Growth, Mortality, Recruitment and Yield-per-recruit of *Strombus canarium* Linnaeus, 1758 (Mesogastropoda: Strombidae) from the West Johor Straits, Malaysia.


1 Marine Ecosystem Research Center (EKOMAR), School of Environmental and Natural Resource Science, Faculty of Science and Technology, National University of Malaysia, 43600 Bangi, Selangor, Malaysia.

2 Department of Aquaculture, Faculty of Agriculture II, Universiti Putra Malaysia, 43400 Upm Serdang, Selangor, Malaysia.

3 Department of Biology, Faculty of Science, Universiti Putra Malaysia, 43400 Upm Serdang, Selangor, Malaysia.

Abstract: Growth, mortality, recruitment and yield-per-recruit of *Strombus canarium* Linnaeus, 1758 were estimated using length-frequency data collected from Sungai Pulai Estuary, West Johor Straits, Peninsular Malaysia from January to December 2005. The relative growth was isometric type with the exponent ‘b’ of the length-weight relationship was very close to 3 (3.05 ± 0.04 S.E.). The von Bertalanffy growth function (V.B.G.F) estimates were; L∞ = 69.91 mm shell length; K = 1.30 year⁻¹. The growth performance index (φᵢ) was estimated as 3.803. Total mortality (Z) was computed as 2.42 year⁻¹ while the natural (M) and fishing (F) mortalities were estimated at 0.93 year⁻¹ and 1.49 year⁻¹ respectively. The recruitment pattern was continuous with one major peak within the months of June to August. The exploitation ratio (E = F/Z) was 0.61 revealed over exploited stock conditions in the study area.

Key words: Growth, mortality, *Strombus canarium*, Peninsular Malaysia

INTRODUCTION

The dog conch, *Strombus canarium* Linnaeus, 1758 is a mesogastropod from the family Strombidae, commonly found in seagrass areas along the coasts and sheltered Islands of Malaysian waters[24, 8]. This species is native to the coastal waters of Indo-Pacific region, widely distributed from southern India to Melanesia, and extended north to the Ryukus in Japan and south to Queensland and New Caledonia, Australia[1]. In many parts of Southeast Asia, such as Malaysia, Indonesia, Philippines and Thailand, the species has been traditionally fished and constitute important food staples especially for those living along the seashore. They largely collected for their meat, apart from the shell which also has considerable ornamental value[23, 24]. Though the fishing activity of this species has long been reported, landing data are almost non-existence, mainly because they only formed subsistence or artisanal fishery and no specific fishing gear involved[7, 24, 21]. Attempt has been made to quantify the fishery in Bintan Island, Indonesia where Amini[21] estimated about 10.4-15.6 tons of total landings per year.

Although the species is widely distributed, conch fishery in Peninsular Malaysia only limited within the Johor Straits. The area has vast tidal flat and subtidal shoals within the protected estuaries and channels, which was easily accessible for conch collecting during low tides. From only a subsistence fishery, conch-fishing activity has now extended and the shells are now available in local markets and sea-food restaurants particularly during peak season. The objective of the present study was to estimate the population parameters and exploitation level of *S. canarium*, and to assess the stock position of the species from west Johor Straits, Malaysia.

MATERIALS AND METHODS

Study was conducted at Merambong Shoal, Sungai Pulai estuary (01°19.778’N, 103°35.798’E), western Johor Straits, Peninsular Malaysia (Fig. 1). It is probably the most extensive, seagrass covered subtidal shoal of the area. The dense seagrass meadows were dominated by *Enhalus acoroides* and *Halophila* spp. complex.
Monthly samples of S. canarium were collected using belt transect. Then they were transported to the laboratory. In laboratory the conchs were cleaned and all encrusting organisms were scraped-off. Shell length (from tip of spire to anterior end of siphonal canal) was measured using a digital vernier caliper to the nearest 0.01 mm and wet weight taken to the nearest 0.01 g using an analytical balance. The data were then grouped into shell length class of 2 mm intervals and were analyzed using the FiSAT software as explained by Gayanilo et al.\textsuperscript{12,13}.

To establish the length-weight relationship, the commonly used relationship $W=AL$ was applied\textsuperscript{14,15} where $W$ is the weight (g), $L$ the total length (mm), $A$ the intercept (condition factor) and $b$ is the slope (growth coefficient, i.e. relative growth rate). The parameter $a$ and $b$ were estimated using least squares linear regression on log-log transformed data of $\log_{10}W=\log_{10}a + b\log_{10}L$. The coefficient of determination ($r^2$) was used as an indicator of the quality of the linear regression\textsuperscript{16}. The 95% confidence limit of the parameters $a$ and $b$ and the statistical significance level of $r^2$ were also estimated.

The asymptotic length ($L_\infty$) and growth coefficient ($K$), of the von Bertalanffy growth function (V.B.G.F) were estimated using means of ELEFAN-1\textsuperscript{17} incorporated in the FiSAT software package. The $L_\infty$ value was estimated using modified Powell-Wetherall plot\textsuperscript{18,19}, which was then used as seed value in ELEFAN-I analysis to assess a reliable estimate of the growth parameter $K$\textsuperscript{20}. The estimates of $L_\infty$ and $K$ were then used to estimate the growth performance index ($\varphi$)$^{21}$, using the equation:

$$\varphi = 2\log_{10} L_\infty + \log_{10} K$$

The inverse von Bertalanffy growth equation\textsuperscript{22} was used to determine the lengths of the S. canarium at various ages. Then VBGF was fitted to estimates the length-at-age curve using non-linear squares estimation procedures\textsuperscript{23}. The VBGF is defined by the equation:

$$L_t = L_\infty \left(1 - e^{-K\left(t-t_a\right)}\right)$$

where $L_t$ is the mean length (mm) at age $t$, $L_\infty$ is the asymptotic length (mm), $K$ is the curvature of the VBGF or growth coefficient (year$^{-1}$), and $t_a$ is the hypothetical age (year) at which length equals to zero\textsuperscript{24}. The growth rate at any point in the lifespan was calculated as:

$$\frac{dL}{dt} = K\left(L_\infty - L_t\right)$$

The weight-based von Bertalanffy growth equation was also determined, by combining the von Bertalanffy growth equation with the length-weight relationship\textsuperscript{25}. Weight-at-age curve of S. canarium was then calculated using the equation:

$$W_t = W_\infty \left(1 - e^{-K\left(t-t_a\right)}\right)^3$$

where $W_t$ is the mean weight (g) at age $t$, $W_\infty$ is the asymptotic weight (g), $K$ is the curvature of the VBGF or growth coefficient (year$^{-1}$), and $t_a$ is the hypothetical age (year) at which length equals to zero. The asymptotic weight, corresponding to the asymptotic length is determined by the equation $W_\infty = aL_\infty^b$.

The annual instantaneous total mortality rate ($Z$) was estimated using the ‘length converted catch curve’\textsuperscript{16,20}. The natural mortality rate ($M$) was estimated using the method as described by Froese and Paolamare. This method was based on Beverton who pointed out that there is an intermediate age $t_{sp}$ at which the biomass (and egg production) of a year class reaches a maximum: $L_{sp} = L_\infty[3/(3 + M/K)]$,

where $M$ is the natural mortality rate. Solving this equation for $M$ resulted in: $M = K^4(3L_{sp}/L_\infty^4-3)$. To obtain an estimate of $L_{sp}$, the length data were grouped into size classes of 2 mm shell length. The animal weights in each size class were summed up, and the $L_{sp}$ was determined based on the length-class with maximum weight.

Once $Z$ and $M$ values were obtained, fishing mortality ($F$) was then estimated using the relationship of: $F = Z - M$, where $Z$ is the instantaneous total mortality rate, $F$ the fishing mortality rate and $M$ is the natural mortality rate. The exploitation level ($E$) then could be determined using the equation of Gulland\textsuperscript{11}: $E = F/Z$.

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length-frequency data as described in FiSAT software package\textsuperscript{17}. This routine reconstructs the recruitment pulse from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse. Input parameters were $L_{sp}$, $K$ and $t_a$ ($t_a = 0$). Normal distribution of the recruitment pattern was determined by NORMSEP\textsuperscript{18} in FiSAT program.

Analysis of yield per recruit was conducted based on the Beverton and Holt\textsuperscript{21} model as modified by Pauly and Soriano\textsuperscript{22}. The input parameters were $L_{sp}$ and $M$, and length at first capture ($L_c$) which was set at 40 mm shell length corresponding to the minimum marketable size for the species. Levels of exploitations were expressed as $E_{opt}$, $E_{opt}$ and $E_{max}$. $E_{opt}$ is level of exploitation at which the marginal increase in yield per recruit reaches one-tenth of the marginal increase.
computed at a very low value of $E$; $E_{0.5}$ is exploitation level which results in a reduction of the unexploited biomass by 50%; and $E_{\text{max}}$ is sustainable exploitation level that produced maximum yield. These parameters were compared with the current rate of exploitation ($E$). The state of the stock was evaluated as: in equilibrium ($E = E_{\text{max}}$), overexploited ($E > E_{\text{max}}$), or underexploited ($E < E_{\text{max}}$).

RESULTS AND DISCUSSION

Results: A total of 2095 individuals have been collected throughout the 12 months study period, with shell length ranged from 18 to 68 mm. Environmental parameters (salinity and temperature) recorded throughout the sampling period is presented in Fig. 2. The salinity remains somewhat constant; ranged from 29.15 - 30.75 ppt, with mean value of 29.85 ± 0.16 ppt. The mean annual temperature was 29.36 ± 0.14°C, ranged from 28.65 - 30.05°C. There was slight increase in seawater temperature after the monsoon during the months of March to August.

Length-weight relationship: A total of 749 individuals were used for length-weight analysis. The lengths range from 17.56 mm to 67.68 mm, while total weight range from 0.57 g to 33.64 g. The calculated length-weight equation was $W = -4.1943 + 3.0463 \log SL$, which in exponential form was $W = 0.00006 \cdot SL^{3.05}$ ($r^2 = 0.88$, p < 0.01) (Fig. 3). The growth co-efficient ($b$) was 3.05 (± 0.04) with 95% confidence limit between 2.905 to 3.187.

Growth parameters: The Asymptotic length ($L_\text{a}$) of the VBGF was 69.91 mm and the growth coefficient ($K$) was 1.3 year$^{-1}$ for $S$. canarium. The computed growth curve using these parameters is shown over the restructured length frequency distribution in Fig. 4.

The observed maximum length was 68.00 mm and the predicted maximum length was 69.20 with 95% confidence interval between 68.51 - 69.89 mm. The best estimated value of $K$ was 1.3 year$^{-1}$, at goodness of fit (Rn) value of 0.195. The growth performance index ($\phi'$) was 3.803.

The weight based von Bertalanffy growth curve is presented in Fig. 5. The estimated asymptotic weight ($W_a$) value was 25.35 g, much inferior compared with the observed maximum weight ($W_{\text{max}}$) value of 33.64 g.

Age and growth: By using the growth parameters described above, growth rate (dL/dt) and shell length at specific age were then calculated with the assumption that $t_e$ equals to zero$^{[19]}$. The growth rates and the absolute increase in length are presented in Fig. 6. From the monthly shell length increment, average growth rate for $S$. canarium was then calculated, resulted in mean growth rate of 6.25 ± 0.2 mm month$^{-1}$ for the first 6 months and 4.75 ± 0.16 mm month$^{-1}$ in the following 6 months.

Mortality and exploitation: Fig. 7 presents the summed weight at specific length classes for $S$. canarium. The population showed maximum weight in the 55 to 59 mm length-classes, thus suggesting an optimum length ($L_{\text{opt}}$) of 56.51 ± 0.52 mm (from Gaussian plot in ORIGIN® software). Solving the

**Fig. 1:** Sampling site (encircled) at Merambong Shoal, west Johor Straits, Peninsular Malaysia.

**Fig. 2:** Salinity and temperature fluctuations at the study site.

**Fig. 3:** Length-weight relationship of $S$. canarium
Fig. 4: Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 ($L_\infty = 69.91$, $K = 1.3$ year$^{-1}$).  

Fig. 5: A weight-based growth curve of $S$. canarium using the von Bertalanffy growth function, based on computed growth parameters ($L_\infty = 69.91$, $K = 1.3$ year$^{-1}$, $t_e = 0$).  

Fig. 6: Plot of age and growth rate of $S$. canarium using the von Bertalanffy growth function, based on computed growth parameters ($L_\infty = 69.91$, $K = 1.3$ year$^{-1}$, $t_e = 0$). The equation of $M = K^*[(3L_\infty / L) - 3]$, with $L_{opt} = 56.51$ mm, $L_\infty = 69.91$ mm, and $K = 1.30$ year$^{-1}$ resulted in natural mortality rate ($M$) of 0.93 year$^{-1}$.  

The length converted catch curve analysis is presented in Fig. 8. Total instantaneous mortality rate ($Z$) was at 2.39 year$^{-1}$ (95% C.I. between 1.97 and 2.81 year$^{-1}$). The fishing mortality rate ($F = Z - M$) was therefore at 1.46 year$^{-1}$. The current exploitation level ($E = F/Z$) for male $S$. canarium was therefore at 0.61. At this exploitation rate, the population was considered slightly overexploited$^{[13]}$.  

Fig. 7: Optimum length (i.e. the length-class with maximum weight, $L_{opt}$) of $S$. canarium population.  

Fig. 8: Length converted catch curve of $S$. canarium.
Based on the length converted catch curve values, the probability of capture was then analyzed and presented in Fig. 9. Using the natural mortality rate \((M) = 0.93\) as seed value, the length at first capture \((L_c)\) was estimated at 18.22 mm shell-length.

**Recruitment:** The recruitment pattern of *S. canarium* was continuous throughout the year, but showed peak between the months of June to August (Fig. 10), which account to 53.77% of total recruitment throughout the year.

**Relative yield per recruit model:** The relative yield per recruit analysis is presented in Fig. 11. Using length at first capture \((L_c)\) of 18.22 mm as derived from the probability of capture analysis, the \(E_{0.1}\) was 0.453, \(E_{0.3}\) was 0.329, and the maximum exploitation level \((E_{max})\) was 0.519 (Fig. 11).

**Discussion:** *S. canarium* considered to have an isometric growth where the growth coefficient parameter \(b\) was found very close to 3. The population showed wide variation in weight among older individuals, which is common among gastropods where thickening and development of shell ornaments took place in adults. *S. canarium* showed deterministic type of growth. They grow in length until the onset of sexual maturity at which time it starts building the flaring lip, with minimal length increment\([11, 29]\). Growth is then more on shell lip (labial lip) thickness. There have been suggestions of incorporating / using lip thickness as reference for growth parameters estimation, which was however only practical among adult group\([4]\). Moreover, shell thickness can be highly varied according to stress levels (pers. observ.), which might interfere growth parameter estimation. The wide variation of animal weight within the adult group also resulted in much inferior value of \(W_c\) compared with the observed weight \((W_{max})\). Therefore the use of weight-based von Bertalanffy equation for *S. canarium* should be treated with cautions.

The growth parameters \((L_c, K)\) obtained in this study was inferior compared with previous finding on the same species by Amini and Pralampita\([3]\) at Bintan Island, Indonesia, where the \(L_c\) was 8.25 and \(K\) 1.656 year\(^{-1}\). In their study the shell length range from 37 to 78 mm, and the maximum length was much higher than the population currently studied. Erlambang\([9]\) also recorded higher shell length range, from 12 mm to 82 mm length for population around Riau Archipelago, Indonesia. *S. canarium* in general showed wide variation in size distribution among locations. According to Abbott\([1]\) the lengths of adult shells varied from as low as 31 mm to the maximum 97 mm length. The current study was conducted at the main conch collecting grounds where the animals were harvested, which might contribute to the low frequency of large sized conch sampled.

The overall growth rate for the first year conch was about 5.5 mm month\(^{-1}\) (± 0.26). At this growth rate, the conch could reach marketable size within
8 months. The growth rate was quite similar with other reported studies\(^5\), thus suggests that culture or rather sea ranching activity could potentially be a successful industry. Growth to marketable size was superior compare to the commercially important S. gigas, which only reached marketable size at age 2.5 years, at 190 mm shell length\(^6\).

The recruitment pattern suggests that annual recruitment consists of one seasonal pulse (Fig.10), which occurs between months of June to August. This period of recruitment referred to migration of new group of juvenile into the adult population, and not the actual spawning. Very high percentages (\(> 50\%\)) of new recruits within this period suggest a highly synchronized reproductive pattern. This was in agreement with previous findings where S. canarium reported to congregate in large numbers during spawning season\(^8\). Field observation also found high frequency of copulation and spawning activities during the months of November to March. The major recruitment peak detected in March (Fig. 4) could be traced back to this period of active reproductive activity and spawning.

To maintain this valuable resource, the exploitation rate should be reduced below the optimum value as well as increasing the length at first capture to increase chances of new recruitments. The maximum \(Y/R\) was obtained at \(E_{\text{max}}\) of 0.52. As the exploitation rate increases beyond this value, relative yield per recruit decreases. The results indicated that the present levels of exploitation rate \((E = 0.62)\) and fishing mortality \((F = 1.49)\) were higher than those which give the maximum \(Y/R\) values \((E_{\text{max}})\). For management purposes, the exploitation rate of S. canarium should therefore be reduced from the current \(E (0.62)\) to \(E_{0.5} = 0.32\), which maintained 50% biomass of the stock (Fig. 11).

Conclusions: S. canarium population showed an isometric growth, with wide variation of weight among older individuals. The species showed deterministic type of growth. The wide variation of animal weight within the adult group also resulted in much inferior value of \(W_c\), thus the use of weight-based von Bertalanffy equation for S. canarium should be treated with cautions. The VBGF growth parameters \((L_0, K)\) obtained in this study was slightly inferior compared with previous study. The overall growth rate was however quite similar with other reported studies\(^8\), and there is potential for mariculture of the species. Result also indicated that the species was slightly overexploited. To maintain this valuable resource, the exploitation rate should therefore be reduced below the optimum value, as well as increasing the length at first capture to increase chances of new recruitments.

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