Length-weight relationship, condition factor and TROPH of *Scatophagus argus* in Malaysian coastal waters

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Abstract. The present study was carried out to investigate the length-weight relationship, condition factor and TROPH of spotted scat, *Scatophagus argus* collected from the fish landing centre at Gelang Patah, Johor. The population growth pattern of scats was allometric negative ($b < 3$) indicated that the weight increment was lesser than length increment. The Fulton condition factor (K) and relative condition factor (K*n*) were greater than 1 indicated the wellbeing of fish. The highest and lowest condition factor values were observed in December and June, which may indicate the spawning and recovery season of *S. argus*. The results of stomach content analysis showed that the algae and detritus are the most abundant prey items by weight/volumes followed by crustaceans, and fish. The most represented taxa were brown seaweed *Sargassum* spp.*,* shrimp *Acetes indicus*, and fish. The overall mean trophic level for *S. argus* was close to 3 (2.977±0.364) suggesting the herbivory and carnivory feeding behaviour of fish. However detail fractal TROPH values analysis explained true scenario of *S. argus* diet denoting that the fish eat wide variety of diet from algae (2.19±0.2804), crustacean, benthic organism (3.55±0.2087) and even fishes (4.26±0.1776) referring the omnivory feeding behaviour. The different value of TROPH for the different standard length indicates that this species developed high degree of resiliency of which the fish can be categorized as an opportunistic feeder. Therefore, the present study nullify the previous statement which stated that the *S. argus* are scat eater. The data obtained from this study would be useful for fish biologist and resource managers to proper management of this important fishery resourcenot only in Malaysian waters but also nearby areas of this country.
Key Words: spotted scat, growth, condition factor, omnivorous.

Introduction. The spotted scat (*Scatophagus argus*) is a euryhaline teleost which is widely dispersed in the near shore waters of the Indo-Pacific (Nelson 1976) and inhibit coastal muddy areas including estuaries, mangroves, harbours and the lower streams of rivers (Bianchi 1985; Rainboth 1996). *S. argus* is a popular ornamental fish because of its attractive pattern (Morgan 1983; Amarasinghe et al 2002; Bambaradeniya et al 2002) and it is also a valuable marketed species especially in Philippines and Thailand (Barry & Fast 1988, 1992; Sawusdee 2010). This species can tolerate high degree of resiliency which makes them highly desired in cultures finfish (Barry & Fast 1988).

In assessing fish species ecological function and impact, it is important to have a knowledge of length-weight relationship (LWR) and condition factor of fishes mainly when the species lies at the base of the higher food web (Lizama & Ambrósio 2002). LWR paramerters (*a* and *b*) are very useful to estimate weight of individual fish from its length, to determine condition indices, to equate life history and morphology of populations belonging to different regions (Petrakis & Stergiou 1995). Fulton's condition factor (K) is generally used in fisheries and fish biology studies to calculate the relationship between weight of the fish and its length, with the aim of depicting the condition of the individual fish (Froese 2006). A series of research on basic biology on *S. argus* by Barry & Fast (1988, 1992) and Sawusdee (2010) have been performed. Relative condition factor (K_n) of *S. argus* have been conducted by Sivan & Radhakrishnan (2011) in Cochin, India but no report on Fulton condition factor (K) is available in the literature.

Aside from the population growth pattern, to understand the trophic interactions in aquatic food webs, accurate description of diets and feedings habits of a fish species is essential (Vander Zanden et al 2000). The quality and quantity of food are among the most important exogenous factors directly affecting growth and, indirectly, maturation and mortality in fish thus being ultimately related to fitness (Wootton 1990).

Qualitative studies on feeding habits of *S. argus* has been made in estuaries of Bengal (Mookerji et al 1949) and Cochin (Sivan & Radhakrishnan 2011); brackish and freshwater (Datta et al 1984); mangrove areas of Thailand (Monkolprasit 1994); and marine environment of Mandapam (Gandhi 2002). Despite the large magnitude of the research on growth and feeding studies of *S. argus*, no studies have been reported in Malaysian coastal waters on their annual condition and trophic level.

The aims of this study were to determine the population growth pattern, annual conditions factor (K, K_n) and trophic level of *S. argus* collected from Johor coastal waters, Malaysia.

Material and Method. Fish samples were collected from fish landing centre of Gelang Patah, Johor from January 2013 to December 2013. A total of 958 fish were collected and fish identification was carried out in the field according to the description of Kottelat (2001). The fresh fish samples in various sizes were random saved for trophic level study. To prevent further decomposition and digestion, 4% (w/v) formaldehyde was also injected directly into the fish's abdomen after length and weight measurement (Simon et al 2009).

Length-weight relationship*.* Population growth of *S. argus* was estimated based on length-weight relationship analysis. Fish specimens were measured using measuring board to the nearest 1 cm (total length, TL) (Simon et al 2008) and weighed to the nearest 0.1 g (total body weight, BW) using electronic weighing balance (Model: KD-300KC) (De et al 2016). The relationship between the length and weight of a fish is expressed by the equation $W = aL^b$ (Ricker 1973), where *W* is body weight (g), *L* is total length (cm), *a* is the intercept, and *b* is the slope (fish growth rate) (Beverton & Holt 1996). The fish were immediately preserved in 10% (w/v) formaldehyde for further analysis in the laboratory. Determination of *a* and *b* values was done using a non-linear regression for which curve fitting was carried out by a non-linear iterative method using Levenberg-Marquardt and Simplex algorithms for obtaining best convergence $\chi 2$ goodness of fit values using a computer programme, Microcal Origin™ Version 6.0 (Simon & Mazlan 2008). The degree of adjustment of the model studied was assessed by the correlation coefficient ($r2$). A *t*-test was performed to test whether the computed value of *b* was significantly different from 3.0, indicating the type of growth: isometric ($b = 3.0$), positive allometric ($b > 3.0$), or negative allometric ($b < 3.0$) (Spiegel 1991; Das et al 2014). In all cases a statistic significance of 5% was adopted.

Condition factors*.* The Fulton condition factor (K) was calculated for each individual fish according to the equation: $K = 1000\ W / L^3$; where *W* is the total body weight in g and *L* is the total length in cm (Bauchot & Bauchot 1978). The relative condition factor (K_n) was calculated according to equation: $K_n = W / aL^3$; the value of a and b from the length-weight relationship were employed in calculating the relative condition factor (K_n) (Godinho 1997). Analysis of variance was carried out to test the effect of monthly variation of condition factor (K, K_n). Tukey's post hoc tests were used to compare the significant differences ($p < 0.05$) in mean monthly condition factors of *S. argus*. All statistical analyses were performed using MINITAB (version 14), and Microcal Origin™ Version 9.0 software (De et al 2016; Simon et al 2013).

Stomach content and trophic level analysis. In the laboratory, the stomach was removed and preserved in 70% (v/v) ethanol for longer preservation. Estimation of diet was achieved by stomach contents analyses from pre-selected samples (n = 360); 30 fish samples were randomly selected from monthly catch collection. In order to provide an indication of homogeneity of feeding within a fish population, both quantitative and qualitative methods are taken into account in stomach content analysis (Hynes 1950; Hyslop 1980; Natarajan & Jhingran 1961; Lin et al 2007; Sivan & Radhakrishnan 2011). Feeding intensity of *S. argus* was obtained by monthly variations in feeding index on stomach fullness as mention by Kow (1950). Estimation of stomach fullness were measured by estimating the space occupied by food contents in the stomach in percentage; 50-75% as actively fed and below 50% as poorly fed. The intensity of feeding was assessed visually based on the distension of the stomachs (Rao 1964) and was classified as empty, ¼ full, ½ full, ¾ full and full. The empty and ¼ full stomachs were considered as poorly fed and others as actively fed.

Stomach contents were analysed and sorted under light microscope to quantify in accordance with occurrence method (Hyslop 1980). Frequency of occurrence (fo) and percentage weight (wt%) were examined for different length classes (Simon & Mazlan 2010). The frequency of occurrence method was applied by counting the number of stomachs which consist of one or more individuals of each consumed item, and the total was enunciate as a percentage of the total number of stomachs examined (FO%).

Trophic level (TROPH) represents the position of an organism which it occupies in the food webs that largely define aquatic ecosystems (Pauly et al 1995, 1998; Pauly & Christensen 1995, 2000; Pauly & Palomares 2000). Trophic level of *S. argus* were estimated using diet composition data of which later analysed using a TROPHLAB software (Pauly et al 2000), which is a stand-alone application for estimating TROPH and its standard error (S.E) using the weight or volume contribution and the trophic level of each prey species to the diet (Pauly et al 2001). Real consumers do not usually have TROPHs with integer values and the definition of TROPH for any consumer species *i* is:

$$TROPH_i = 1 + \sum_{j=1}^{G} DCij \times \mathrm{TROPH_j}$$

where *TROPHj* is the fractional trophic level of prey *j*, DC*ij* represents the fraction of *j* in the diet of *i*, and *G* is the total number of prey species. Thus defined, the trophic level of aquatic consumers is a measurable entity that can take any value between 2.0 for herbivours and 5.0 for piscivorous/carvivous organisms (Pauly et al 1998; Pauly & Palomares 2000).

Results

Length-weight relationship. General analysis of length and weight of the whole samples (n = 958) indicated that the total body wet weight of fishes collected throughout the study ranged within 11.69 to 470.0 g and total length ranged between 9.00 to 24.30 cm, respectively. Further analysis of length-weight relationship ($W = aL^b$) provides population growth information of *S. argus* fish collected from study areas. The results of analysis for combined length-weight relationship (LWR) showed that intercept *a* were 0.05537 (±0.00557) whiles exponent *b* were 2.76035 (±0.03681), with correlation coefficient $r^2 = 0.82445$. The exponent *b* value were significantly ($p < 0.05$) below than 3 indicate it is negative allometric growth pattern which explains the increment of weight in *S. argus* does not in proportionate to its length increments (Figure 1).

However calculated monthly LWR of *S. argus* showed a variation of parameters. The exponent b value for April, July, August, September and October is less than 3 was expected considering the laterally compressed body form of *S. argus* and the exponent b value is the same as the entire sample. Meanwhile for January, February, March, May, June and November shows that the exponent b value is more than 3 indicating that the growth is positive allometric, the fish is relatively stouter or deeper-bodied as it increases in length. The growth coefficient was minimum in July/August (b = 1.44/2.14) and maximum in February (b = 3.37) (Table 1). The calculated *b* value for combined LWR is significantly different from $b = 3$ ($p < 0.05$), however in monthly b values as presented in Table 1 all are significantly different from b except March and November ($p > 0.05$) representing isometric growth form.

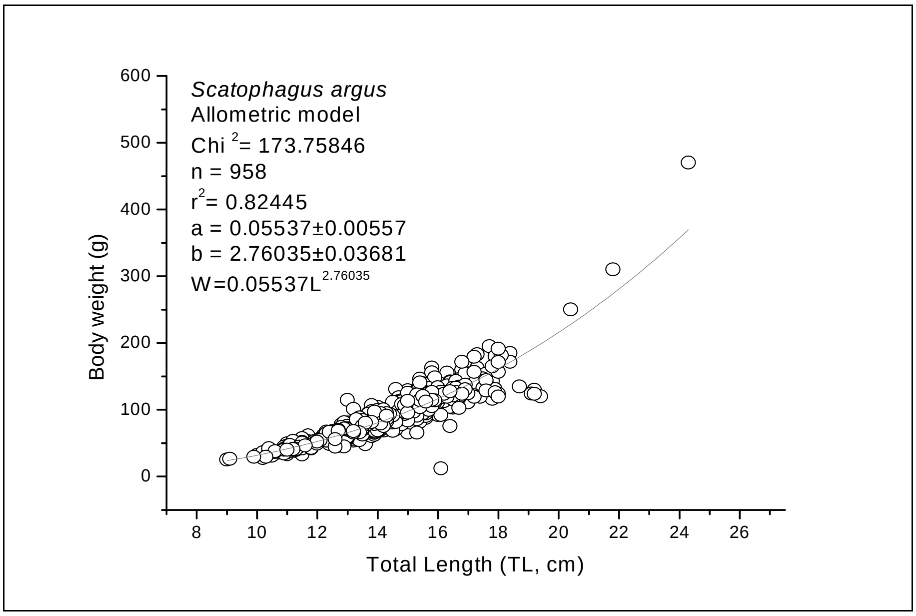

Figure 1. Length-weight relationship of *S. argus* samples collected from January to December 2013 (combined sex). Empty circles represent individual sample and solid line represents non-linear curve fitting.

Table 1

Estimated parameters of length-weight relationship, Fulton's condition factor and relative condition factor analysis based on monthly data collection from January to December 2013 of *S. argus* from Gelang Patah, Johor, Malaysia

Month	*n*	*a*	*b*	*r²*	*K*	K_n
January	56	0.01±0.005	3.28±0.11	0.95604	2.99^{cd}±0.17	1.03^{cdef}±0.08
February	118	0.01±0.003	3.37±0.09	0.90228	3.18^{b}±0.24	1.10^{b}±0.10
March	72	0.03±0.009	3.02±0.11	0.92003	3.20^{b}±0.13	1.06^{bc}±0.04
April	101	0.07±0.020	2.66±0.11	0.84287	2.75^{ef}±0.22	0.96^{efg}±0.08
May	95	0.01±0.003	3.26±0.08	0.93434	2.82^{def}±0.13	0.97^{efg}±0.06
June	110	0.01±0.002	3.27±0.05	0.9446	2.73^{f}±0.12	0.95^{g}±0.05
July	52	2.06±0.916	1.44±0.16	0.62452	2.96^{cde}±0.31	1.03^{cde}±0.09
August	86	0.30±0.104	2.14±0.12	0.76193	2.92^{de}±0.18	1.02^{cd}±0.06
September	99	0.05±0.145	2.78±0.10	0.88285	2.75^{ef}±0.08	0.96^{fg}±0.03
October	108	0.06±0.016	2.74±0.10	0.87381	2.88^{def}±0.17	0.99^{defg}±0.05
November	47	0.03±0.012	3.05±0.16	0.88579	3.17^{bc}±0.22	1.07^{bc}±0.09
December	48	0.20±0.035	2.51±0.07	0.94846	3.65^{a}±0.19	1.33^{a}±0.07

N: number of sample; *a*: intercept; *b*: slope (fish growth form); r^2: the goodness of fit; K: mean Fulton condition factor; K_n: mean relative condition factor; $K^{a\text{-}f}$ and $K_n^{a\text{-}g}$: Tukey pairwise comparison means that do not share a letter are significantly different at $p < 0.05$.

Condition factors. The mean condition factors for *S. argus* from Gelang Patah, Johor are shown in Table 1. The results indicated that there was a significant difference between mean K and K_n in January, March, April, May, Jun, August, September and October ($p < 0.05$). There were no significant differences between monthly K and K_n in February, July, November and December ($p < 0.05$). The mean Fulton condition factor (K) for *S. argus* ranged from 2.73 to 3.65. The relative condition factor (K_n) ranged from 0.95 to 1.33 (Figure 2). In January, the mean monthly K rose from 2.99 to reach a peak of 3.20 in March and then decline abruptly in April to 2.75 and reached their lowest mean K values of 2.73 in June. In July it rose to 2.96 and declined again to 2.75 in September and reached the highest peak of 3.65 in December. The mean monthly K_n also followed similar trend rising from 1.03 in January however to reach a peak of 1.10 in February and decline gradually to 0.96 in April and reached their lowest mean K_n values of 0.95 in June. In July it rose to 1.03 and declined again to 0.96 in September and reached the highest peak of 1.33 in December. Overall, the mean monthly K and K_n have three noticeable peaks which is in February, July and December with the highest peak in December and the values were no significantly different ($p < 0.05$).

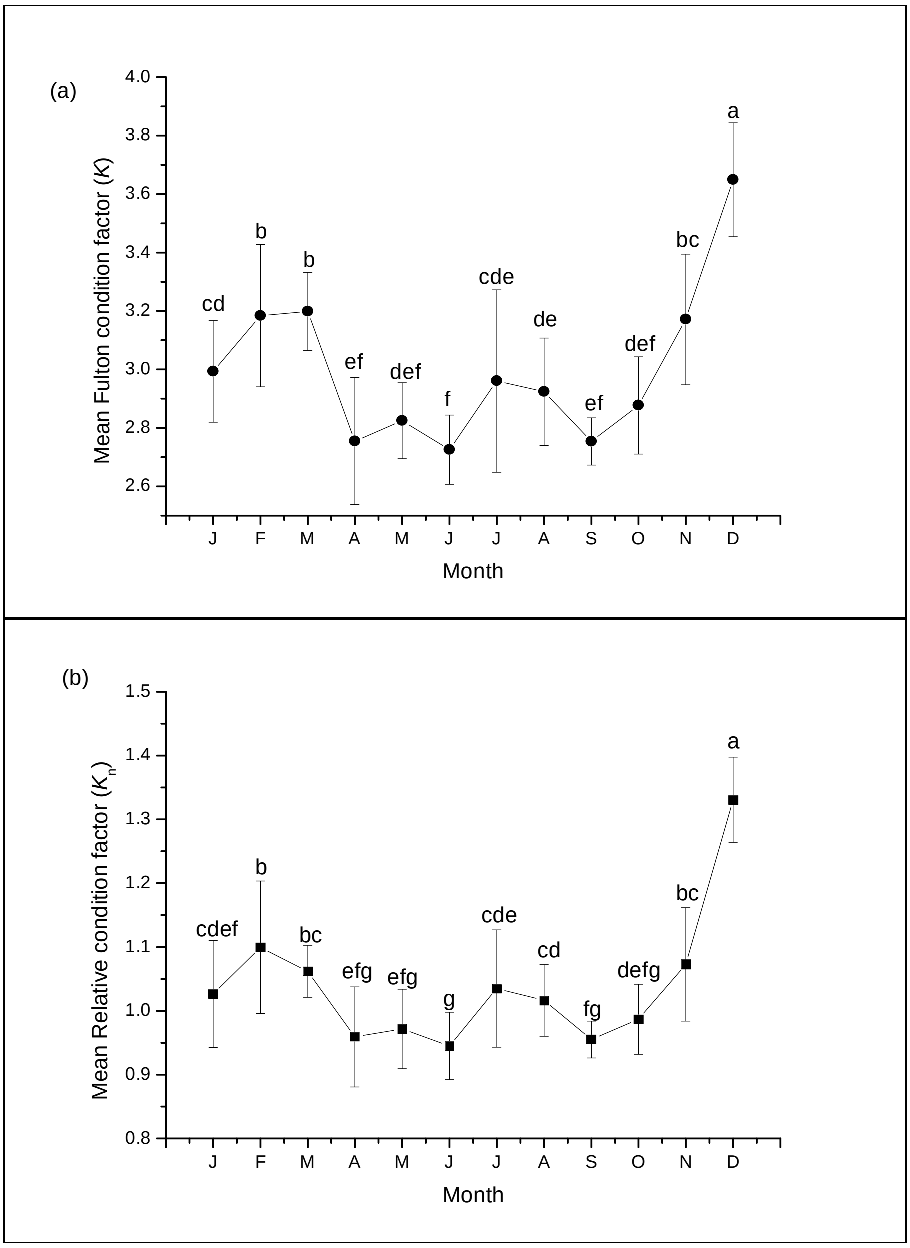

Figure 2. Monthly variation in condition factor of *S. argus*: (a) Fulton condition factor (K), and (b) relative condition factor (K_n). Letters above the mean values indicate significant differences of mean condition factors at $p < 0.05$. Data are represented as mean±SD.

Stomach content and Troph level analysis. The stomachs of 360 *S. argus* samples were examined, and only 85% contained food items and 15% were found empty. The food items were grouped into eleven major categories, detritus (38.03%) were found the most abundant by weight/volumes followed by crustaceans (20.26%), algae (17.10%), brown seaweed (12.28%), and teleost (9.41%). Other prey categories which contributed a small proportion of diet were scales (2.16%), insect (1.45%), cnidaria (0.89%), cephalopod (0.48%), polychaetes (0.08%) and bivalve (0.01%) (Table 2). The most dominant and most frequent food items were algae (Cyanophyceae) f_o = 19.4 (17.10% w/v) followed by detritus f_o = 19.4 (38.03% w/v), shrimp (*Acetes indicus*) f_o = 18.9

(19.2% w/v), teleost f_o = 13.1 (9.41% w/v), and brown seaweed (*Sargassum* sp.) f_o = 8.9 (12.28% w/v). The least prey item occur were Bivalve (juveniles cockles) f_o = 1.32 (0.01% w/v) which found only in two fish stomach. The presence of scales (f_o =2.2%) could not be considered as intended feeding item as observation on the groups of *S. argus* in captivity exhibits antagonistic behavior where the fish fighting by biting scales of their tank mate. Therefore this may indicate that the fish either purposely biting their mate for scales or it was one of offensive strategies during fighting.

Table 2
Prey items observed in 360 spotted scat stomachs from Gelang Patah, Johor, Malaysia were grouped by major prey categories

Prey category	*N*	*W (g)*	*wt %*	*n*	f_o	*w (g)*
Algae - Cyanophyceae		82.3	16.73	70	19.4	0.23
Bivalve - cockles	10	0.07	0.01	2	0.6	0.0002
Seaweed - brown seaweed		59.1	12.02	32	8.9	0.16
Cephalopod - squid	17	2.3	0.47	11	3.1	0.01
Cnidaria - jellyfish	724	4.28	0.87	6	1.7	0.01
Crustaceans - amphipod	7361	5.1	1.04	10	2.8	0.01
Crustaceans - shrimp	975	92.4	18.79	68	18.9	0.26
Detritus		183	37.20	70	19.4	0.51
Insect	233	7	1.42	7	1.9	0.02
Polychaetes	8	0.4	0.08	4	1.1	0.001
Scales	532	10.63	2.16	8	2.2	0.03
Teleost	323	45.3	9.21	47	13.1	0.13
Total	10183	491.88	100			1.37

N: number of organisms of prey category; *W*: total weight; wt%: percentage weight in g; *n*: number of stomachs with prey item; f_o: frequency of occurrence; *w*: weight per stomach sampled in g.

The estimated trophic level ranged from 2.0 to 4.5 with mean values of 2.977±0.364 (Figure 3).

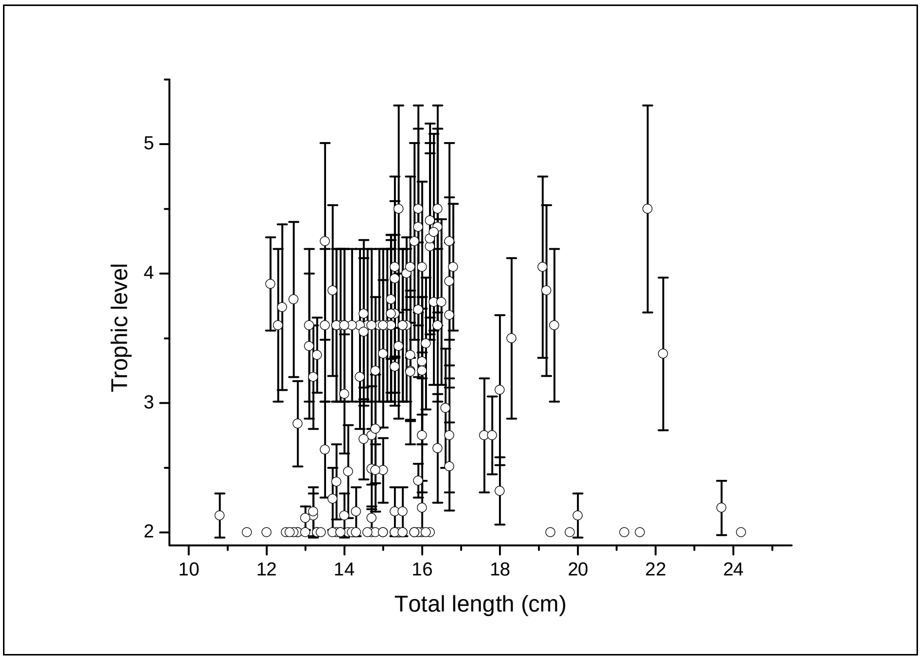

Figure 3. Trophic level-size relationship of *S. argus* (circles represent mean trophic level estimated by TROPHLAB program and bars represent variants of prey items).

The trophic level for smallest (TL = 10.8 cm) and the largest fish (TL = 24.2 cm) were estimated at 2.13 and 2.0 respectively indicating the fish is herbivores/detritivores.

Trophic level class between 3.0 to 3.5 were omnivorous ranging from 12.1 cm to 22.2 cm in total length and trophic level 4 were piscivorous ranged from 13.5 cm to 21.8 cm. Overall, the smallest fish size, 10.8 cm, were herbivorous then the diet shift to omnivorous at size length 12.0 cm and at size length 20.0 cm it shift it's diet back to herbivorous. The results of fractal TROPH analysis may indicate that there is a possibility of ontogenetic shift of feeding throughout life history of *S. argus*. However, overall trophic level analysis of *S. argus* did not follow a regular pattern and the diet highly depended on the availability of food.

Discussion. In the current study, *S. argus* displayed negative growth (b < 3) pattern, indicating fish become more slender as length increases. The similar growth pattern for *S. argus* was recorded in Thailand and Philippines waters (Sawusdee 2010; Barry & Fast 1992). The exponent 'b' values of afore mentioned areas are within the range of 2.552~2.92 (Bagenal & Tesch 1978). High values of correlation coefficient r^2 indicated a high degree of positive correlation between the total length and total weight of this species. In terms of monthly growth type, it was observed in January, February, May, and June fish present positive allometric growth (b > 3) while in other month it shows negative allometric growth (b < 3) except for March and November (p > 0.05) representing isometric growth form. Such changes in b value may be attributed to certain environment factors such as food competition, availability of food, season, temperature, salinity, time of maturity and sex (Pauly 1984; Sparre 1992). Considering the b values at the time of samplings, large specimens have a body shape that becomes more elongated or the small specimens were in better nutritional condition (Froese 2006). Unlike parameter a that may vary between habitats, seasonally or even daily (Bagenal & Tesch 1978; Gonçalves et al 1997; Taskavak & Bilecenoglu 2001; Özaydin & Taskavak 2007). Therefore, the LWR in fish is influenced by gonad development, feeding intensity, diet, stomach fullness, and preservation technique, nevertheless none of them are taken into account in the present study.

The condition factor of *S. argus* showed no regular patterns. The Fulton condition factor (K) in this study were above 1 which shows that the fish in this study are in good condition. It is documented by Bagenal & Tesch (1978) that the ideal condition factor for mature fresh and brackish water fish were ranged of 2.9-4.8. Sivan & Radhakrishnan (2011) studied the relative condition factor (K_n) of *S. argus* in Cochin, India in 2007 ranged from 0.9 to 1.3 which was similar with our findings which ranged from 0.95 to 1.33. There were three evident peaks in both condition factor K and K_n which is in February, July and December and the values were no significantly different ($p < 0.05$). However, Sivan & Radhakrishnan (2011) findings were otherwise for June and September. These high and low peaks suggest that the energy of the fish is concentrated on the growth of the fish and development of the gonad. This suggests that *S. argus* may start its reproductive period in February/March and recover in December.

The authors' findings show that the *S. argus* in Johor coastal waters feed primarily on algae (Cyanophyceae) followed by detritus, shrimp, teleost and brown seaweed (*Sargassum* sp.) (Table 1). In terms of dominated the stomach content by weight was detritus and algae, while bivalve (cockles juvenile) was the least. The presence of detritus, algae, brown seaweed and fish scales prove that *S. argus* is a bottom feeder. It is believed that the cockle juveniles were fed by accident while they are feeding on algae and detritus on the ocean floor.

This study shows that *S. argus* in Johor coastal waters feed primarily on algae (Cyanophyceae) followed by detritus, shrimp, teleost and brown seaweed (*Sargassum* sp.) (Table 2). In terms of dominated item (preys) by weight were detritus and algae, while bivalve (cockles juvenile) was the least. The presence of detritus, algae, brown seaweed and fish scales prove that *S. argus* is a bottom feeder. It is believed that the cockle juveniles were fed by accident while they are feeding on algae and detritus on the ocean floor. Similar findings were reported in previous studies (Mookerji et al (1949), Khan (1979), Datta et al (1984), Monkolprasit (1994), Gandhi (2002), Wongchinawit & Paphavasit (2009) and Sivan & Radhakrishnan (2011)) in different localities, however, our findings reported for the first time some new prey items including insect, cephalopod (squid juvenile), teleost and cnidarian (jellyfish juvenile) in *S. argus* stomach. It is presumed that the insects were attracted to light at the jetty / harbour and fall on the water surface which then was eaten up by *S. argus*. Sivan & Radhakrishnan (2011) found that detritus and algae were always associated together in the diet which actually the fish preferred algae while feeding on algae attached with detritus. Shrimp and teleost were found frequently in fish stomach which suggests that *S. argus* diets are related to food availability. The presence of both animal and plant food items in the diet indicates that the fish is omnivorous.

The overall mean trophic level for *S. argus* is 2.977±0.364 indicating that they fell in between herbivorous and omnivorous category. However detail fractal troph values analysis explained true scenario of *S. argus* diet denoting that the fish eat wide variety of diet from algae (2.19±0.2804), crustacean, benthic organism (3.55±0.2087) to fish species (4.26±0.1776). At TL < 12.0 cm the trophic level was mainly 2, meanwhile at TL ranged 12-20 cm the trophic level was in between 2 to 4.5. When the scat fish reach at certain length (TL > 19.0 cm), the diet are mainly plant food items. The different value of trophic level for the different standard length indicates that this species developed high degree of resiliency of which the fish can be categorized as an opportunistic feeder. The TROPH of *S. argus* have not been previously recorded in Malaysia or elsewhere.

Conclusions. Our study provides the first report on population growth pattern and condition of *S. argus* in Malaysian waters. The calculated LWR analyses denoted that *S. argus* exhibit negative allometric growth (b < 3) indicating its length increased faster than its body weight while growing. High condition factor in December suggest that the energy of the fish is concentrated on the growth of the fish and recovering after spawning season. The estimated trophic level of 2.977±0.364 indicates that *S. argus* is omnivorous feeder. However, the ontogenetic niche shift throughout their different development stages of life considering them an opportunistic feeder. New diet findings of *S. argus* also include fish juvenile, jellyfish juvenile, insect, and squid juvenile. The information obtained from this study would add some basic information on the growth, condition factor, and TROPH of *S. argus* in Johor coastal waters.

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References

Amarasinghe U. S., Amarasinghe M. D., Nissanka C., 2002 Investigation of the Negombo estuary (Sri Lanka) brush park fishery, with an emphasis on community-based management. Fisheries Management and Ecology 9:41-56.

Bagenal T. B., Tesch F. W., 1978 Age and growth. In: Methods for assessment of fish in freshwaters. 3rd edition, Bagenal T. (ed), IBP Handbook No. 3, Blackwell Scientific Publications, Oxford, UK, pp. 101-136.

Bambaradeniya C. N. B., Ekanayake S. P., Kekulandala L. D. C. B., Fernando R. H. S. S., Samarawickrama V. A. P., Priyadharshana T. G. M., 2002 An assessment of the status of biodiversity in the Maduganga mangrove estuary. Occasional Papers of IUCN Sri Lanka, 49 pp.

Barry T. P., Fast A. W., 1988 Natural history of the spotted scat (*Scatophagus argus*). In: Spawning induction and pond culture of the spotted scat (*Scatophagus argus* Linnaeus) in the Philippines. Fast A. W. (ed), Mariculture Research and Training Center, Hawaii Institute of Marine Biology, University of Hawaii at Manoa, pp. 4-31.

Barry T. P., Fast A. W., 1992 Biology of the spotted scat (*Scatophagus argus*) in the Philipines. Asian Fisheries Science 5:163-179.

Bauchot R., Bauchot M. L., 1978 Coefficient de condition et indice pondéral chez les téléostéens. Cybium 4:3-16. [in French]
Beverton R. J. H., Holt S. J., 1996 On the dynamics of exploited fish populations. Chapman and Hall, London, 568 pp.
Bianchi G., 1985 FAO species identification sheets for fishery purposes. Field guide to the commercial marine and brackish-water species of Pakistan. Prepared with the support of PAK/77/033/ and FAO (FIRM) Regular Programme. FAO, Rome, 200 pp.
Das S. K., De M., Ghaffar M. A., 2014 Length-weight relationship and trophic level of hard-tail scad *Megalaspis cordyla*. Science Asia 40(5):317-322.
Datta N. C., Bandyopadhyay B. K., Barman S. S., 1984 On the food of an euryhaline perch *Scatophagus argus* (Cuv. and Val.) and the scope of its culture in fresh water. International Journal of the Academy of Ichthyology, Modinagar 5:121-124.
De M., Ghaffar M. A., Bakar Y., Cob Z. C., Das S. K., 2016 Optimum temperature for the growth form of tiger grouper (*Epinephelus fuscoguttatus* ♀) × giant grouper (*E. lanceolatus* ♂) hybrid. Sains Malaysiana 45(4):541-549.
Froese R., 2006 Cube law, condition factor and weight–length relationships: history, meta analysis and recommendations. Journal of Applied Ichthyology 22:241-253.
Gandhi V., 2002 Studies on the food and feeding habits of cultivable butterfish *Scatophagus argus* (Cuv. And Val.). Journal of the Marine Biological Association of India 44(1-2):115-121.
Godinho A. L., 1997 Weight-length relationship and condition of the characiform *Triportheus guentheri*. Environmental Biology of Fishes 50(3):319-330.
Gonçalves J. M. S., Bentes L., Lino P. G., Ribeiro J., Canário A. V. M., Erzini K., 1997 Weight–length relationships for selected fish species of the small-scale demersal fisheries of the south and southwest coast of Portugal. Fisheries Research 30:253-256.
Hynes H. B. N., 1950 The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. Journal of Animal Ecology 19:36-58.
Hyslop E. J., 1980 Stomach contents analysis: a review of methods and their application. Journal of Fish Biology 17(4):411-429.
Khan M. Z., 1979 A note on the occurrence of a large sized spotted butterfish, *Scatophagus argus* (Linnaeus) at Rajpara (Guijarat). Journal of the Marine Biological Association of India 21:193-194.
Kottelat M., 2001 Scatophagidae. Scats. In: FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles. Carpenter K. E., Niem V. (eds), Food and Agriculture Organisation, Rome, pp. 3623-3626.
Kow T. A., 1950 The food and feeding relationship of the fishes of Singapore straits. Colonial Office, Fishery Publications, UK 1(1):1-35.
Lin H. J., Kao W. Y., Wang Y. T., 2007 Analyses of stomach contents and stable isotopes reveal food sources of estuarine detritivorous fish in tropical/subtropical Taiwan. Estuarine, Coastal and Shelf Science 73:527-537.
Lizama M. de Los A. P., Ambrosio M. A., 2002 Condition factor in nine species of the Characidae family in the upper Parana River Floodplain Brazil. Brazilian Journal of Biology 62(1):113-124.
Monkolprasit S., 1994 Fish composition and food habits in Mangrove forests at Phang-Nga Bay and Ban Don Bay, Thailand. Kasetsart University Fishery Research Bulletin No. 20, Faculty of Fisheries, Kasetsart University, Bangkok, 21 pp.
Mookerji J. K., Ganguly D. N., Mazundar T. C., 1949 On the food and feeding of a leopard pomfret *Scatophagus argus* (Pallas) and the possibility of its culture near the estuaries of Bengal. Science and Culture 15(2):76-77.
Morgan S., 1983 Scats. Personable, hardy garbage dispersals for the brackish water aquarium. Tropical Fish Hobbyist, April, pp. 65-69.
Natarajan A. V., Jhingran A. G., 1961 Index of preponderance - a method of grading the food elements in the stomach analysis of fishes. Indian Journal of Fisheries 8(1):54-59.

Nelson J. S., 1976 Fishes of the World. Wiley, New York, 416 pp.
Özaydin O., Taskavak E., 2007 Length-weight relationships for 47 fish species from Izmir Bay (eastern Agean Sea, Turkey). Acta Adriatica 47(2):211-216.
Pauly D., 1984 Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews 8:52-80.
Pauly D., Christensen V., 1995 Primary production required to sustain global fisheries. Nature 374(6519):255-257.
Pauly D., Christensen V., 2000 Trophic levels of fishes. In: Fish Base: concepts, design and data sources. Froese R., Pauly D. (eds), ICLARM, Manila, Philippines, 181 pp.
Pauly D., Palomares M. L., 2000 Approaches for dealing with three sources of bias when studying the fishing down marine food web phenomenon. In: Fishing down the Mediterranean food webs? Briand F. (ed), CIESM Workshop Series 12:61-66.
Pauly D., Trites A., Capuli E., Christensen V., 1995 Diet composition and trophic levels of marine mammals. International Council for the Exploration of the Sea Conference and Meeting, 1995/N: 13, pp. 22.
Pauly D., Trites A., Capuli E., Christensen V., 1998 Diet composition and trophic levels of marine mammals. ICES Journal of Marine Science 55(3):467-481.
Pauly D., Froese R., Sa-a P. S., Palomares M. L., Christensen V., Rius J., 2000 TrophLab manual. ICLARM, Manila, Philippines, 115 pp.
Pauly D., Palomares M. L. D., Froese R., Sa-a P., Vakily M., Preikshot D., Wallace S., 2001 Fishing down Canadian aquatic food webs. Canadian Journal of Fisheries and Aquatic Sciences 58(1):51-62.
Petrakis G., Stergiou K. I., 1995 Weight-length relationships for 33 fish species in Greek waters. Fisheries Research 21(3-4):465-469.
Rainboth W. J., 1996 FAO species identification field guide for fishery purposes. Fishes of the Cambodian Mekong. Rome, FAO, 265 pp.
Rao K. S., 1964 Food and feeding habits of fishes from trawl catches in the Bay of Bengal with observations on the diurnal variation in the nature of the feed. Indian Journal of Fisheries 11(1):277-314.
Ricker W. E., 1973 Linear regressions in fishery research. Journal of the Fisheries Research Board of Canada 30:409-434
Sawusdee A., 2010 Population dynamics of the spotted scat *Scatophagus argus* (Linnaeus, 1766) in Pak Panang Bay, Nakhon Si Thammarat, Thailand. Walailak Journal of Science and Technology (WJST) 7(1):23-31.
Simon K. D., Mazlan A. G., 2008 Length-weight and length-length relationship of archer and puffer fish species. Open Fish Science Journal 1(1):19-22.
Simon K. D., Mazlan A. G., 2010 Trophic position of archerfish species (*Toxotes chatareus* and *Toxotes jaculatrix*) in the Malaysian estuaries. Journal of Applied Ichthyology 26(1):84-88.
Simon K. D., Mazlan A. G., Cob Z. C., Samat A., Arshad A., 2008 Age determination of archer fishes (*Toxotes jaculatrix* and *Toxotes chatareus*) inhabiting Malaysian estuaries. Journal of Biological Sciences 8(6):1096-1099.
Simon K. D., Bakar Y., Samat A., Zaidi C. C., Aziz A., Mazlan A. G., 2009 Population growth, trophic level, and reproductive biology of two congeneric archer fishes (*Toxotes chatareus*, Hamilton 1822 and *Toxotes jaculatrix*, Pallas 1767) inhabiting Malaysian coastal waters. Journal of Zhejiang University B 10(12):902-911.
Simon K. D., Mazlan A. G., Cob Z. C., 2013 Condition factors of two archerfish species from Johor coastal waters, Malaysia. Sains Malaysiana 42(8):1115-1119.
Sivan G., Radhakrishnan C. K., 2011 Food, feeding habits and biochemical composition of *Scatophagus argus*. Turkish Journal of Fisheries and Aquatic Sciences 11:603-608.
Sparre P., 1992 Introduction to tropical fish stock assessment. Part I. Manual. FAO Fisheries Technical Paper 306/1. Rev 1, Rome, Italy, 376 pp.
Spiegel M. R., 1991 Théorie et applications de la statistique. McGraw-Hill, Paris, 358 pp. [in French]
Taskavak E., Bilecenoglu M., 2001 Length weight relationships for 18 Lessepsian (Red Sea) immigrant fish species from the eastern Mediterranean coast of Turkey. Journal of the Marine Biological Association of the United Kingdom 81(5):895-896.

Vander Zanden M. J., Shuter B. J., Lester N. P., Rasmussen J. B., 2000 Within- and among-population variation in the trophic position of a pelagic predator, lake trout (*Salvelinus namaycush*). Canadian Journal of Fisheries and Aquatic Sciences 57:725-731.

Wongchinawit S., Paphavasit N., 2009 Ontogenetic niche shift in the spotted scat, *Scatophagus argus*, in Pak Phanang Estuary, Nakhon Si Thammarat Province, Thailand. The Natural History Journal of Chulalongkorn University 9(2):143-169.

Wootton R. J., 1990 Ecology of teleost fishes. Chapman and Hall, New York, US, 404 pp.

Youson J. H., Holmes J. A., Guchardi J. A., Seelye J. G., Beaver R. E., Gersmehl J. E., Sower S. A., Beamish F. W. H., 1993 Importance of condition factor and the influence of water temperature and photoperiod on metamorphosis of sea lamprey, *Petromyzon marinus*. Canadian Journal of Fisheries and Aquatic Sciences 50:2448-2456.

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