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ON THE BIOLOGY AND BASIC CHARACTERISTICS OF THE POPULATION DYNAMIC OF THE DOG CONCH, *STROMBUS CANARIUM* LINNAEUS, 1758 (STROMBIDAE)

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Abstrak: *Strombus canarium* Linnaeus, 1758 merupakan antara sumber perikanan gastropoda paling utama di perairan Selat Johor, Malaysia. Dalam kajian ini, persampelan dilakukan secara rawak menggunakan kaedah jalur transek, bermula dari Januari hingga Disember 2005. Data panjang cangkerang dibahagikan mengikut jantina dan panjang, dengan sela-kelas 2 mm. Secara keseluruhannya, nisbah jantan kepada betina adalah pada kadar 1:1.73, yang tidak berbeza secara signifikan berbanding nisbah yang dijangka iaitu 1:1 ($P > 0.05$). Struktur populasi dianalisis menggunakan kaedah *'Length-based Fish Stock Assessment'* (LFSA) yang terdapat dalam perisian FiSAT *(FAO-ICLARM Stock Assessment Tools)*. Taburan panjang-berat bulanan kedua-dua subpopulasi siput jantan dan betina bersifat polimodal. Populasi juga didapati menunjukkan ciri-ciri dwimorfisma jantina. Parameter tumbesaran spesifik bagi setiap kohot menunjukkan nilai panjang 'asimptotik' (L_∞) dan pemalar tumbesaran (K) yang lebih tinggi bagi siput betina berbanding siput jantan. Nilai min L_∞ adalah 62.90 ± 3.68 mm bagi jantan dan 69.73 ± 0.80 mm bagi betina, sementara nilai min K adalah 1.10 ± 0.15/thn bagi jantan dan 1.40 ± 0.10/thn bagi betina. Kadar tumbesaran yang tinggi dan masa bagi mencapai saiz pasaran yang cepat, ditambah dengan keupayaan untuk membiak sepanjang tahun menjadikan siput ini berpotensi besar bagi aktiviti akuakultur. Walau bagaimanapun, kajian lanjut diperlukan dalam menilai kadar tumbesaran sebenar, serta beberapa parameter lain yang penting bagi sesuatu spesies sebelum sebarang tindakan pengkomersialan dapat dilakukan.

Abstract: *Strombus canarium* Linnaeus, 1758 is among the important gastropod fishery within the western Johor Straits, Malaysia. In this study, systematic random samplings using belt transect were conducted from January to December 2005. Shell-length data were grouped into different sexes and length-classes of 2 mm intervals. Overall ratio of males to females was 1:1.73, which was not significantly deviated from the expected 1:1 ($P > 0.05$). The population structure was analyzed using the Length-based Fish Stock Assessment (LFSA) protocol in FiSAT (FAO-ICLARM Stock Assessment Tools) software package. Both males and females were highly polymodal in monthly length-frequency distributions. Sexual dimorphism was evident within the population. Specific cohort growth parameters found higher asymptotic length (L_∞) and growth constant (K) in females compared to the males. The mean L_∞ was 62.90 ± 3.68 mm in males and 69.73 ± 0.80 mm in females, while the mean K was 1.10 ± 0.15 yr^{-1} in males and 1.40 ± 0.10 yr^{-1} in females. The higher growth rates and faster growth to marketable size, combined with all

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year round recruitment indicated great potential for introduction into aquaculture. However, further studies are greatly needed in assessing actual growth and other parameters of this important gastropod species.

Keywords: ELEFAN-I, VBGF Growth Parameters, Population Ecology

INTRODUCTION

Strombus canarium is a widely distributed strombid species in tropical waters, which is highly associated with muddy bottom and seagrass bed areas (Abbott 1960; Chuang 1973; Purchon & Purchon 1981; Cob *et al.* 2005). This species (Fig. 1) is among the most important benthic macroinvertebrate fauna within the seagrass bed of the Johor Straits, where it formed the most abundant, and one of the largest herbivorous mollusks present (Cob *et al*. 2005). This species is also economically important as it was traditionally collected by the locals for food (Chuang 1973; Cob *et al*. 2005).

Currently, there are very few publications available regarding the biology and ecology of *S. canarium*. Apart from works done by Amini (1986), Amini and Pralampita (1987), Erlambang and Siregar (1995), Erlambang (1996) and recently by Cob *et al*. (2008a), no other study ever addressed issues related to the population ecology of Strombidae within Southeast Asian waters. The *S. canarium* fishery activity in the area has greatly expanded in the past few years and the shells are now available in local markets and seafood restaurants, particularly during peak collecting season (Cob *et al*. in press). There is certainly great potential for mariculture of this species (Cob *et al*. 2007), which is currently not viable since information regarding their life history and ecology is still not well-established. The objective of this study were to analyze and estimate important population parameters of *S. canarium* from the western Johor Straits, Malaysia. The information obtained would certainly provide better understanding and management of this important gastropod species.

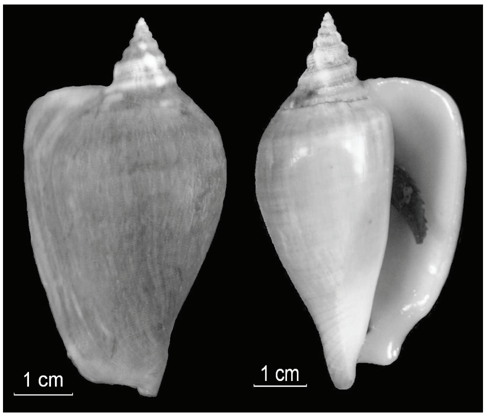

Figure 1: *Strombus canarium* Linnaeus, 1758.

MATERIALS AND METHODS

Study was conducted at Merambong Shoal, West Johor Straits, Malaysia (01°19.778'N, 103°35.798'E). It is the most extensive subtidal shoal of the area, covered with dense seagrass meadows dominated by *Enhalus acoroides* and *Halophila* spp. complex. Sample collection was conducted monthly, during low tides, from January to December 2005, using a belt transect approach. Transects (N = 3) were deployed randomly, and always perpendicular to the water edge. All *S. canarium* within the transect area (30 x 2 m^2) were sampled. In laboratory, the shell-length, from tip of spire to anterior end of siphonal canal was measured to the nearest 0.01 mm, using a digital vernier caliper. Since *S. canarium* showed sexual dimorphism where substantial differents in morphological characteristics of the male and female have been recognized (Cob *et al*. 2008a, b), analyzes were therefore conducted separately for both sexes. The monthly and overall sex ratios were also determined.

To establish the length-weight relationship, the commonly used relationship $W = aL^b$ was applied (Ricker 1975; Quinn & Deriso 1999) where W is the weight (g), L is the total length (mm), a is the intercept (condition factor) and b is the slope (growth coefficient, i.e. relative growth rate). The a and b parameters were estimated using least squares linear regression on log-log transformed data of: $\log_{10}W = \log_{10}a + b\log_{10}SL$. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression (Scherrer 1984).

The length data was grouped into 2 mm shell-length class and analyzed using the LFSA approaches, incorporated in the FiSAT software package (Gayanilo *et al*. 1996). Using this method, the composite length-frequency distributions were split into separate modes of normal distributions (Bhattacharya 1967; Pauly & Caddy 1985; Sparre 1987; Gayanilo *et al*. 1996). All the identified size/age groups were derived from at least three consecutive points and selection of the best results was based on: (a) the values of separation index (*S.I.*) for the different age groups; (b) the number of the identified age groups; and (c) the standard deviation (Gayanilo *et al*. 1989). Values from Bhattacharya method were then re-analyzed using Hasselblad's NORMSEP method (Pauly & Caddy 1985) to obtain the best estimate of mean cohort length, which was assumed to represent an age-length of the cohort.

The mean lengths of the components (cohorts) were then plotted against the sampling dates and then linked in order to trace the modal length progression of the cohorts. This enables the tracing of growth curves, and/or the computation of growth increments between modes. The linking process is however highly subjective, which rests entirely on the experience of the person performing the analysis (Gayanilo & Pauly 1997).

The resulting mean sizes for each cohort and sexes were then analyzed using ELEFAN-I (Pauly & David 1981) for specific cohort growth parameter (von Bertalanffy growth function, VBGF) estimation. But prior to that, the L_∞ value was first estimated using the modified Powell-Wetherall plot (Wetherall 1986), which was then used as seed value in order to assess a more reliable estimate of the growth parameter (Gayanilo & Pauly 1997). The VBGF is defined by the equation: $L_t = L_\infty \left(1 - e^{-k(t - t_o)}\right)$, where L_t is the mean length (mm) at age t, L_∞ is the asymptotic length (mm), K is the curvature of the VBGF or growth coefficient (yr^{-1}), and t_o is the hypothetical age (year) at which length equals to zero.

The estimated L_∞ and K values were then used to determine the growth performance index (φ') (Pauly & Munro 1984), using the equation: $\varphi' = 2\log_{10} L_\infty + \log_{10} K$. Estimates of maximum length (L_{max}) were obtained using the extreme value theory (Gumbel 1954; Formacion *et al*. 1991), as implemented in the FiSAT software (Gayanilo *et al*. 1996; Gayanilo & Pauly 1997).

RESULTS

Sex Ratio

The abundance of female conch was higher than that of males. The overall sex ratio per month (male:female) was 1:1.73, which was not significantly deviated from the expected 1:1 (one-way ANOVA: F = 2.80, *d.f.* = 23, P = 0.108). However, females were always dominant than males, ranging from 55.33% to 76.34% (Fig. 2). The sex ratio of conch in the study area varies considerably, possibly as a result of differential behavior of the sexes (e.g. lower growth rates of males, males are less abundant than females). The highest abundance of males was observed in October to December, which coincides with their reproductive season.

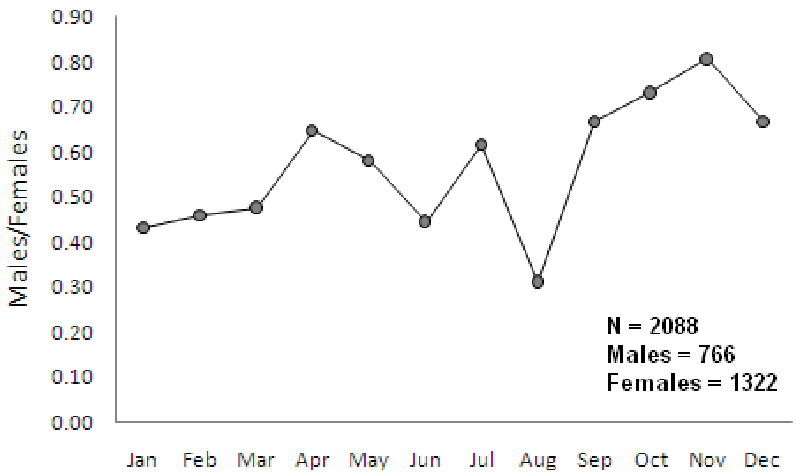

Figure 2: Monthly fluctuations of the sex ratio of *S. canarium* population in the Merambong Shoal, Johor Straits.

Length-weight Relationship

During the course of the study, a total of 197 males and 239 females were weighed (wet weight and ash-free dry weight) and the computed length-weight relationships were:

$W_{(AFDW)} = 0.00000093{*}SL^{3.48}$. $r^2 = 0.98$, for males; and

$W_{(AFDW)} = 0.0000013{*}SL^{3.38}$. $r^2 = 0.96$, for females.

Length Frequency and Cohort Analyses

The identified age groups from length-frequency analysis using Bhattacharya method, followed by Hasselblad's NORMSEP method is presented in Figures 3 and 4 for male and female conch sub-population, respectively. The groups (cohorts) mid-length and their abundance are presented in Table 1. The monthly length-frequency histograms showed polymodal in distribution where it was possible to identify at least two to the maximum of five modal classes each month.

Through modal group progression analysis (FiSAT), six major cohorts were recognized in both male and female sub-populations (Fig. 5). The Bhattacharya's plot (curvature) might suggest linkages between some of the cohorts, such as between C6-C1-C3 and C5-C2 for male population and between C7-C2 and C6-C4 for female population. The monthly length-frequency data of each cohort was then analyzed using ELEFAN-I for specific cohort growth parameters estimation (Tables 2 & 3).

The L_∞ values ranged from 50.60 mm to 70.61 mm (mean = 62.90 ± 3.68 mm) and from 67.33 mm to 71.40 mm (mean = 69.73 ± 0.80 mm), for male and female conch sub-population, respectively. The K values on the other hand ranged from 0.66 yr^{-1} to 1.60 yr^{-1} (mean = 1.10 ± 0.15 yr^{-1}) and from 1.00 yr^{-1} to 1.60 yr^{-1} (mean = 1.40 ± 0.10 yr^{-1}), for male and female sub-population, respectively. The *Rn* (goodness of fit) values ranged from 0.246 to 0.817 in males and from 0.229 to 2.833 in females. The φ' ranged from 3.322 to 3.886 in males and from 3.656 to 3.912 in females. The predicted maximum length was estimated at 67.47 mm (95% confidence interval between 66.29 mm to 68.65 mm) for male, and at 69.20 mm (95% confidence limit between 68.51 mm to 69.89 mm) for female *S. canarium*.

Both L_∞ and K data of male and female cohorts were normally distributed (Anderson-Darling, $P > 0.05$) and met the assumption of homogeneity of variance (*F*-tests) (L_∞, test statistic = 0.30, $P = 0.21$; K, test statistic = 0.25, $P = 0.15$). Analyses of variance showed that the L_∞ and K of the male and female were not significantly different compared to each other (one-way ANOVA, $F = 1.67$, *d.f.* = 11, $P = 0.23$ for L_∞; $F = 3.88$, *d.f.* = 11, $P = 0.08$ for K).

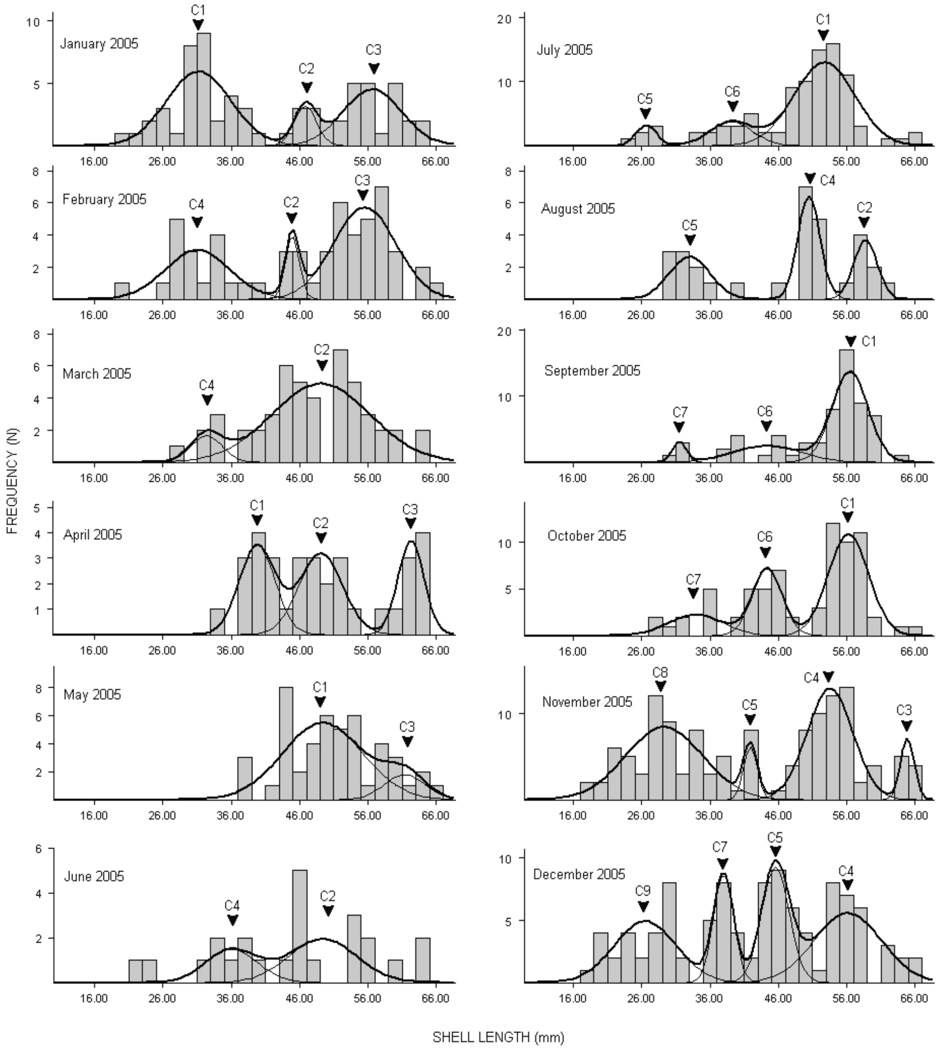

Figure 3: Male *S. canarium* length-frequency histogram, with separation into its normal components (cohorts) using Bhattacharya's and Hasselblad's NORMSEP method. The positions of the cohort's mean lengths are as indicated by triangles. C1 to C9 represent cohorts.

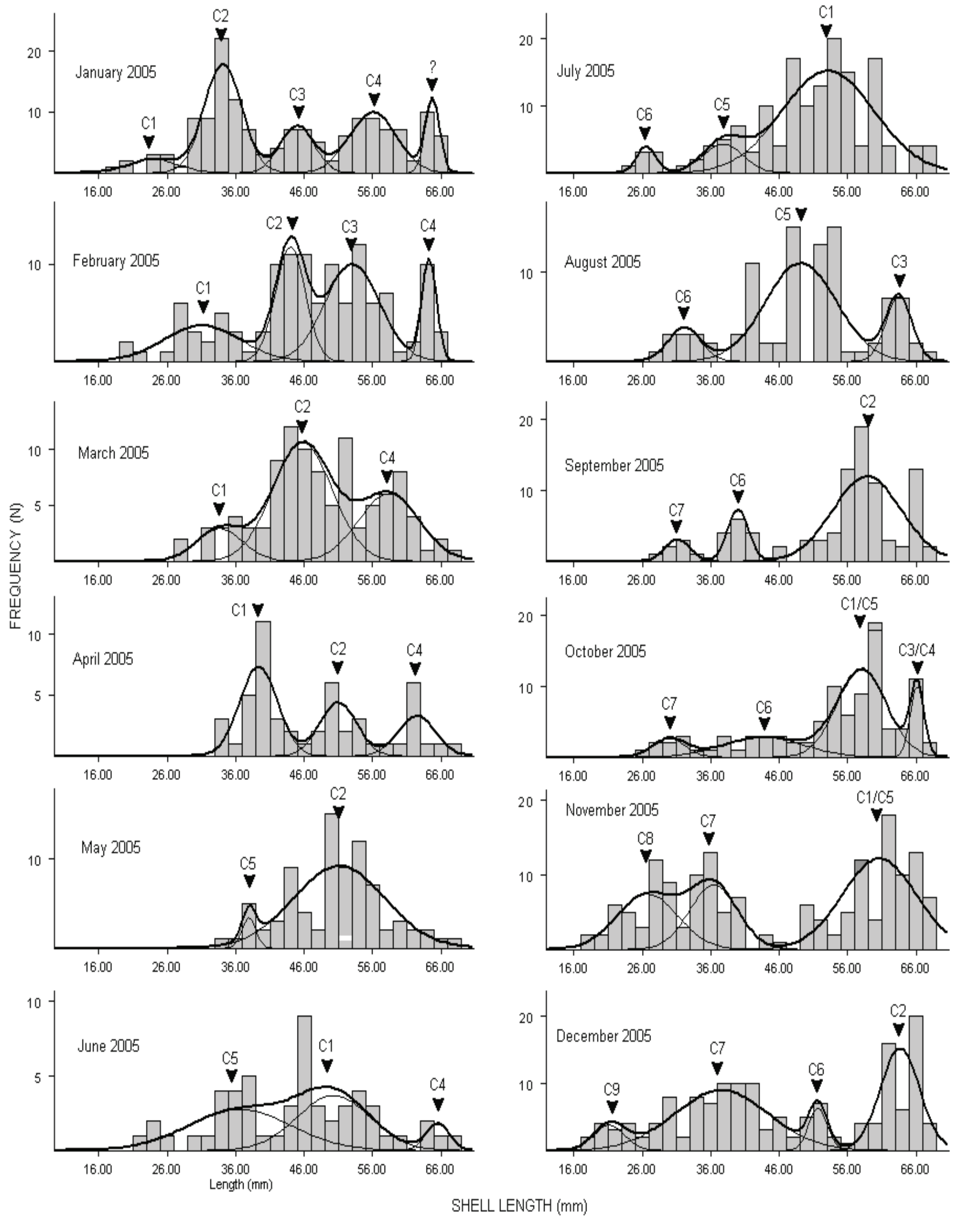

Figure 4: Female *S. canarium* length-frequency histogram, with separation into normal components (cohorts) using Bhattacharya's and Hasselblad's NORMSEP method. The positions of the cohort's mean lengths are as indicated by triangles. C1 to C9 represent cohorts.

Table 1: Identified age groups from the length-frequency analysis of females and males *S. canarium* during the 12 months sampling (January–December 2005), using Bhattacharya's and followed by Hasselblad's NORMSEP method.

	Females				Males			
	SL	*S.D.*	*N*	*S.I.*	*SL*	*S.D.*	*N*	*S.I.*
JAN	23.96	3.57	10.13		31.23	4.73	35.23	
	34.15	2.73	60.93	3.24	46.85	1.62	6.47	4.92
	44.97	2.47	23.82	4.17	56.65	4.28	24.30	3.32
	56.05	3.44	42.67	3.75				
	64.72	1.04	15.46	3.88				
FEB	31.05	5.56	25.76		31.05	4.71	18.06	
	43.99	2.17	32.23	3.35	44.94	1.02	5.01	4.84
	53.04	3.99	50.16	2.94	55.51	4.59	32.93	3.77
	64.26	1.05	13.85	4.45				
MAR	33.65	3.33	12.16		32.35	2.28	4.68	
	45.76	4.33	57.56	3.16	49.11	7.22	44.32	3.53
	58.39	4.40	33.28	2.89				
APR	39.36	2.75	25.21		39.78	2.62	11.48	
	50.98	2.68	14.71	4.28	49.12	3.18	12.71	3.22
	62.47	2.69	11.07	4.28	62.31	1.91	8.81	5.18
MAY	37.94	1.00	4.37		49.36	5.88	40.37	
	51.10	6.66	76.63	3.44	61.40	2.99	6.63	2.72
JUN	36.58	7.53	25.77		36.00	3.80	7.00	
	50.31	5.32	24.48	2.14	49.40	4.92	12.00	3.07
	65.55	1.69	3.75	4.35				
JUL	26.57	1.40	6.96		26.66	1.49	5.99	
	37.80	2.89	15.57	5.23	39.04	3.11	14.57	5.38
	53.12	6.73	128.47	3.19	52.73	4.44	72.44	3.62
AUG	32.13	2.37	11.20		33.00	3.01	10.00	
	49.16	5.18	71.56	4.51	50.47	1.61	13.01	7.57
	63.45	1.90	17.24	4.03	58.75	1.71	7.98	4.99
SEP	31.14	1.81	7.00		31.50	1.00	3.85	
	40.00	1.52	13.95	5.31	44.31	4.93	15.24	4.32
	58.81	4.99	75.05	5.78	56.50	2.62	44.91	3.23
OCT	29.97	2.39	7.77		33.88	3.98	11.25	
	43.69	5.87	20.68	3.33	44.36	2.18	19.51	3.41
	58.06	3.61	55.91	3.03	56.25	2.95	40.24	4.63
	66.11	1.00	12.64	3.49				
NOV	26.73	4.43	41.28		29.25	5.64	59.50	
	36.39	3.50	37.91	2.44	41.88	1.00	7.62	3.80
	60.61	5.36	81.81	5.47	53.55	3.34	53.99	5.37
					64.90	1.00	8.89	5.23
DEC	21.19	2.21	10.51		26.50	4.53	27.91	
	37.58	6.90	77.36	3.60	37.96	1.48	15.98	3.81
	51.66	1.35	10.72	3.42	45.55	2.04	23.62	4.32
	63.63	2.86	54.41	5.69	56.14	4.93	34.49	3.04

Note: SL = shell length (mm); *S.D.* = standard deviation; *N* = number of individuals; *S.I.* = separation index

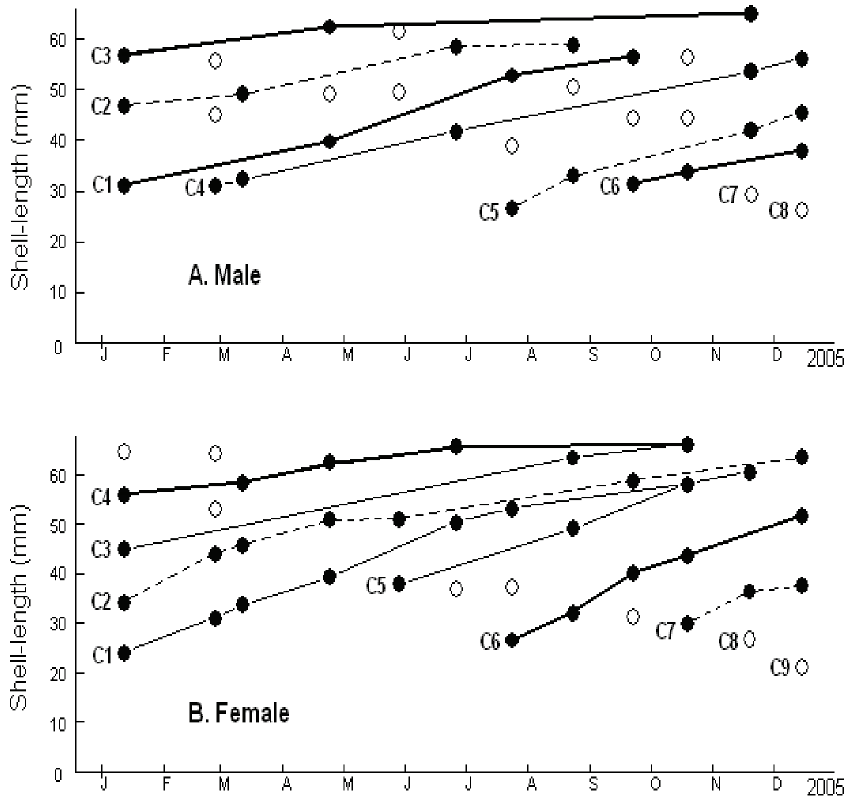

Figure 5: Modal group progression of: (A) Male, and (B) Female cohort. C1 to C9 represent mean cohort shell lengths. Cohorts with similar connecting line (bold and dashed) suggest similarity in growth pattern.

Table 2: Specific cohort growth parameters for male *S. canarium* determined using ELEFAN-1.

	L_∞ (mm)	K (yr^{-1})	(φ')	*Rn*	Recruitment
C1	69.30	1.60	3.886	0.545	9/2004
C2	65.10	1.00	3.627	0.246	4/2004
C3	69.30	0.66	3.501	0.817	11/2002
C4	70.61	1.50	3.874	0.392	1/2005
C5	50.60	0.82	3.322	0.732	8/2004
C6	52.50	1.00	3.440	0.444	12/2003
Mean	62.90 ± 3.68	1.10 ± 0.15	3.61 ± 0.095		

Note: K = growth constant (yr^{-1}); L_∞ = asymptotic length (mm); *Rn* = goodness of fit; φ' = growth performance index

Age, Growth and Recruitment

The VBGF growth curve for male and female cohorts, superimposed on their respective restructured length frequency distribution is presented in Figures 6 and 7. Recruitments occurred all year round, but most cohorts were recruited during wet season (from November to March). Except for C1, C2 and C5, in male, and C2 and C3 in female, other cohorts were recruited during the period of the observed main spawning season (see Figs. 6 & 7).

Table 3: Specific cohort growth parameters for female *S. canarium* determined using ELEFAN-1.

	L_∞ (mm)	K (yr^{-1})	(φ')	*Rn*	Recruitment
C1	71.40	1.50	3.883	0.230	11/2004
C2	69.33	1.60	3.886	0.229	8/2004
C3	71.40	1.60	3.912	2.833	6/2004
C4	71.40	1.50	3.883	1.310	1/2005
C5	67.52	1.20	3.738	0.287	11/2003 or 11/2004
C6	67.33	1.00	3.656	0.269	2/2004 or 2/2005
Mean	69.73 ± 0.80	1.40 ± 0.10	3.83 ± 0.04		

Note: K = growth constant (yr^{-1}); L_∞ = asymptotic length (mm); *Rn* = goodness of fit; φ' = growth performance index

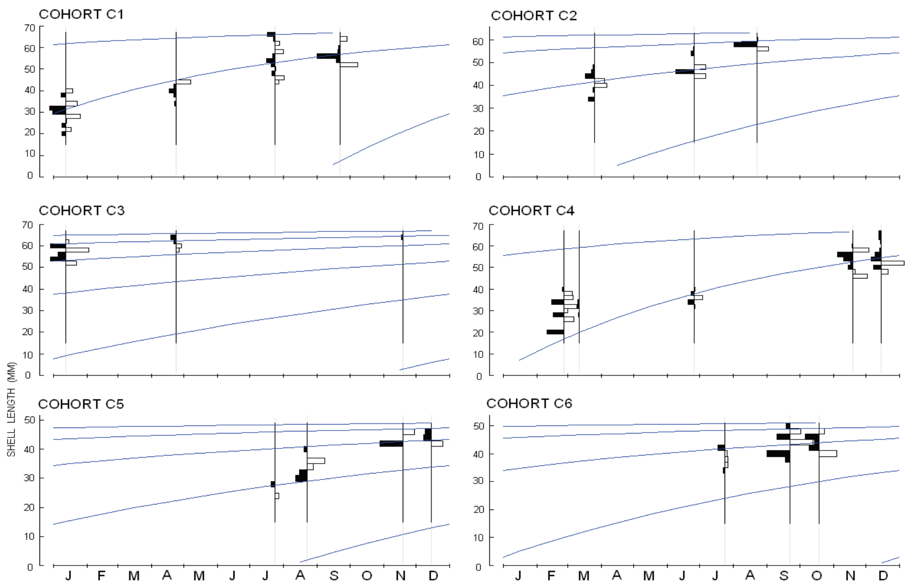

Figure 6: Restructured length-frequency distribution of male cohorts (C1 to C6) with superimposed growth curves calculated using ELEFAN-1.

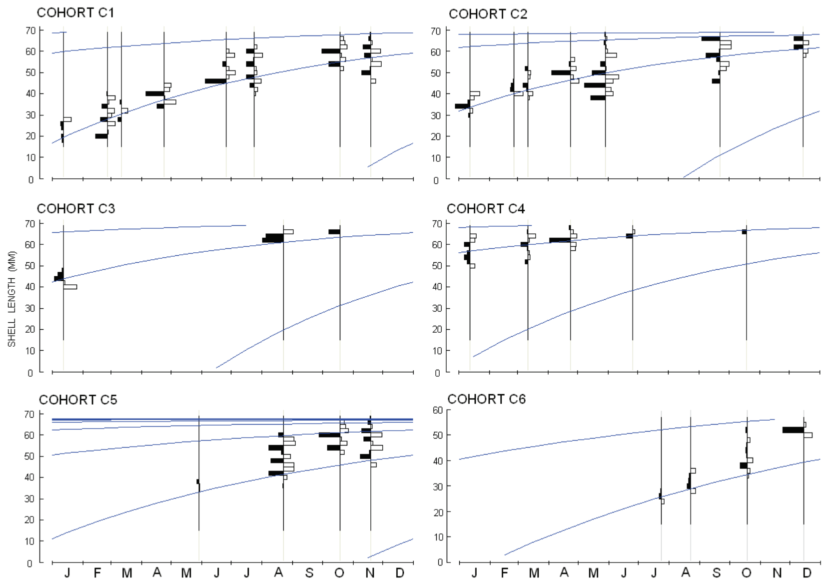

Figure 7: Restructured length-frequency distributions of female cohorts (C1 to C6) with superimposed growth curves determined using ELEFAN-1.

Within the male sub-population, cohort C1 belongs to individuals recruited in September 2004 (1+ year group), cohort C2 to individuals recruited in April 2004 (1+ year group), cohort C3 to individuals recruited in November 2002 (3+ year group), cohort C4 to individuals recruited in January 2005 (0+ year group), cohort C5 to individuals recruited in August 2004 (1+ year group), and C6 to individuals recruited in December 2003 (2+ year group). Within the female sub-population, cohort C1 belongs to individuals recruited in November 2004 (1+ year group), cohort C2 to individuals recruited in August 2004 (1+ year group), cohort C3 to individuals recruited in June 2004 (1+ year group), cohort C4 to individuals recruited in January 2005 (0+ year group), cohort C5 to individuals recruited in November 2004 (1+ year group) and/or November 2003 (2+ year group), and C6 to individuals recruited in February 2005 (0+ year group), and/or February 2004 (1+ year group).

Using the above L_∞ and K values, with assumption that t_o equals to zero (Pauly & David 1981), VBGF growth curve for male and female sub-population were plotted (Fig. 8). During the first six months the growth rates were at 3.48 mm/mths and 4.2 mm/mths, respectively for male and female conch. At this growth rates, the estimated sizes (shell length) were about 26.60 mm for males and 35.10 mm for females.

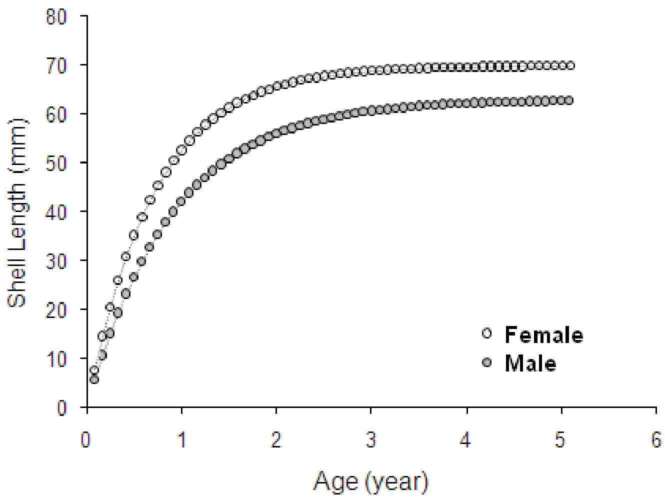

Figure 8: von Bertalanffy growth model for male and female *S. canarium*. (Male: L_∞ = 62.90 mm, VBGF growth coefficient (K) = 1.10 yr^{-1}, t_o = 0 yr; female: L_∞ = 69.73 mm, K = 1.40 yr^{-1}, t_o = 0 yr).

DISCUSSION

The population studied was highly polymodal in length frequency distribution, which was typical for most tropical species as they normally reproduce all year-round and have faster growth rates compared to those from the temperate. The result was in agreement with studies on other *Strombus* species where polymodal distributions have also been reported (Wada *et al*. 1983; Wood & Olsen 1983; Appeldoorn 1988). There were six major cohorts detected for both male and female populations, with estimated age of up to 3+ year groups.

Specific cohort growth parameters were varied between sexes, indicating a prominent sexual dimorphism within the population (Cob *et al*. 2008a, b). Most of the larger individuals were females, which was a normal phenomenon for most gonochoristic gastropods (Table 4). Nevertheless, although the overall L_∞ and K values of females were higher than males, there was no significant difference between them ($P > 0.05$).

Result from this study showed a much inferior asymptotic length value compared to earlier studies on *S. canarium*. Amini and Pralampita (1987) reported that L_∞ value of 82.50 mm, while Erlambang (1996) recorded shell length of up to 82 mm. In addition, Abbott (1960) reported maximum shell length of up to 98 mm for *S. canarium* from the Philippines. The K however, was quite similar to that reported by Amini and Pralampita (1987) for Bintan Island's population. It was also comparable to some other gastropod species, e.g. *Haliotis mariae* (Siddeek & Dawson 1997) and *Haminoe orbygniana* (Malaquias & Sprung 2005).

Table 4: VBGF growth-parameter for *S. canarium* and comparisons with other studies.

Species	L_∞ (mm)	K (yr^{-1})	φ'	Source and locality
S. canarium (male)	62.90 ± 3.68	1.10 ± 0.15	3.61 ± 0.095	Current study
S. canarium (female)	69.73 ± 0.80	1.40 ± 0.10	3.83 ± 0.04	Current study
S. canarium	82.50	1.66	4.05	Amini & Pralampita (1987), Indonesia
S. gigas	260	0.515	4.55	Wood & Olsen (1983), US Virgin Islands
S. gigas	241.70	0.42	4.39	Berg (1976), Caribbean
S. gigas	340	0.437	4.71	Appeldoorn (1990), Puerto Rico
Cittarium pica	104	0.19–0.28	3.31–3.48	Schmidt *et al.* (2002), Costa Rica
Haliotis mariae	126.60	0.97	4.19	Siddeek & Dawson (1997), Oman
Haminoe orbygniana	21.01	0.76	2.53	Malaquias & Sprung (2005), Portugal
Hydrobia ulvae	4.84	0.484	1.05	Cardoso *et al.* (2002), Portugal

Note: K = growth constant (yr^{-1}); L_∞ = asymptotic length (mm); *Rn* = goodness of fit; φ' = growth performance index

The growth rate was comparable, if not better than other cultured mollusks (Berg 1976; Spight *et al*. 1989; Kraeuter *et al*. 1989; Nugranad & Kerdpoom 1995; Patterson *et al*. 1995; Chaitanawisuti & Kritsanapuntu 1997; Lipton & Selvakku 2001). Recently the larval stages of the species have been described and conch spat has successfully been produced in laboratory (Cob *et al*. 2007). Thus there is great potential for mariculture or rather sea ranching activity of the species. Considering minimum market shell length of 40 mm (Amini 1986), *S. canarium* could reach marketable size within eight to ten months, which is faster than some commercially important gastropods, e.g. *S. gigas* (Berg 1976), *Chicoreus ramosus* (Nugranad & Kerdpoom 1995) and *Babylonia areolata* (Chaitanawisuti & Kritsanapuntu 1997).

CONCLUSION

The growth parameter estimation in general showed higher L_∞ value in female compared to the male, which was in agreement with previous studies on other *Strombus* species. The mean growth rate for the first six months was estimated at 3.48 mm/month for male, and at 4.2 mm/month for female, which was also within the average monthly growth rates reported in previous studies. Considering the minimum marketable size of 40 mm shell length, *S. canarium* could reach marketable size within eight to ten months, which was better than *S. gigas*, and some other commercially important gastropod species. Since the population parameters were derived based on estimation, further studies are greatly needed in assessing the actual growth, maturity and longevity, by means of tagging or other appropriate methods.

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