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Length-weight relationship and trophic level of hard-tail scad *Megalaspis cordyla*

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ABSTRACT: *Megalaspis cordyla* popularly known as hard-tail scad or torpedo scad is a commercially important fish in Malaysia. The present study describes the length-weight relationship and trophic level of *M. cordyla* collected from the coastal waters of Tanjung Sepat, Selangor, Malaysia from December 2010 to November 2011. A total of 375 specimens ranging from 17.3–37.5 cm total length and 52.40–451.12 g body weight were analysed in this study. The growth form meant that the allometric coefficient b of the length-weight relationships was less than three, suggesting negative allometric growth for males ($b = 2.65$), females ($b = 2.77$), and combined sex ($b = 2.64$). The regression coefficient was not significantly different between the sexes. Stomach content analysis revealed that both males and females fed mostly on teleost (90%, 88%) followed by crustaceans (7%, 8%) and molluscs (4%, 4%), respectively. The estimated mean trophic level for the males and females were 3.67 ± 0.04 and 3.84 ± 0.05, respectively, indicating that they are largely carnivorous. In this study we found less diverse diets compared to previous reports, which might be indicative of anthropogenic disturbance to their food chain and ecosystem.

KEYWORDS: population growth, pelagic fish, feeding niche, diet, tropical waters

INTRODUCTION

Megalaspis cordyla (Linnaeus 1758), commonly known as hard tail scad or torpedo scad, is a tropical to subtropical euryhaline fish, occupying diverse habitats. It is widely distributed throughout the tropical Indo-Pacific region, ranging from East Africa to Japan and Australia[1]. *M. cordyla* is a schooling pelagic fish and inhabits surface layers of both inshore and offshore oceanic waters[2]. *M. cordyla* is of commercial importance in the wild fishery in Malaysia, with annual catches estimated at 22 000 tonne, making up 15–20% of the total pelagic catch[1]. In spite of their commercial value and the long-standing interest in this fish, very few studies have been conducted in Malaysia. Nevertheless, research has been conducted on this species elsewhere (e.g., India, Bangladesh) investigating; larval development[3], anatomy[4], sex ratio, length at first maturity, spawning season[5], morphometric measurement (e.g., body shape measurement), meristic counts (e.g., number of fin rays)[6], occurrence of heavy metals in tissue[7,8], feeding habits[9], age and growth[10], and growth form (length-weight relationship)[11–14].

There are data which suggest that length-weight relationships (LWR) are useful in fishery management namely, to: (i) estimate body weight from length observation (ii) calculate production and biomass of a fish population; and (iii) provide information on stocks or organism condition at the corporal level[15,16].

Apart from LWR, the quality and quantity of food consumed are considered important exogenous factors that have an effect on growth and overall wellbeing of fish[17]. The analysis of stomach contents can provide essential information about the diet and trophic level of a species and this has become a standard practice in fisheries ecology because it provides numerical values of trophic position in fishes (e.g., trophic level $> 4 =$ piscivores)[18]. Although there have been some reports on the trophic level of *M. cordyla* in Indian waters[9], no report is available on this important exogenous factors in Malaysian waters. In addition, there is a scarcity of information on LWR of *M. cordyla* in Malaysian waters despite their abundance and commercial importance[19].

The objectives of this study were to describe the length-weight relationship and trophic level of *M. cordyla* collected from the coastal waters of Tanjung Sepat, Selangor, Malaysia.

MATERIALS AND METHODS

Field sampling

Sampling was carried out monthly in the coastal waters of Tanjung Sepat (2° 41′ 56.60″ N, 101° 27′ 16.38″ E and 2° 36′ 52.29″ N, 101° 36′ 13.29″ E), Selangor, Malaysia from December 2010 to November 2011. The samples were collected on board a local fishing vessel using trawl nets (20 m foot rope opening with 5 m height and 3.5 cm cod end mesh size). Upon capturing, the total length (L) (tip of the upper jaw to tip of the caudal fin) and body weight (W) of the fish samples ($N = 375$) were measured to the nearest 0.1 cm and 0.1 g, respectively[20–22]. A subsample of 210 fish comprising 105 males and 105 females of varying sizes (representing all size classes) were injected with 4% (w/v) formaldehyde into the body cavity soon after body weight measurement to prevent further digestion and decomposition of the stomach content[23]. All specimens were sexed by gonad observation under a binocular microscope[24].

Length-weight relationship

The relationship between length and weight of a fish is usually expressed by the equation[25] $W = aL^b$ where W is the body weight in g, and L is the total length in cm. The coefficient a is the intercept in the y-axis, and the allometric or regression coefficient b is an exponent indicating isometric growth when equal to 3. The parameters a and b were estimated by nonlinear regression. Curve fitting was carried out by an iterative method using χ^2 goodness of fit test using MICROCAL ORIGIN 8.0 (OriginLab, Northampton, MA)[23,26]. The measurement of model fit (goodness of fit of calculated L and W) was evaluated by the coefficient of determination (r^2). Student's t-tests[27] were performed to test whether the computed value of b was significantly different from three, indicating the type of growth[28]: isometric ($b = 3$), positive allometric ($b > 3$), or negative allometric ($b < 3$), and to compare the regression coefficients b for possible significant differences between male and female. In addition, the analysis of covariance (ANCOVA) was also applied to evaluate the homogeneity of the regression slopes whereby log weight was modelled as a function of sex, covariate (i.e., log length), and their interaction. The interaction term tested for homogeneity of the slopes. The computer software MINITAB 17 was used for the statistical analysis. Statistical differences were considered significant when $p < 0.05$.

Trophic level analysis

Trophic level of males (105) and females (105) were analysed based on the stomach content analysis. Stomach contents were analysed under the microscope[29,30] to identify prey items and frequency of occurrence[18,31]. Finally, the trophic level of individual fish was estimated using TROPHLAB[32] with

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

where TROPH_j is the fractional trophic level of prey j, DC_{ij} represents the fraction of j in the diet of an individual fish i, and G is the total number of prey species in a stomach. Thus defined, the trophic level ranges between 2.0 for herbivorous/detritivorous and 5.0 for piscivorous/carnivorous species[33,34]. The mean values (± S.E.) estimated from the equation were input into the MICROCAL ORIGIN 8.0 graphic software (OriginLab, Northampton, MA)[23] for acquiring the trophic position pattern according to the fish size class.

RESULTS AND DISCUSSION

A total of 375 specimens were collected during the study period; 200 males and 175 females. The male samples ranged from 17.3–35.5 cm in L, and 52.4–446.0 g in W; female samples ranged from 20–37.5 cm in L and 79.43–470.56 g in W.

Length-weight relationship

The LWR indicated negative allometric growth in male ($W = 0.034L^{2.65}$), female ($W = 0.021L^{2.77}$), and combined sex ($W = 0.034L^{2.64}$) of *M. cordyla* samples, meaning that their length increases faster than their body weight (Fig. 1). The calculated regression coefficients b were significantly ($p < 0.05$) lower than 3 for males ($p < 0.05$, df = 198, SE = 0.07), females ($p < 0.05$, df = 173, SE = 0.05), and combined sex ($p < 0.05$, df = 371, SE = 0.04), indicating negative allometric growth. The correlation coefficient values ($r^2 > 0.90$) revealed that the observed and calculated length and weight relationship was closely fitted (Fig. 1).

The t-test for the comparison of the regression coefficients between the sexes was not significant ($t = 0.563$, df = 371, $p = 0.287$). Similarly, ANCOVA analysis showed that the interaction between the covariate (log length) and sex was not significant ($F = 0.61$, df = (1, 371), $p = 0.578$). This indicates

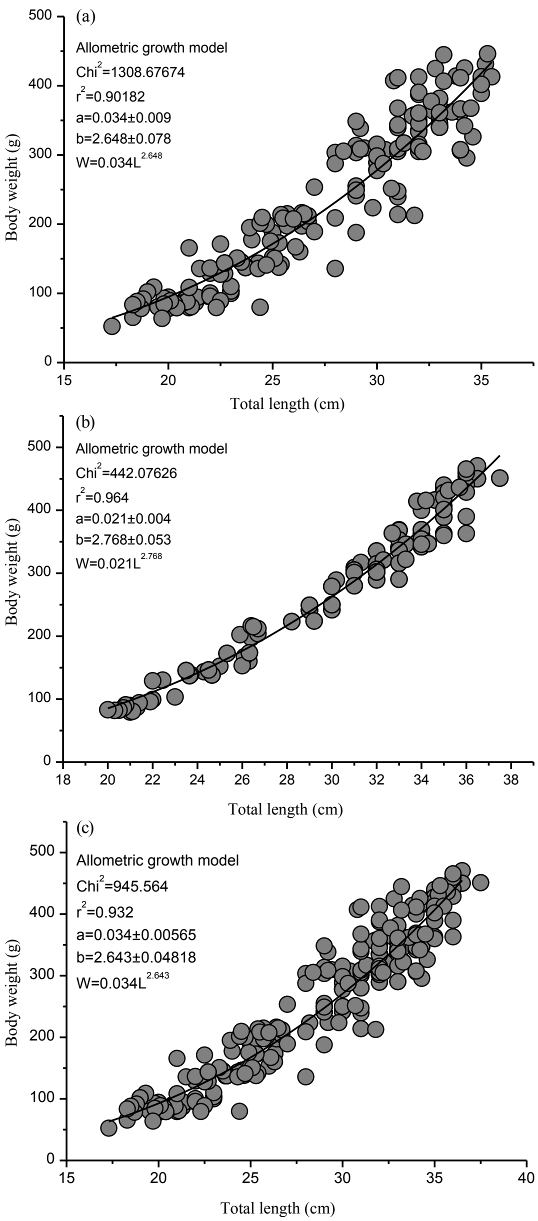

Fig. 1 Length-weight relationships of *Megalaspis cordyla* (a) males, (b) females, (c) combined sex. Line represents nonlinear fit whereas circles represent individuals.

that there was no significant difference in the LWR for different sexes.

The allometric coefficients (b) estimated in this study (2.64–2.78) were within the expected range of 2–4 commonly observed in teleost[16,35]. The present findings are in agreement with previous studies on this species where negative allometric growth ($b < 3$) has been reported[9,10,13], except in one study[11] in which isometric growth ($b = 3.0$) for male, female and combined sex of *M. cordyla* in Mumbai waters was observed (Table 1). These variations in allometric coefficient for *M. cordyla* in the Mumbai coast might be attributed to differences in sample size and different locations[36]. Moreover, other factors including temperature, food (quantity, quality, and size), and stage of maturity may also account for the differences in allometric coefficient values of fishes[37–39] namely, Panda et al[11] reported isometric growth form for *M. cordyla* in Mumbai waters whereas our study found negative allometric growth for male, female and combined sex. The regression model fitting in the present study showed that L and W of the fish are highly correlated ($r^2 = 0.90$–0.96), which is consistent with Panda et al[11].

Trophic level analysis

A total of 210 specimens (105 males and 105 females) were examined, 5% and 10% of the stomachs were empty for males and females, respectively. Three families of crustacean, two families of mollusc and six species of fish were identified (Table 2). After grouping all food items into three categories, teleost were the main prey items observed in male and female stomachs (90% and 88%), followed by crustaceans (7% and 8%) (Table 2), and mollusc (4% and 4%), respectively. Among the identified teleost species *Leiognathus* sp. formed the majority of the diet by weight 71 g and 89 g in male and female samples, respectively, as shrimp and copepods occurred most frequently in male (frequency of occurrence *fo* = 86%, 81%) and female (*fo* = 90%, 76%) samples (Table 2), respectively. Frequency of occurrence of the major food categories did not differ between sexes (e.g., difference observed 4–5%), although more prey items were observed in female stomachs. The reason might be the females were bigger in size than males. It was observed that crustaceans formed the majority of the diet by number whereas teleost formed the majority of the diet by weight in both sexes and size classes (Table 2).

In the present study the stomach content analysis shows that the diets of male and female *M. cordyla* includes crustaceans, teleosts, and molluscs, which is consistent with Sivakami's[9] results. However, Sivakami[9] reported that *M. cordyla* in Indian waters also takes other fishes: Silverbellies, Nemipterids, flatfishes, perches; crustaceans: Cladocerans, *Squilla* spp., alima larvae; molluscs: *Morula* sp., *Nucula* sp., *Cavolina* sp., juvenile squids; detritus, and even sand particles, which were not found in the present study. The feeding niche of this pelagic species largely depends on the food availability and ecosystem

Table 1 Length-weight relationship in *M. cordyla* compared to previous studies.

Author(s)	Area of study	Male		Female		Combined sex	
		$a^{\dagger}$	$b^{\dagger}$	a	b	a	b
Reuben et al [13]	East coast of India	–	–	–	–	0.000012	2.94
	North-west coast of India	–	–	–	–	0.000127	2.52
	South-west coast of India	–	–	–	–	0.000050	2.72
Saker et al [10]	Mumbai coast, India	0.00007	2.64	0.00020	2.46	0.000010	2.88
Sivakami [9]	Cochin, India	0.01741	2.58	0.00865	2.86	0.013419	2.69
Zafar et al [14]	Bangladesh	–	–	–	–	0.017940	2.82
Panda et al [11]	Mumbai, India	0.01119	2.92	0.00713	3.08	0.008577	3.02
Present study	Malaysia	0.03400	2.65	0.02100	2.77	0.034000	2.64

† a is the intercept and b is the allometric/regression coefficient.

Table 2 Prey items observed in 210 *M. cordyla* (105 male, and 105 female) stomachs from coastal waters of Tanjung Sepat Selangor, Malaysia, grouped by major categories.

Prey category	Male						Female					
	$N^{\dagger}$	W (g)†	% wt†	$n^{\dagger}$	*fo* (%)†	w (g)†	N	W (g)	% wt	n	*fo* (%)	w (g)
Shrimp												
Penaeidae	154	14	5	90	86	0.13	176	22	7	95	90	0.21
Copepod												
Corycaeidae	75	2	0.70	85	81	0.01	87	2	0.6	80	76	0.02
Amphipod												
Pontogeneiidae	64	2	0.80	75	71	0.02	75	2	0.4	77	73	0.02
Total Crustacea	293	18	6.5	250*	238	0.16	338	26	8	252*	239	0.25
Leiognathus sp.	75	71	27	55	52	0.67	100	89	29	60	57	0.85
Gazza sp.	35	61	23	25	24	0.58	27	53	17	20	19	0.50
Caranx sp.	20	32	12	12	11	0.31	24	41	13	17	16	0.39
Scomberomorus sp.	17	28	11	10	10	0.27	17	36	12	9	9	0.34
Stolephorus sp.	16	23	9	9	9	0.22	15	30	10	10	10	0.29
Apogon sp.	13	21	8	10	10	0.20	10	19	7	7	7	0.18
Total teleost	176	236	90	121*	116	2.25	193	268	88	123*	118	2.55
Bivalvia												
Mactridae	65	8	3	35	33	0.07	77	8	3	27	26	0.08
Lucinidae	10	1	0.50	5	5	0.01	30	3	1	14	13	0.03
Total mollusc	75	9	3.50	40*	38	0.08	107	11	4	41*	39	0.11
Grand total	544	263	100	411	392	2.49	638	305	100	416	396	2.91

† N: number of individuals of prey category; W: total weight; % wt: percent by weight; n: number of stomachs with prey item; *fo*: frequency of occurrence; w: total weight of prey category per stomach.
* the cumulative prey items in each category

health, and larger individuals in healthy ecosystems tend to consume more diversified food in comparison to smaller fish and those in unhealthy ecosystems, particularly ecosystems with high fishing pressure. The limited diversity of food items in the diets of the fish studied here may also reflect the short duration of our study, since diet changes with season and availability and therefore longer-term studies will inevitably report a great diversity of food items potentially eaten by a species then short term studies. Diversity of diet is also affected by body size and therefore gapes, since fish are gape limited. Despite these limitations the diversity of diet may also reflect the diversity available to the species, which may be a direct reflection of low species richness in their ecosystem and therefore poor ecosystem health.

The estimated trophic levels were 3.67 ± 0.04 for males and 3.84 ± 0.05 for females (Fig. 2). Similar trophic levels were also reported by Blaber et al [40] for *M. cordyla* in coastal waters of Solomon islands and Simon et al [23] for *Toxotes chatareus* and *T. jaculatrix* in Malaysian waters, and Stergiou and Karpouzi [41] for *Gadiculus argenteus argenteus*, *Trachurus mediterraneus*, and *T. trachurus* in Mediterranean waters. All these species exhibit similar feeding preferences, namely, crustaceans, teleosts, and mollusc and can be considered as carnivores. Trophic levels in both sexes gradually increased with size (Fig. 2).

This study has described the length-weight relationship and diet of *M. cordyla* in Malaysian coastal

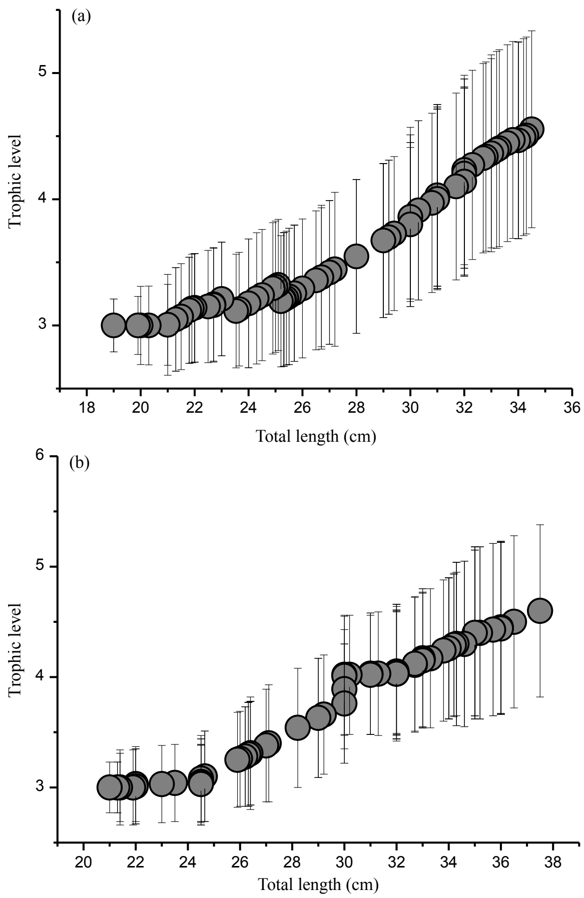

Fig. 2 Trophic level-size relationship of *M. cordyla* (a) males and (b) females (circles represent mean trophic level estimated by TROPHLAB program and bars represent variants of prey items).

waters. The population size ($N = 375$) used in the present study is considered small and might have the effect on the negative allometric growth of *M. cordyla*. Moreover, the feeding niche of fishes depends on ecosystem health and as the Indian Ocean is healthier than Malaysian waters we found less diverse food items in the stomach contents, although the calculated trophic level indicated a carnivorous feeding habit. As no information exists on the biological aspects of this fish in Malaysian coastal waters, the present findings will be of use as a reference for future works not only in Malaysia but also in nearby areas of this country.

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