.57	3.21	*1.15 ± 0.20
Monsoon	*C. dussumieri*	9	10.86 ± 5.19	8.38 ± 15.30	2.91	*0.39 ± 0.06
	N. nenga	28	17.36 ± 3.14	53.31 ± 29.60	2.67	*0.95 ± 0.17
	N. soldado	11	10.74 ± 3.12	15.90 ± 12.82	2.94	*1.04 ± 0.16

*K = significantly different between season

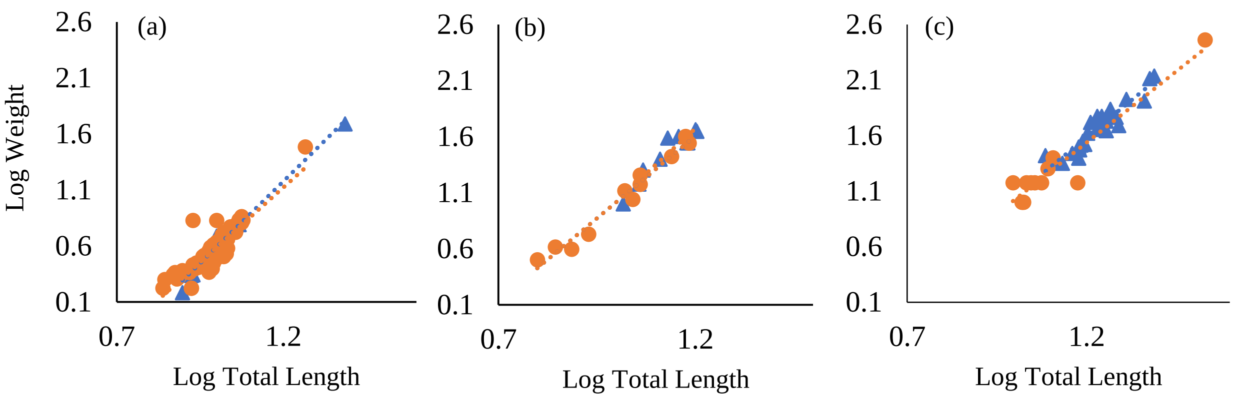

Figure 2. Relationships between total length and weight of (a) *N. soldado*, (b) *C. dussumieri* and (c) *N. nenga*. The triangle (▲) represented the monsoon season and the circle (●) represented the non-monsoon season

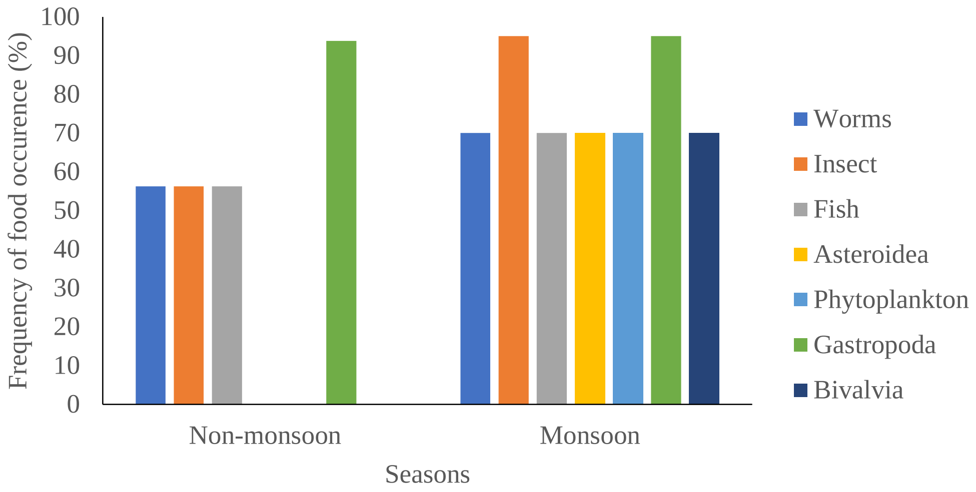

Figure 3. Frequency of food occurrence of three fish species during the monsoon and non-monsoon season

During the non-monsoon season, the highest frequency of food occurrence was gastropods (94 %) while worms, insect and fish were (56 %) (Figure 3). Meanwhile, during monsoon season, gastropods and insect were found to be in the highest frequency (95 %) while worms, fish, asteroidea, phytoplankton and bivalve were (70 %).

DISCUSSION

Length-weight relationship

A total of 182 fish samples of three fish species were collected during non-monsoon and monsoon seasons. *C. dussumieri* was from the family of Engraulidae, *N. nenga* from the family of Ariidae and *N. soldado* from the family of Sciaenidae. These fish species are the common fish found at the mangrove estuary areas in Malaysia (Jalal *et al*., 2012, Nyanti *et al*., 2012, Hoque *et al*., 2015, Kamal *et al.*, 2017). The common name for *C. dussumieri* is goldspotted grenadier anchovy, *N. nenga* is catfish and *N. soldado* is soldier croaker. Based on previous studies done on these species, the maturity size of *N. soldado* is approximately 18 cm (Carpenter and Niem, 1998), *C. dussumieri* is about 16 cm (Srinath, 2003) and Arius species is about 22.5 cm (Jalal *et al*., 2012). These indicated that the fishes caught in this Santubong estuary were mostly in juvenile stages as the study area is a mangrove area that acts as a breeding ground for many fishes (Kamal *et al*., 2017). Nyanti *et al*. (2012) stated that fish spend their early juvenile stages in mangrove as their nursery ground before moving into the sea to spend their juvenile and successive adult stages. The highest number of the catch was recorded during the non-monsoon season with a total of 134 while the lowest number of 48 was during the monsoon season. The low catch during monsoon season was believed to happen due to the large input of freshwater (high rain fall) into mangrove area that may increase the dilution effect of salinity to the mangrove area, hence, would change the fish fauna composition and species diversity too (Nyanti *et al.*, 2012).

The growth pattern was measured based on the exponent *b* which is a measure of the robustness of the fish. The b values in this study were observed to fall within the range of 2.5-3.5 recorded by Basumatary *et al*. (2017). When the *b* value equals to 3, it implies isometric growth while a value above or below 3 suggests allometric growth (Alam *et al*., 2014). In this study, the *b* values showed no significant differences between seasons ($p > 0.05$). The variation in slope may be associated with the sample size, life stages and environmental factors as stated by Datta *et al*. (2013). A high b value also reflects the overall condition of appetite and gonad content of the fish. The weight of fish increases when they make use of the food items that are available for growth and energy (Hamid *et al*., 2015). The b values may also differ significantly due to other reasons such as sex, growth phase, stomach contents, gonad development, preservation techniques, age and maturity stage (Hamid *et al*., 2015).

The Student’s t-test showed that the *b* values of all fish species obtained during both seasons were significantly different from the theoretical ‘$b = 3$' (p

< 0.05). This study involved three types of fish species and each species showed different type of growth. *C. dussumieri* and *N. nenga* were found to have negative allometric growth ($b < 3$) which they grew quicker in length than in weight in both seasons. A study conducted by Amin and Zafar (2004) in Bangladesh reported a comparable result showing allometric growth in *C. dussumieri*. Shingadia (2014) stated that LWRs were not constant over the year, varying with food availability and spawning period, while the parameter *b* is characteristic of the species and usually does not vary significantly the whole year. For *N. soldado,* it also showed a negative allometric during non-monsoon but showed a positive allometric during monsoon season. Generally, in this study the *b* values in both seasons showed that most of the fish species exhibited negative allometric growth which means that the length of fish increased more than their weight and the fish became slender and thinner as they increased in length, hence disobeying the cubic law. However, the *N. soldado* recorded a positive allometric growth during monsoon season indicating that the species became heavier as they grew longer (Ontomwa *et al*., 2018).

Overall, the highest value of r^2 was shown by *C. dussumieri* during monsoon season and the lowest value also was shown by *C. dussumieri* during non-monsoon season. In this study, the r^2 of the fish species was high ($r^2 \geq 0.7$) during both seasons indicating a proportional increase in weight and length. This is similar with the other studies on different fish species from other water bodies (Koffi *et al*., 2014). The *b* values and r^2 of *N. soldado* in this study is similar to the previous study on LWRs of *N. soldado* by Kamal *et al*. (2017) which recorded *b* value of 3.10 and r^2 of 0.95. While the previous study of *C. dussumieri* by Mahapatra *et al*. (2015) recorded lower *b* value of 2.41 but similar r^2 of 0.78 with this study. Ya *et al*. (2015) recorded higher *b* value of 3.29 and r^2 of 0.97 for *N. nenga* compared to this study.

Condition Factor

When the $K \geq 0.5$, it indicates that the fish is in a healthy condition (Abdul *et al*., 2016). In this study, *N. soldado* and *N. nenga* were found to be in good condition. While the low K value for *C. dussumieri* indicating spawning periodicity of the fish (Shingadia, 2014). The low K values in particular times of the year might be influenced by the low feeding intensity and degeneration of ovaries while high K values are associated to the high fat deposition preparing for spawning season (Shingadia, 2014, Abdul *et al*., 2016). The K values of our study for all fish species were significantly different between seasons ($p < 0.05$) because K values could vary according to seasons depending on the environmental conditions (Ontomwa *et al*., 2010). The low K values could be attributed to stress-related factors such as the low availability of food and competition for resources. During the monsoon season, the mangrove shoreline is severely affected by erosion due to the constant heavy rainfall. This heavy rainfall may have brought a significant input of sewage from nearby villages, Demak Laut Industrial Park area, neighbouring agricultural and aquaculture activities at the eastern side of the mangrove and added extra pollutants into the water body. This substantial input of sewage could have affected the spawning ground, food sources and in extreme cases can cause fish kills and loss of mangrove area as stated by Nyanti *et al*. (2012). Most of the previous studies Kamal *et al*. (2017); Mahapatra *et al*. (2015); Ya *et al*. (2015) only examined the LWR study without conducting the study on their condition factors. Both of these parameters are equally important to be examined to fully understand about fish biology and ecology for their sustainable management and conservation.

Feeding habits

To understand the food items and feeding habits of these fish species, a total of 56 stomach specimens from fish samples with standard length ranging from 5.50 to 28.00 cm were examined. Only 48 specimens were found with food items while 8 stomachs were empty and too small to be evaluated. This indicated that the fish examined in this study were mostly in the young or juvenile stage because younger fish had no full stomach while older fish had no empty stomach (Iyabo, 2014). In this study, the feeding habit is broadly categorised into carnivores. Typically, herbivorous fish demonstrates higher RGI value suggesting longer gut length which aids for digestion of cellulose cell wall. The RGI of 50-240, 80-400 and 400-2100 for carnivorous, omnivorous and herbivorous, respectively (Steinberg, 2018).

N. soldado is generally bottom dwellers. It feeds mainly on crustaceans, copepods, decomposed unidentified tissue and fishes (Jeyaraj *et al*., 2015). In this study, *N. soldado* was found to be carnivorous which tallied with a previous study done at Hooghly estuarine which also reported *N. soldado* as carnivorous (Chakraborty *et al*., 2004; Jeyaraj *et al*., 2015). As for *N. nenga*, it belongs to the Ariidae family that can be found in all stations as they are euryhaline and able to stay with a narrow range of dissolved oxygen and fluctuation of pH. This species has catholic food habits, feeding on materials ranging from domestic wastes to rotting carcasses (Jalal *et al*., 2012). In this study, *N. nenga* was found to be carnivorous. While for *C. dussumieri*, this species generally accepts a wide variety of temperature and salinity. They live in large schools in estuaries, bays and freshwater (Jalal *et al*., 2012). In this study, most of *C. dussumieri*'s gut content was empty so the feeding habit of *C. dussumieri* was unable to be determined based on their gut content due to their small body sizes. However, Froese and Pauly (2020a) characterised *C. dussumieri* as a carnivorous species which feeds on zooplankton, prawn and fish larvae, various zoobenthos, and isopods. The RGI of the *C. dussumieri* from both seasons (Table 2) also resembles the reported RGI of carnivores.

Based on the frequency of food occurrence, seven food items consisted of worms, insects, fish, gastropods, asteroidea, phytoplankton and bivalve were found in the stomach of the fishes (Figure 3). Based on the results, gastropods (shrimp juveniles) was the most dominant food items found and this may be due to the juveniles living mainly in estuaries, unlike the adults who live offshore and spawn in deeper waters (Kurniawan *et al*., 2020). Monsoon season recorded high variations of food items compared to non-monsoon season. Kumar *et al*. (2015) stated that the seasonal fluctuations in abundance of the organisms that constitute the food of a species could influence the growth, condition, shoaling behaviour, migration and the fishery of fishes. *N. nenga* feeds mainly on gastropods during the non-monsoon season and feeds on a variety of food during monsoon seasons. *N. soldado* on the other hand feeds mostly on the same type of food for both seasons. The wide array of food items found in the stomach of the fish indicates the constant availability of food within the study area. The diet of fishes in this study also showed that they have unspecialised feeding habit. This unspecialised flexible dietary habits are an optimal strategy for survival in habitat where food source is subject to fluctuation (Iyabo, 2014).

CONCLUSION

This study has provided baseline information on LWR, K and feeding habits of three fish species found in Santubong Estuary for the first time. The *b* values were in the expected range of 2.5-3.5 and no significant difference was found in *b* values between seasons. Most of the *b* values showed a negative allometric growth which might be attributed to environmental conditions and morphological characteristics of each species. K was generally close to 0.5 suggesting that almost all the species were surviving well in the river. This study suggests that the condition of fishes in Santubong Estuary is affected by seasonal variation. Therefore, it can be concluded that the Santubong Estuary offers optimum habitat conditions for the survival of *C. dussumieri*, *N. nenga* and *N. soldado*. More variability in food was observed during the monsoon season but no significant changes were recorded in the feeding behaviour of the species studied over both seasons. Thus, the study of LWR and K is a valuable approach that needs to be conducted together with feeding habit study so that detailed information on both biological and ecological aspects can be obtained for their sustainable management and development of conservation measures which will help to maintain the supply of these fishes as food source for both human and migrating birds in Santubong Estuary. The main limitations in the present study was that the sampling period did not extend over a full cycle of the year and the sample size may not be optimal for some of the species studied. Thus, future studies should consider the sex differentiation which might influence LWR and K of the fishes and expanding the study stations around the Santubong area. A study of heavy metals can also be included in future to assess the contamination level from the nearby industrial area.

ACKNOWLEDGEMENTS

Authors extend their gratitude to Universiti Malaysia Sarawak (UNIMAS) and Ministry of Higher Education (MOHE) Malaysia for financial research support through RAGS grant E14099 F07 69 1320/2015(14). A big thank you is dedicated to all laboratory staffs from UNIMAS and local guides during the sampling and data analysis.

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