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Original Article

Length-weight relationship, condition factors and trophic level of Buffon's river-garfish *Zenarchopterus buffonis* from the coastal waters of Malaysia

Diana Atiqah Zainal Abidin[1], Simon Kumar Das[2*], and Mazlan Abd Ghaffar[3, 4*]

[1] *School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, 43600 Malaysia*

[2] *Marine Ecosystem Research Centre, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, 43600 Malaysia*

[3] *Institute of Tropical Aquaculture, University of Malaysia Terengganu, Kuala Nerus, Terengganu, 21030 Malaysia*

[4] *School of Fisheries and Aquaculture Sciences, University of Malaysia Terengganu, Kuala Nerus, Terengganu, 21030 Malaysia*

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Abstract

Length-weight relationship (LWR), condition factors, and trophic level of *Zenarchopterus buffonis* from the coastal waters of Malaysia were evaluated between November 2013 and March 2014. Three hundred individuals of *Z. buffonis* ranging between 8.7−16.0 cm total length and 3.67−22.19 g body weight were investigated in this study. The length-weight relationship demonstrated that the parameter *b* values at Sungai Likas, Tanjung Belungkor, Langkawi, Klang, and Matang were 3.3114, 3.0534, 2.5442, 2.2018, and 2.8998, respectively, which suggested positive and negative allometric growth patterns for this species. Specimens from Matang recorded the lowest mean condition factor, *K* (0.2292±0.0578) whereas Tanjung Belungkor displayed the highest value of 0.6556±0.0526. Matang was discovered to display the lowest relative condition factor (*Kn*) of 0.0330±0.2336, whereas Klang had the highest *Kn* value of 3.5097±0.4232. The trophic level for *Z. buffonis* was analyzed based on 84 specimens. Gut content analysis revealed that *Z. buffonis* consume primarily insects (57%), followed by plant materials (33%), and crustaceans (10%). The calculated TROPH values (1−3.2) signified that *Z. buffonis* has an omnivorous feeding habit. This study provides the pioneer description of LWR parameters, condition factors, and diet preferences for *Z. buffonis*, which would be beneficial for the sustainable fishery management in the coastal waters of Malaysia and neighboring provinces.

Keywords: halfbeak, growth pattern, condition factor, feeding habit, Malaysian coastal waters

*Corresponding author
Email address: skdas_maa@yahoo.com;
magfish05@yahoo.com

1. Introduction

Zenarchopterus buffonis, which is typically known as halfbeak fish, exists in both tropical and subtropical regions (Collette, 2004). It is also reported that *Z. buffonis* is widely distributed in Indo-West Pacific region, ranging from India, Malay Peninsula to northern Australia (Collette & Su, 1986). *Z. buffonis* can be mostly found at the surface levels in coastal waters, estuaries and rivers to hunt mainly insects (Rainboth, 1996).

An increase in the length and weight of a fish is the result of conversion of the food material consumed into development of muscle mass by the nutritional process (Farzana & Saira, 2008). The length-weight relationship (LWR) plays a great role in fisheries science and stock assessment because it provides a valid evaluation of a fish's average weight at a given length class by applying a mathematical relationship between them (Mir *et al.,* 2012). Carlander (1969) reported that the body weight increases exponentially as the length increases in fish, with a *b* value that is normally near 3.0 and may range between 2.5 and 3.5. The fish possesses an isometric growth if the *b* value is 3.0 and remains when the shape and thickness of the fish are consistent. If the fish grows allometrically, the body weight of the fish will increase slowly (b<3.0) or faster (b>3.0) relative to the growth in length.

The Fulton condition factor (*K*) is most typically used by fishery researchers to access the plumpness and health (Mir *et al.,* 2012) of fish, assuming that the fish is in better condition when it is heavier at a given length. The relative condition factor (*Kn*) considers variations like those related with food items, feeding habits, and sexual maturity (Le Cren, 1951), and an investigation based on *Kn* can be useful in analyzing the fatness of fish, hence allowing a fish culturist to examine the body weight of fish with reference to a standard calculated body weight (Kurup & Samuel, 1987).

The key role of feeding studies for fisheries biology was discovered in the last decade using the trophic level to determine the consequences of fishing on the equilibrium of the ocean food chain (Pauly, Christensen, Dalsgaard, Froese, & Torres, 1998). The trophic level estimation is valuable to quantify the impact of fishing on the environment and ocean ecosystem because it permits the development of modern techniques for the study of marine food chains (Pauly *et al.,* 2000).

Several studies on *Z. buffonis* have been conducted that include mating behaviour (Kottelat & Lim, 1999), habitat preferences (Ikejima, Tongnunui, Medej, & Taniuchi, 2003), description on pharyngeal jaw apparatus and diets (Abidin, Hashim, Das, & Ghaffar, 2015), and morphometric variations of the population from Indonesian waters (Syaifullah, 2015). However, documented information on the LWR and trophic values of this particular fish species in Malaysian waters are still lacking.

It is important to know the biological diet and other physiological adaptations to achieve a high degree of resiliency in the harsh environment of Malaysian coastal waters. Food resources for this species have been depleted due to several factors such as coastal zone destruction, chemical pollution from the urban areas, and rapid deforestation. Due to restricted food items available in their habitat, this fish species has shifting diets that range from herbivory to insectivory, which makes them known as an opportunistic surface feeder. The objectives of the present study were to describe the LWR, condition factors, and trophic level of the *Z. buffonis* from the Malaysian coastal waters.

2. Materials and Methods

2.1 Field sampling and laboratory preparation

A total of 300 halfbeak fish were collected from five sites in Malaysia, namely Sungai Likas in Sabah, Tanjung Belungkor in Johor, Langkawi in Kedah, Klang in Selangor, and Matang in Perak (Table 1). Fresh samples were stored in a deep freezer (−4 °C) for subsequence observation. The left side of the specimens was photographed using a Canon G12 with 3648×2736 pixel dimension images. Some individuals were saved for diet studies. In order to avoid further digestion of the gut content, 4% (w/v) formaldehyde was injected directly into each gut of the fish.

Table 1. Number of fish samples collected (*n*), range of total length and body weight, t-test value, growth pattern and parameters of LWR of *Z. buffonis* in five different locations in coastal waters of Malaysia.

Location	Coordinate	*n*	Total length range (cm)	Body weight range (g)	Growth pattern	$W = aL^b$	*b*	r^2	*t*-test
Sg. Likas	5°59'34.8"N, 116°06'03.0"E	52	9.20−13.20	4.08−15.30	PA	$W = 0.0036L^{3.2114}$	3.3114	0.9465	2.67, P<0.05
Tg. Belungkor	1°26'42.5"N, 104°03'47.4"E	50	7.20−15.00	2.40−23.35	PA	$W = 0.0057L^{3.0534}$	3.0534	0.9191	0.27, P >0.05
Langkawi	6°22'17.8"N, 99°40'18.5"E	98	12.00−19.30	2.52−16.23	NA	$W = 0.0193L^{2.5442}$	2.5442	0.9200	5.11, P<0.05
Klang	3°00'36.0"N, 101°23.01.6"E	50	8.70−16.00	3.67−22.19	NA	$W = 0.003\ 4L^{2.2018}$	2.2018	0.9029	8.16, P<0.05
Matang	4°50'37.3"N, 100°37'.37.9"E	50	12.50−24.00	11.45−40.06	NA	$W = 0.0032L^{2.8998}$	2.8998	0.8367	0.54, P<0.05

*PA, positive allometric growth; NA, negative allometric growth

2.2 Length-weight relationship

The mathematical relationship between the total length and total weight of *Z. buffonis* was estimated according to LWR analysis ($W=aL^b$) (Abdallah, 2002), where W = total body weight of the fish (g), L = total length of the fish (cm), *a* is the regression intercept of the regression curve, and *b* is the regression coefficient. The total length of the fish sample (from tip of upper jaw to the tip of caudal fin) was measured to the closest 0.01 cm using a digital caliper (Fisherbrand™ Traceable™, ±0.03mm). Whole body weight of the fish was recorded on a digital balance (Shimadzu, AUW220D) to an accuracy of 0.01 g.

2.3 Condition factor (*K*) and relative condition factor (*Kn*)

Fulton (1904) proposed the application of a mathematical formula that would evaluate the condition factor (*K*) of fish:

$$K = W/L^3 \times 100$$

where W = whole body wet weight (g), L = total length in centimeter (cm), and 100 is a factor to bring the value *K* close to unity. The relative condition factor (*Kn*) is computed according to the empirical LWR and is calculated by the formula:

$$Kn = W / aL^b$$

where W = observed weight of fish whereas aL^b = calculated weight of fish. The difference between *K* and *Kn* is that the former measures the deviation from a hypothetical ideal individual whereas the latter measures the deviation of an individual from the average weight for length (Saha, Vijayanand, & Rajagopal, 2009).

2.4 Trophic level analysis

The guts and digestive tracts of 84 individuals of *Z. buffonis* were dissected out and placed in 70% ethanol for a longer preservation. Prey items were identified and classified to large taxonomic groups, counted, and weighed to the closest 0.01 g. Gut content analysis was performed according to recommendations provided by Stergiou and Karpouzi (2002). Gut contents were examined carefully using a dissecting microscope and evaluated in accordance with the occurrence method (Hyslop, 1980). Weight percentage (wt%) and frequency of occurrence (f_o) were analyzed for different fish length classes. Composition data were applied to estimate the trophic levels of *Z. buffonis* captured from Malaysian coastal waters. The trophic level helps indicate the position of animals inside the marine food chain to widely explain aquatic ecosystems (Pauly & Palomares, 2000). TrophLab was used to calculate the TROPH value from the dataset and also its standard error by applying the volume contribution and the trophic level of each prey species to the diet. The trophic level was calculated per length class based on the following equation (Pauly *et al.,* 2000):

$$\text{TROPH}_j = 1 + \sum_{j=1}^{G} \text{DC}_{ij} \times \text{TROPH}_j$$

where TROPH_j represents the fractional trophic level of prey (*j*), *G* is the total number of prey species in a gut and DC_{ij} is the fraction of *j* in the diet of *i*. Hence this explained the value of trophic level ranges between 2.0 (herbivore) and 5.0 (carnivore) (Pauly & Palomares, 2000). The mean values (±SE) estimated from the equation were input into the MICROCAL ORIGIN 8.0 graphic software (OriginLab, Northampton, MA, USA) (Simon *et al.,* 2009) to acquire the trophic position pattern according to the fish size class.

2.5 Statistical analysis

A non-linear regression was applied to obtain the values of *a* and *b*. A curve fitting was performed by a non-linear repetitive technique using Levenberg-Marquardt and Simplex algorithms to achieve the best convergence χ^2 goodness-of-fit values by using a computer software program (OriginLab, Northampton, MA, USA). The degree of modification of the model obtained was determined by the coefficient of determination (r^2). Student's *t*-test (Das, De, & Ghaffar, 2014) was carried out to check whether the *b* values obtained were significantly different (P<0.05) from 3, signifying the growth pattern of fish as negative allometric (*b*>3.0), positive allometric (*b*>3.0) or isometric (*b*=3.0) (Spiegel, 1991). Statistical significance was set at 5% (P<0.05) in all cases.

3. Results

3.1 Length-weight relationship

The range of total length, body weight, regression parameters, and growth pattern of *Z. buffonis* from each location are summarized in Table 1. It was discovered that *Z. buffonis* from the Sungai Likas region had *b* values greater than 3 and had the highest *b* values compared with the other sampling sites (Figure 1). The value of *b* was also greater than 3 in the Tanjung Belungkor region (Figure 2) which indicated

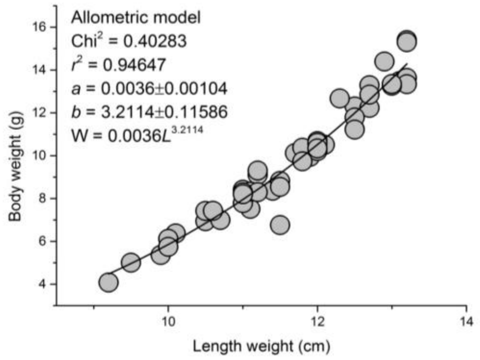

Figure 1. Length-weight relationships of *Z. buffonis* in Sg. Likas. The regression line represents the non-linear fit of the fish and the circles represent individuals.

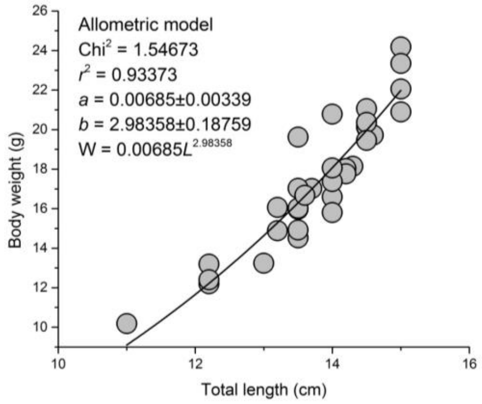

Figure 2. Length-weight relationships of *Z. buffonis* in Tg. Belungkor. The regression line represents the non-linear fit of fish and the circles represent individuals.

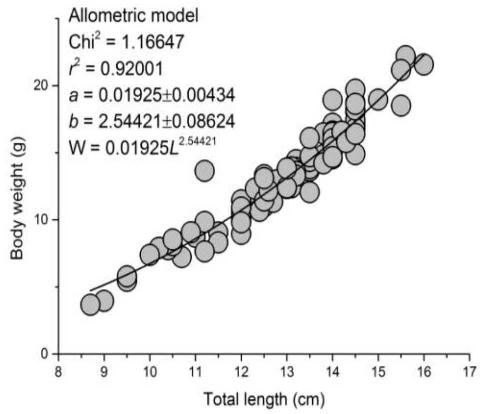

Figure 3. Length-weight relationships of *Z. buffonis* in Langkawi. The regression line represents the non-linear fit of fish and the circles represent individuals.

a positive allometric growth pattern. The populations of *Z. buffonis* in the Langkawi, Klang, and Matang areas showed negative allometric growth (b<3) (Figures 3−5). The *Z. buffonis* from Klang waters displayed the lowest b value among all sampling sites.

An analysis of the condition factor (K) and relative condition factor (Kn) of *Z. buffonis* from all sampling sites are presented in Table 2. All of the fish sampled in this study showed K values lower than 1.0 and all the values were considered significant (P<0.05) with the lowest value in Matang of 0.2292±0.0578 and highest value in Tanjung Belungkor of 0.6556±0.0526. The Kn value was the lowest in Matang (0.9339±0.2336) and highest in Klang (3.5097± 0.4232).

3.2 Trophic level analysis

Three percent of the guts were empty and 97% contained prey items. Three different families of insects, one family of shrimp, and plant materials were identified in this study (Table 3). Insects were the main prey items (57%), followed by plant materials (33%), and crustaceans (10%). Among the identified insect species, weaver ants (Formicidae) and plant materials formed the majority of the diet by weight 7 g. Weaver ants also occurred most frequently (*fo*=96) in the fish samples. It was observed that insects were the majority of the diet by number (*N*=124) and weight (*W*=12g).

The calculated TROPH value for *Z. buffonis* ranged from 1 to 3.3 with a mean value of 3.2±0.55 (Figure 6). Fish with a total length of 8 to 13 cm had trophic values of 1.0 to 3.5 while fish with a total length of 11.5 to 13 cm had a trophic value of 1.0. The diets of the smallest length class consisted entirely insects. The length class of fish of 10.5−12.5 cm showed that the diet shifted by consuming crustaceans with a great contribution of arthropods. The larger length class of fish (12.5−15.5 cm) demonstrated a wider array of food consumption which was comprised of plant materials and insects which indicated that the species has a tendency to be generalist feeders as it grows larger (Figure 7).

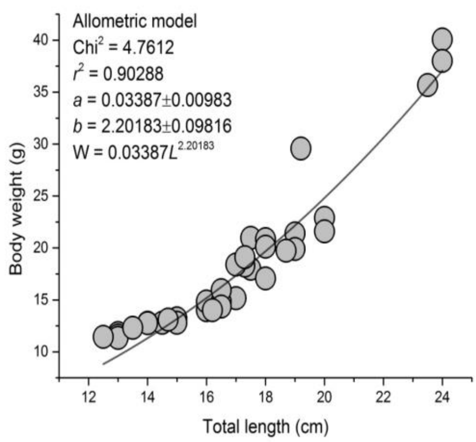

Figure 4. Length-weight relationships of *Z. buffonis* in Klang. The regression line represents the non-linear fit of fish and the circles represent individuals.

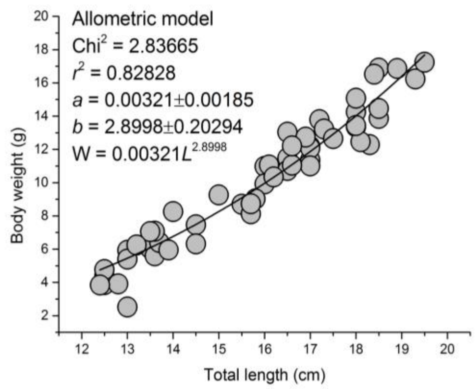

Figure 5. Length-weight relationships of *Z. buffonis* in Matang. The regression line represents the non-linear fit of fish and the circles represent individuals.

Table 2. Condition factor (mean and SD) and relative condition factor (mean and SD) of *Z. buffonis* for five different locations in coastal waters of Malaysia.

Location	Condition factor (*K*)	Relative condition factor (*Kn*)
	Mean±SE	Mean±SE
Sg. Likas	0.6045±0.0403	1.0284±0.0658
Tg. Belungkor	0.6556±0.0526	1.0010±0.0801
Langkawi	0.6007±0.0656	2.9339±0.2336
Klang	0.3613±0.0791	3.5097±0.4232
Matang	0.2292±0.0578	0.9964±0.0937

Table 3. Prey items observed in 84 guts of *Z. buffonis* from coastal waters of Malaysia, were classified by major categories.

Prey category	*N*	*W* (g)	%wt	*n*	*fo*	*w* (g)
Insects	124	12	57	81	96	0.14
Weaver ants (Formicidae)	58	7	33	32	38	0.08
Diving beetles (Dytiscidae)	42	3	14	27	32	0.04
Winged insects (Diptera)	16	2	10	22	26	0.02
Plant materials	16	7	33	3	4	0.08
Mangrove petal fragments	16	7	33	3	4	0.08
Crustaceans	3	2	10	1	1	0.02
Shrimp (*Penaeus sp.*)	3	2	10	1	1	0.02
Total	143	21	100	85	101	0.24

**N*: number of individuals of prey category; *W*: total weight; % wt: percent by weight; *n*: number of guts with prey items; *fo*: frequency of occurrence; *w*: total weight of prey category per gut.

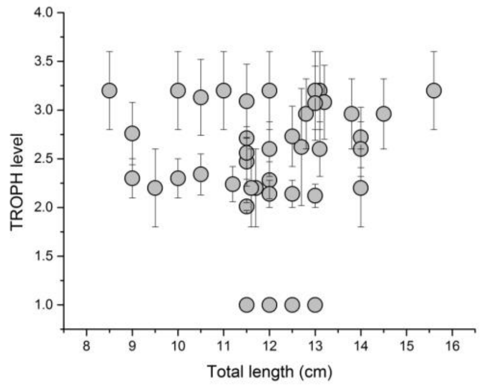

Figure 6. Trophic level-size relationship of *Z. buffonis*. The circles represent the mean trophic level estimated by the TrophLab program and the bars represent the variants of prey items.

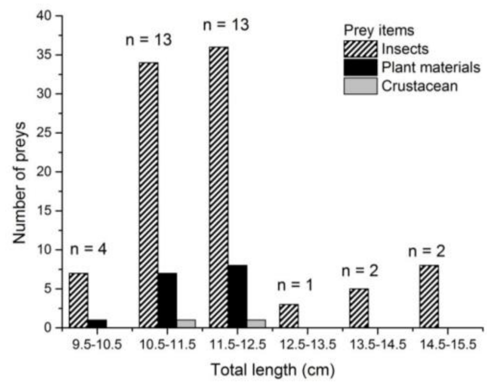

Figure 7. Number of food items ingested by *Z. buffonis*. n=number of fish in each length class (excluding empty gut).

4. Discussion

The present investigation agrees with earlier studies on different species of halfbeak fish from the same family (Hemiramphidae), where positive (b>3) and negative (b<3) allometric growth was reported (Table 4). Various factors may influence the dissimilarity in the growth pattern of this species throughout the seasons and years, for example, salinity, climate, food, and sexual maturity (Sparre, 1992). Therefore, the ecosystem health associated with human exploitation involving aquaculture fish farming and logging activities could be other factors that would disturb the ecological balance of this area.

The greatest exponent b value of this *Z. buffonis* in Sungai Likas indicated that it provided a more favorable environment with an abundance of food availability, thus the fish population had better growth than other regions of coastal waters of Malaysia. The coastal area of Klang had the lowest b value. Klang might be relatively less healthy and at a disadvantage as a result of illegal logging activities that may disturb the water quality, especially sedimentation, dissolved oxygen, temperature, and pH (Mashhor, 2010). Hamzan, Zaini, Ibrahim, and Ariffin (2015) proposed that the natural environment and the water quality of the coastal waters of Klang had deteriorated because of increased waste disposal into the upstream catchment areas from industrial and construction regions. These phenomena may have caused a detrimental influence on the ecosystem health that has resulted in poor growth of the *Z. buffonis*.

Hile (1936) suggested that the allometric coefficients (b) for an optimal fish might vary in the range of 2.5−4.0 and *Z. buffonis* from coastal waters of Malaysia conforms with the typical b values (2.5−3.5) even though it may vary significantly within this range (Froese, 2006). Pervin and Mortuza (2008) stated that higher b values give an

Table 4. Population growth form of hemiramphid as reported from various countries.

Families	Species	Number of fishes collected	Total length range (cm)	*a*	*b*	r^2	Locality	Growth pattern	Author(s)
Hemiramphidae	*Hyporhamphus unifasciatus*	201	4.4 – 22.0	0.008	2.760	0.899	Mexico	NA	González Acosta *et al*. (2004)
Hemiramphidae	*Hemiramphus far*	69	22.0 – 44.5	0.329	1.831	0.848	New Caledonia	NA	Kulbicki *et al*. (2005)
Hemiramphidae	*Hemiramphus brasiliensis*	34	12.9 – 36.4	0.002	3.172	0.977	Grand Cul-de-Sac Marin Bay, Guadelopue	PA	Bouchon-Navaro *et al*. (2006)
Hemiramphidae	*Hyporhamphus roberti roberti*	94	7.0 – 17.2	0001	3.540	0.967	Curucá Estuary, Brazil	PA	Giarrizzo *et al*. (2006)
Hemiramphidae	*Chriodorus atherinoides*	165	10.2 – 26.0	0.004	3.300	0988	La Carbonera lagoon, Mexico	PA	Bonilla-Goméz *et al*. (2013)
Hemiramphidae	*Hyporhamphus affinis*	12	13.5 – 27.5	0.001	3.575	0.970	New Caledonia	PA	Kulbicki *et al*. (2005)
Hemiramphidae	*Hyporhamphus intermedius*	103	10.5 – 14.3	0.002	2.860	0.943	Tian-e-zhou Oxbow Yangtze River, China	NA	Wang *et al.* (2012)
Hemiramphidae	*Zenarchopterus dispar*	36	10.3 – 13.7	-	3.494	0.805	Pidie Jaya, Indonesia	PA	Fadhil *et al.* (2016)
Hemiramphidae	*Zenarchopterus buffonis*	300	7.2 − 24.0	0.007	2.802	0.905	Malaysia	NA	Present study

* *a* is the intercept, *b* is the allometric regression coefficient and r^2 is the correlation coefficient.

indication of the overall condition of the appetite and gonad composition of fish.

The *K* values for *Z. buffonis* were less than 1, with average condition factors of *Z. buffonis* in Sungai Likas, Tanjung Belungkor, and Langkawi that were similar (0.6007−0.6556). Other species of hemiramphids also showed a relatively low (less than 1) condition factor value, such as *Hemiramphus archipelagicus* from Karachi Coast, Pakistan which had a range of condition factors of 0.197−0.257 (Tabassum *et al.*, 2015). In this study, the *K* values of Tanjung Belungkor were higher compared to the other four habitats which indicated that the body specimens in Tanjung Belungkor were fatter and had thicker bodies than the other populations. This may be due to several factors, such as sex (Muchlisin *et al.*, 2010) and maturity (Doddamani & Shanbouge, 2001), spawning (Al-Daham & Wahab, 1991), and the effects of pollutants (Bakhoum, 1999).

The *Kn* value indicates fatness, condition, and welfare of fish. The *Kn* value is an important index used to monitor the feeding intensity and growth rate of fish and is based on the theory that heavier fish at a given length are healthier (Bagenal & Tesch, 1978). Values of *Kn* that are >1 indicate that the well being of the fish is good whereas a value <1 indicates that the fish is in bad condition. In the present investigation, it was found that the *Kn* values were similar (0.9−1.0) for all localities except for Klang (*Kn*>3.0). This may due to random collection of fish samples around the year and the diverse range of available food (Sarkar *et al.*, 2013). This is further supported by similar findings in respect to *Kn* values for different geographical areas, such as the *Barilius bendelisis* populations which exhibited different *Kn* values at different hill stream areas in India (Singh & Nautiyal, 2017). It can be suggested from the results of the current study that the conditions of the fish could be considered as good for all localities from the coastal waters of Malaysia.

This study provides an important understanding into the dietary and feeding habits of *Z. buffonis* in Malaysian coastal waters. Most of the guts of the *Z. buffonis* observed in this study were filled with food items and the percentage of the absence of food was very low. The relatively low percentage of the occurrence of an empty gut possibly resulted from food material availability in the environment, rejection or digestion of food materials in the fish gut while struggling to escape from the hook. This halfbeak species in the Malaysian waters feeds fundamentally on insects in decreasing order of abundance of Formicidae, Dysticidae, and Diptera followed by plant materials and crustaceans. The diet structure of *Z. buffonis* demonstrated that this halfbeak species often feeds at the water surface since insects were the principal content in the gut rather than crustaceans and mangrove petal fragments (Abidin *et al.*, 2015). This may be due to the vast availability of arthropods on mangrove leaves and trees in the environment.

There were some inherent complications with the gut content analysis, for example the complicated taxonomic identification due to the digestive activity especially along the gut and difficulties in quantifying several components in the food items, including detritus and plankton (Polluning & Pinnegar, 2002). Since the gut content analysis was dependent on prey items that could flee instantly before capture, hence they describe a limited perspective of the dietary preference in time and area (de la Moriniere *et al.*, 2003). Nevertheless, gut content analysis is a widely applied method to study the relationships in diet composition and trophic position (Hyslop, 1980).

The calculated value of the trophic level of *Z. buffonis* indicated that they are omnivorous in nature, which signified that their feeding preferences consisted of plant materials (herbivory) to crustaceans and fishes (carnivory). Carnivory feeding preferences were observed in archer fishes (*Toxotes chatareus* and *T. jaculatrix*) which dwell in a similar habitat in Malaysian waters (Simon *et al.,* 2009; Simon & Mazlan 2010). Although no research was previously conducted in the halfbeak trophic level in Malaysian waters, similar feeding preferences of other halfbeak species were documented in coastal waters of North Stradbroke Island (Dey *et al.,* 2011). All of these species exhibited similar feeding preferences, namely crustaceans, insects, and plant materials and can be considered as omnivores. The trophic levels in halfbeak fishes differ with size. The estimated TROPH values suggested that bigger size or adult halfbeak fish can be either herbivorous or carnivorous. But smaller size or juveniles of halfbeak fish can only be carnivorous and possess a dietary protein restriction as they consume primarily insects and crustaceans. This ontogenic trophic shift from carnivorous to omnivorous may be caused by the inability to perform enzymatic digestion of carbohydrates as herbivorous adult fish (Day *et al.,* 2011). The alimentary tract of juveniles may lack the capability to digest plant items adequately, as trophic shifts likely to correspond with elongation of gut (German & Horn, 2006). The results showed that this species of halfbeak fish fed principally on insects rather than crustaceans and plant materials. This was possibly due to the vast availability of insects on mangrove leaves in the environment.

Typically for most fish species, the sizes of prey consumed increase correspondingly to the size of the predator, which is applicable for comparisons within a fish species (Stergiou & Karpouzi, 2002). This is because as a fish grows, their relative success rate increases as the result of an ontogenetic shift in the sensory system and swimming efficiency (Juanes & Conover, 1994). In addition, a few studies also assessed the dietary shifts in relation to ontogenic changes in attributes, such as mouth gape, pharyngeal morphology, digestive anatomy, and nutritional requirements of gastrointestinal development, that are needed for fish growth (Davis, 2012).

5. Conclusions

The specimens from Matang had the lowest mean *K* of 0.2292±0.0578 whereas Tanjung Belungkor demonstrated the highest value of 0.6556±0.0526. Matang was discovered to display the lowest *Kn* of 0.0330±0.2336 whereas Klang had the highest *Kn* value of 3.5097±0.4232. The gut content analysis revealed that *Z. buffonis* consume primarily insects (57%), followed by plant materials (33%) and crustaceans (10%). The calculated TROPH values of 1−3.2 signified that *Z. buffonis* has an omnivorous feeding habit. The present study document the fundamental information on LWR parameters, condition factors, and diet preference for *Z. buffonis* collected from the Malaysian coastal waters that can be helpful for ichthyologists and environmentalists to enforce adequate management and regulations to ensure sustainable fisheries and biodiversity conservation, specifically in the coastal waters of Malaysia.

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