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Morphometric Variations among Three Different Populations of Cobia, *Rachycentron canadum* (Linnaeus 1766) in Peninsular Malaysia

(Variasi Morfometri dalam Kalangan Tiga Populasi Cobia Berbeza, *Rachycentron canadum* (Linnaeus 1766) di Semenanjung Malaysia)

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ABSTRACT

Cobia Rachycentron canadum*, is one of the emerging aquaculture species but is usually a non-target resource in fisheries industry and within Malaysia, their landings are among the highest worldwide. Identification of stocks with unique morphological characters is important for effective management and sustainable utilization. Morphometric variations among three different cobia populations from Kedah, Terengganu and Johor were studied. All the morphometric characteristics varied among the three populations as all the elements of the first Eigen vector were positive. Discriminant analysis suggested that head depth (HD) and maximum body depth, (MaxD) were the most varied among the populations. Cobia populations from Kedah and Johor were in a single cluster in the dendrogram with a 63.69% similarity while Terengganu was in another cluster with a similarity of 8.01% from Kedah and Johor. The differences in the observed morphometry may be resulted from different trophic activities and/or habitat productiveness explored by each of the populations.*

Keywords: Cobia; Malaysia; morphometric variation; population size; Rachycentron canadum

ABSTRAK

Haruan tasik Rachycentron canadum*, adalah salah satu spesies akuakultur yang terkenal tetapi selalunya tidak menjadi tangkapan utama dalam perikanan. Hasil tangkapan ikan ini di Malaysia adalah antara yang tertinggi di seluruh dunia. Pengenalan stok dengan sifat morfologi yang unik adalah penting bagi pengurusan yang berkesan dan penggunaan yang lestari. Kepelbagaian morfometri antara tiga populasi haruan tasik dari Kedah, Terengganu dan Johor telah dikaji. Semua sifat morfometri boleh dikatakan menyumbang kepada kepelbagaian kerana semua unsur pada vektor Eigen pertama adalah positif. Analisis perbezaan telah menunjukkan bahawa panjang kepala (HD) dan panjang badan maksimum (MaxD) adalah paling ketara bagi populasi ini. Populasi haruan tasik dari Kedah dan Johor berada dalam satu kelompok dendrogram dengan 63.69% persamaan manakala Terengganu berada dalam kelompok yang berlainan dengan persamaan sebanyak 8.01% dari Johor dan Kedah. Perbezaan yang diperhatikan pada morfometri tidak boleh diterjemahkan terus tetapi mungkin boleh menjadi keputusan bagi perbezaan aktiviti trofik dan produktiviti habitat bagi setiap populasi tersebut.*

Kata kunci: Haruan tasik; Malaysia; Rachycentron canadum*; saiz populasi; variasi morfometri*

INTRODUCTION

Rachycentron canadum belongs to the order Perciformes, the only representative of the genus *Rachycentron* and the family Rachycentridae and it has a worldwide distribution (Ditty & Shaw 1992; Shaffer & Nakamura 1989). Countries that capture cobia include Malaysia, Brazil, Iran, the Philippines and Pakistan. Landings in Iran, Pakistan and Malaysia were among the highest worldwide exceeding 100 mt (FAO 2009). Total landing of cobia in 2012 was 1,351 tonnes in Malaysia (DOF 2012). Currently, however, assessment of cobia stock in Malaysia has not been carried out for management purposes and few studies were available concerning stock assessments of *R. canadum* in areas such as south-eastern Arabian Sea (Ganga et al. 2012), northern and eastern Australia (Fry & Griffiths 2010) and North Carolina (Smith 1995). This may be due to the fact that cobia is incidental in catches throughout its range and long-term life history dataset is not available (Williams 2001). Sustainable exploitation of fish resources requires knowledge of population structure in order to define appropriate stock management and to accurately delineate stocks for allocation of landings (Turan et al. 2006). Morphometric measurements have been reported for wild cobia larvae in the northern Gulf of Mexico (Ditty & Shaw 1992). Meanwhile, Johnson (1984) utilized a morphological study to provide evidence of a relationship between cobia and dolphin fishes with respect to similarities in the patterns of head spin. Both cobia and dolphin fishes possess a single spine on the supra-orbital ridge of each frontal bone, a small post-temporal spine and several spines along the anterior and posterior pre-opercula. Salze et al. (2011) used morphological examination to

establish growth differences in post-hatched cobia larvae fed with different diet and the work also described the ontogeny and morphology of the lateral line system and olfactory organ of *R. canadum*. Therefore, morphometric characteristics have been employed in fisheries biology to measure discreteness and relationships among various taxonomic categories (Turan et al. 2006) and as well as for studying short-term and environmentally induced variations (Hossain et al. 2009). Fish populations exploring different habitats may differ in their morphological characteristics such as body coloration, meristic characteristics, growth rate, size and age at sexual maturity (Sandlund et al. 1992). Despite Malaysia being an important country in terms of the cobia fishing nations, examination of its population size in this region has not been documented. Therefore, this study aimed to investigate potential morphometric differences among three cobia populations around Peninsular Malaysia.

Materials and Methods

Sample Collection

Cobia samples were collected from fishermen catches at three locations in Peninsular Malaysia: Bedong, Kedah (05˚70'N; 103˚78'E); Dungun, Terengganu (04˚45'N; 100˚36'E) and Mersing, Johor (02˚34'N; 103˚83'E) (Figure 1). Twenty cobia specimens were obtained from the local fisherman at Mersing (Johor), 30 from Bedong (Kedah) and 30 from Dungun (Terengganu). In total, 80 samples were used for this research. Immediately after collection, the samples were transported to the Department of Aquaculture, Universiti Putra Malaysia and stored in a freezer prior to morphometric measurements.

Morphometric Measurement

Morphometric characters and weight were measured to the nearest centimeter and kilogram, respectively. In total 19 morphometric characters of *R. canadum* were measured and Table 1 contains the list of these while the character are illustrated in Figure 2.

Data Analysis

Data on morphometric characters were expressed based on the ratios of the total length (TL) or the head length (HL). Comparisons of morphometric variations were analyzed using multivariate analyses between two different populations. Because of the absence of observable external sexual differences between males and females, morphometric measurements and analysis were carried out for combined sexes. A dendrogram was constructed

FIGURE 1. Map of Peninsular Malaysia showing the sampling locations

TABLE 1. Morphometric characters used for the analysis of variation among the three different populations of *R. canadum* in Peninsular Malaysia

Character	Description
Total length (TL)	Distance from tip of the mouth to end of caudal fin
Standard length (SL)	Distance from tip of the mouth to the anterior margin of peduncle caudal
Head length (HL)	Distance from tip of the mouth to the posterior end of the opercula membrane
Dorsal fin length (DFL)	Distance from the first dorsal spine to the last dorsal fin ray
Snout length (SNL)	Distance from the front of the upper lip to the fleshy anterior edge of the orbit
Head depth (HD)	Maximum depth of the head
Pectoral fin length (PFL)	Distance from base to tip of the pectoral fin
Anal fin length (AFL)	Distance from the base to the tip of the anal length
Caudal peduncle length (CPL)	Distance from the end of the anal fin and the base of caudal fin
Caudal fin length (CFL)	Distance from tail base to tip of the caudal fin
Body depth (BD)	Maximum depth measured from the base of the dorsal spine
Pre dorsal length (PDL)	Distance from the upper lip to the origin of the dorsal fin
Eye diameter (ED)	The greatest diameter of the orbit
Anal to body (ATB)	Depth from the anal to the upper body
Left pelvic fin length (LPFL)	Distance from base to tip of the left pelvic fin
Right pelvic fin length (RPFL)	Distance from base to tip of the right pelvic fin
Max depth (MaxD)	Maximum depth of the fish body
Pre anal length (PreAL)	Distance from the upper lip to the origin of the anal fin
Minimum depth (MinD)	Minimum depth of the fish body from the caudal peduncle

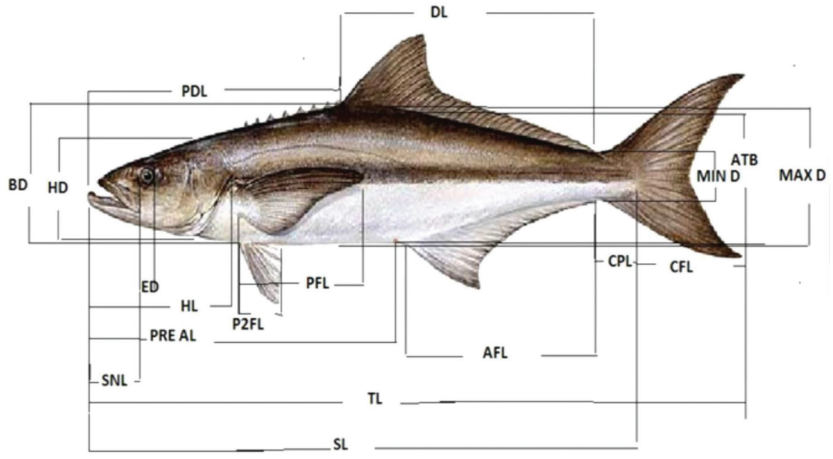

FIGURE 2. Morphometric characters of *R. canadum*

to compare the mean similarities between and within the populations.

RESULTS

The total length (TL) of 80 samples of *R. canadum* collected from the three different stations ranged from 68.40 to 87.20 cm with a mean of 76.78 ± 4.54 cm (Figure 3). The body weight (BW) was between 1.80 and 4.70 kg with an average of 2.98 ± 0.71 kg (Figure 4). The overall ratio of each morphometric characters to TL or HL for *R. canadum* is presented in Table 2. The standard length (SL) was 72 to 96% of the TL, while the caudal peduncle length (CPL) was 5 to 9% of the TL. Table 3 presents the summary of the statistical data analysis from three populations of *R. canadum* based on 19 morphometric characters. The summary of the statistical analyses of the ratio for each character to TL or HL for the three populations is presented in Table 4. The ratios of SL/TL, HD/HL, PFL/TL and CPL/TL were significantly different ($p<0.05$) among the three populations while there were no significant differences ($p>0.05$) in the following ratios HL/TL, SN L/HL, ED/HL, P DL/TL, BD/TL, AF L/TL and CFL/TL. Meanwhile, significant differences among the three populations for most of the morphometric characters were detected ($p<0.05$), with the exception for HL, SNL, PF L, CFL, ED and PreAL. Among the three populations, the first Eigen vector was positive with nearly the same value in component 1 (Table 5). The stepwise discriminant analysis retained two characters that most differentiated the populations and these characters were HD ($\lambda = 0.881$; $p<0.001$), MaxD ($\lambda = 0.3242$; $p<0.001$). A dendrogram was performed to illustrate the similarity among the three populations of *R. canadum* and two clusters were obtained (Figure 5). The populations in

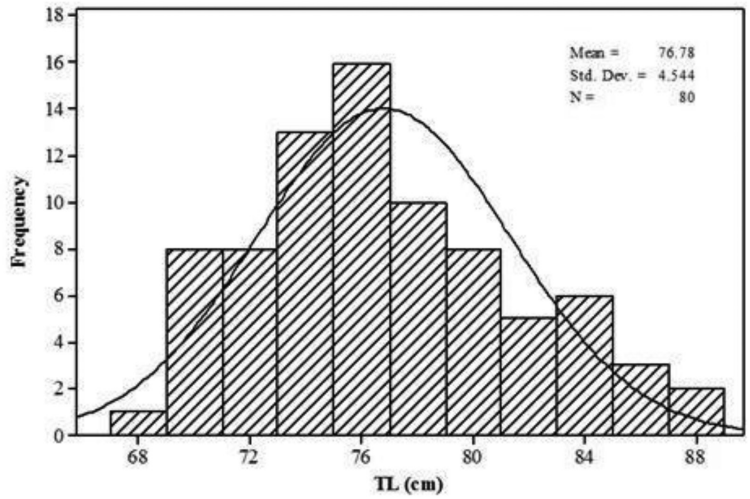

FIGURE 3. Size frequency distribution of *R. canadum*

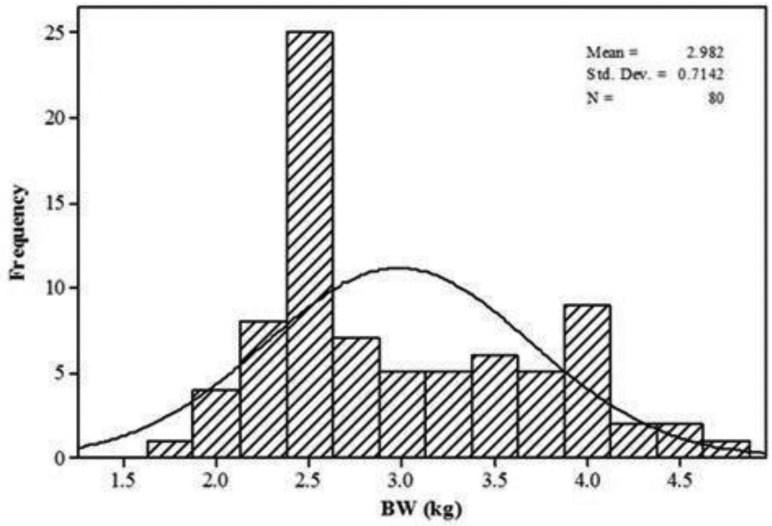

FIGURE 4. Weight frequency distribution of *R. canadum*

TABLE 2. Ratios of each morphometric characters to TL or HL of *R. canadum*

Character	N	Minimum	Maximum	Mean	SD
SL/TL	80	0.72	0.96	0.8402	0.05876
HL/TL	80	0.19	0.26	0.2244	0.01881
HD/HL	80	0.35	0.79	0.5165	0.10733
SNL/HL	80	0.32	0.63	0.4415	0.08307
ED/HL	80	0.15	0.22	0.1802	0.01734
PDL/TL	80	0.27	0.44	0.3725	0.02743
BD/TL	80	0.11	0.21	0.1543	0.02041
PFL/TL	80	0.16	0.27	0.2042	0.02207
AFL/TL	80	0.22	0.32	0.2743	0.02355
CFL/TL	80	0.19	0.32	0.246	0.02091
CPL/TL	80	0.05	0.09	0.0672	0.00853

Abbreviations of morphometric characters are given in Table 1

TABLE 3. Ratios of morphometric characters to TL or HL of *R. canadum* in different populations

Character	Kedah = 30	Johor (N =20)	Terengganu (N=30)		
	Mean ± SD	Mean ± SD	Mean ± SD	F	P
SL/TL	$0.86^{a} \pm 0.04$	$0.82^{b} \pm 0.07$	$0.84^{ab} \pm 0.06$	3.35	0.040*
HL/TL	$0.23^{a} \pm 0.02$	$0.23^{a} \pm 0.02$	$0.22^{a} \pm 0.02$	0.55	0.574^{ns}
HD/HL	$0.44^{b} \pm 0.06$	$0.48^{b} \pm 0.06$	$0.62^{a} \pm 0.09$	50.26	0.000**
SNL/HL	$0.44^{a} \pm 0.09$	$0.43^{a} \pm 0.09$	$0.45^{a} \pm 0.08$	0.30	0.745^{ns}
ED/HL	$0.18^{a} \pm 0.02$	$0.18^{a} \pm 0.02$	$0.18^{a} \pm 0.02$	0.98	0.378^{ns}
PDL/TL	$0.37^{a} \pm 0.02$	$0.36^{a} \pm 0.03$	$0.38^{a} \pm 0.03$	1.97	0.147^{ns}
BD/TL	$0.15^{a} \pm 0.02$	$0.16^{a} \pm 0.02$	$0.16^{a} \pm 0.02$	2.36	0.101^{ns}
PFL/TL	$0.21^{a} \pm 0.02$	$0.21^{ab} \pm 0.03$	$0.20^{b} \pm 0.02$	3.53	0.034*
AFL/TL	$0.27^{a} \pm 0.02$	$0.28^{a} \pm 0.03$	$0.28^{a} \pm 0.02$	0.23	0.794^{ns}
CFL/TL	$0.25^{a} \pm 0.02$	$0.24^{a} \pm 0.02$	$0.24^{a} \pm 0.02$	1.40	0.253^{ns}
CPL/TL	$0.07^{b} \pm 0.01$	$0.06^{b} \pm 0.01$	$0.07^{a} \pm 0.01$	7.90	0.001*

N=number of populations, ns= not significant ($p>0.05$), *significant at $p<0.05$, **highly significant $p<0.001$ and values of means were presented in the same row. See Table 1 for abbreviations of morphometric characters

Kedah and Johor were in the first cluster and the similarity between them was 63.69%, while the population in Terengganu was in the second cluster and the similarity was 8.01% compared to those from Kedah and Johor.

DISCUSSION

This study showed the morphological variations among the three populations of cobia in Peninsular Malaysia. Among the 19 morphological characters, only the HL, SNL, PFL, CFL, ED and PreAL were not significantly different. This morphometric study provides evidence of heterogeneity among cobia populations in Peninsular Malaysia. The results also demonstrated that the highest significant differences were from the TL, HD, CPL, PDL and MinD. The biggest individual was observed in this study from Terengganu with a TL of 87.20 cm, while the smallest individual was found in Johor with a TL of 68.40 cm. Based on the morphometric ratios, the SL was 72 to 96% of TL, while the CPL was 5 to 9% of the TL. Akyol and Unal (2013) reported a percentage of SL to TL of 119.3% for cobia in Mediterranean Sea. This is comparable with what was observed in this study. Cobia is a carnivore, feeding extensively on crabs, fish and other benthic invertebrates (Ganga et al. 2012; Rohith & Bhat 2012; Sajeevan & Kurup 2014) and assemblages of these prey items in terms of abundance, species richness and community structure have been reported to be impacted by habitat water quality parameters and season (Hajisamae & Yeesin 2014; Johnston & Sheaves 2007). Spatial temporal variations in these parameters may therefore offer different foraging opportunities to different populations of cobia. This may not be directly interpreted as the reason for the morphological differences as the causes of such differences between populations since such differences are often quite complicated to explain. However, it is well known that morphometric characters can explain a high degree of flexibility in response to environmental conditions (Wimberger 1992). From the results of the ratio of each morphometric character to TL or HL of *R. canadum*, some of the body ratios were significantly different among the three populations. Thus, a population exploring a narrow range during migration and feeding may differ from others that utilize a wider range like the open sea. Based on the stepwise discriminant analysis, the two characters that most discriminated the different populations were head depth ($\lambda = 0.881$; $p<0.001$) and maximum body depth ($\lambda = 0.3242$; $p<0.001$). Abdolhay et al. (2010) used discriminant analysis to analyze morphological data from Mahisefid cyprinids, *Rutilus frisii kutum*, populations from the southern Caspian Sea rivers basin. The study observed significant variations in all the morphometric characters utilized in the study between different river populations. The dendrogram obtained in the current study showed two major clusters of *R. canadum* from the three different stations in Malaysia and a similarity matrix indicated that there were about a 63.69% similarity between Johor and Kedah. The dendrogram offers a concise picture of the overall strength of a classification as well as the compactness and isolation of individual classes (van Sickle 1997). Similar studies on other species have been reported by several authors including Alberto (2010), Arshad et al. (2013) and Siti khalijah et al. (2005). According to Benetti et al. (2010), wild cobia are elongated, thin and streamlined whereas cultured cobia are shorter and fatter, exhibiting an elliptical, oval appearance in response to captive conditions and increased feeding rates. Therefore, it seems possible that this morphological disparity can also manifested between wild populations as demonstrated in this work, which may be due to various reasons including differences in diet, water quality and feeding rates but requires more investigations.

TABLE 4. Ranges and mean of each morphometric character and F-values of three different populations of *R. canadum*

MC	Kedah (N = 30)		Johor (N = 20)		Terengganu (N = 30)			
	Range (cm)	Mean ± SD	Range (cm)	Mean ± SD	Range (cm)	Mean ± SD	F	P
TL	70.10 - 83.40	$74.88^{b} \pm 3.40$	68.40 - 83.20	$74.89^{b} \pm 4.08$	70.50 - 87.20	$79.95^{a} \pm 4.14$	16.109	0.000**
SL	56.30 - 79.70	$64.31^{ab} \pm 5.15$	52.10 - 76.70	$61.26^{b} \pm 7.88$	54.20 - 79.70	$67.07^{a} \pm 6.28$	5.091	0.008*
DL	19.80 - 31.70	$27.35^{ab} \pm 2.24$	18.90 - 31.40	$26.42^{b} \pm 2.99$	21.50 - 35.50	$28.92^{a} \pm 3.32$	4.904	0.010*
HL	14.00 - 20.50	$16.93^{a} \pm 1.77$	14.80 - 20.00	$16.95^{a} \pm 1.74$	14.10 - 22.00	$17.74^{a} \pm 1.99$	1.746	0.181ns
SNL	5.50 - 10.00	$7.39^{a} \pm 1.06$	5.20 - 10.00	$7.22^{a} \pm 1.28$	6.00 - 11.50	$7.88^{a} \pm 1.26$	2.219	0.116ns
HD	6.00 - 9.00	$7.39^{c} \pm 0.77$	6.10 - 9.30	$8.05^{b} \pm 0.86$	8.70 - 15.60	$10.90^{a} \pm 1.60$	74.234	0.000**
PFL	13.00 - 20.60	$15.79^{a} \pm 1.53$	12.30 - 20.10	$15.40^{a} \pm 2.25$	12.10 - 20.10	$15.70^{a} \pm 1.65$	0.302	0.740ns
AFL	17.00 - 25.60	$20.34^{b} \pm 1.77$	17.50 - 25.20	$20.61^{b} \pm 1.99$	18.50 - 27.10	$22.06^{a} \pm 2.31$	5.937	0.004*
CPL	4.00 - 5.80	$4.92^{b} \pm 0.51$	4.00 - 6.00	$4.72^{b} \pm 0.62$	4.00 - 7.00	$5.72^{a} \pm 0.80$	17.245	0.000**
CFL	14.90 - 22.40	$18.70^{ab} \pm 1.68$	15.10 - 22.50	$18.28^{b} \pm 1.79$	14.00 - 22.50	$19.38^{a} \pm 1.99$	2.228	0.115ns
BD	8.20 - 13.70	$11.06^{b} \pm 1.30$	10.00 - 15.40	$11.75^{b} \pm 1.39$	9.40 - 17.20	$12.71^{a} \pm 2.12$	7.318	0.001*
PDL	18.90 - 32.80	$27.75^{b} \pm 2.27$	23.50 - 32.80	$27.30^{b} \pm 2.22$	26.10 - 37.20	$30.37^{a} \pm 2.99$	11.465	0.000**
ED	3.00 - 3.30	$3.07^{ab} \pm 0.09$	3.00 - 3.20	$3.05^{b} \pm 0.07$	3. 00 - 3.30	$3.10^{a} \pm 0.11$	2.942	0.059ns
ATB	13.20 - 16.20	$14.59^{b} \pm 0.92$	13.00 - 16.10	$14.49^{b} \pm 1.09$	13.40 - 20.00	$15.25^{a} \pm 1.32$	4.221	0.018*
LPFL	6.20 - 6.80	$6.51^{ab} \pm 0.19$	5.70 - 6.80	$6.41^{b} \pm 0.33$	5.80 - 7.30	$6.62^{a} \pm 0.34$	3.410	0.038*
RPFL	7.00 - 8.00	$7.36^{a} \pm 0.23$	6.80 - 8.00	$7.40^{a} \pm 0.27$	6.00 - 8.00	$7.08^{b} \pm 0.52$	5.751	0.005*
MaxD	13.80 - 16.40	$14.84^{ab} \pm 0.69$	12.70 - 15.30	$14.22^{b} \pm 0.78$	12.10 - 20.20	$15.28^{a} \pm 1.60$	5.194	0.008*
PreAL	31.90 - 40.30	35.04a ± 2.46	30.30 - 41.40	$35.25^{a} \pm 3.58$	31.70 - 41.40	$36.47^{a} \pm 3.20$	1.868	0.161ns
MinD	4.80 - 6.50	$5.49^{b} \pm 0.42$	4.10 - 6.70	$5.51^{b} \pm 0.64$	5.10 - 7.60	$6.16^{a} \pm 0.57$	14.013	0.000**

N = Number of samples, ns= not significant ($p>0.05$), *significant at $p<0.05$, **highly significant $p<0.001$ and values of means were represents in the same row. See Table 1 for abbreviations of morphometric characters

TABLE 5. Values of first two components obtained through a PCA of raw morphometric data of *R. canadum*

Morphometric characters (cm)	Component	
	1	2
TL	0.240	-0.121
SL	0.227	0.250
DL	0.239	0.136
HL	0.239	-0.129
SNL	0.243	0.053
HD	0.228	-0.237
PFL	0.112	0.604
AFL	0.231	-0.216
CPL	0.244	0.008
CFL	0.232	0.205
BD	0.201	-0.386
PDL	0.243	-0.028
ED	0.240	0.120
ATB	0.240	-0.111
RPFL	0.230	0.222
LPFL	-0.243	0.035
MaxD	0.220	0.294
PreAL	0.232	-0.208
MinD	0.239	-0.135
Eigen value	16.843	2.157
Variance explained (%)	88.60	11.40
Cumulative variance (%)	88.60	100.00

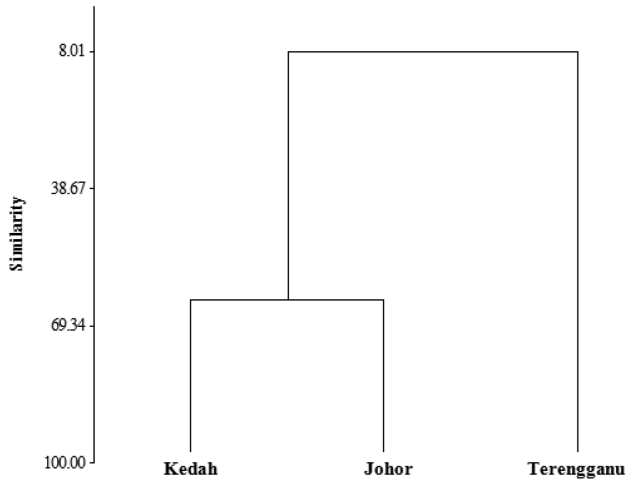

FIGURE 5. Dendrogram of the similarity of *R. canadum* among the different populations

CONCLUSION

Analysis of morphometric characters undertaken in this study showed significant differences among the three populations of cobia in Peninsular Malaysia. Even though all the morphometric characters contributed to the population discrimination to some degree, head depth and maximum body depth were the most variable among the three populations. While the factor responsible for the observed variation cannot be easily determined, environmental variability and food availability could play a vital role. The use of morphometric characters may therefore be useful in population stock analysis and in turn, stock management.

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