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Spatial and Temporal Variations in *Strombus canarium* (Gastropoda: Strombidae) Abundance at Merambong Seagrass Bed, Malaysia

(Variasi Reruang dan Temporal bagi Kelimpahan *Strombus canarium* (Gastropoda: Strombidae) di Hamparan Rumput Laut Merambong, Malaysia)

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ABSTRACT

The abundance of marine benthic organisms often exhibits distinct distributional patterns, which is generally governed by many physical and biological factors specific to the habitat. In this study, the spatial and temporal variations in abundance of the dog conch, Strombus canarium *Linnaeus 1758, a commercially important marine gastropod, was investigated. Assessment of conch abundance at Merambong seagrass bed, Malaysia, was conducted using a transect belt method. Sampling stations were randomly selected and environmental parameters associated with the habitat were recorded. The species showed distinct spatial distributional pattern. Conch densities were significantly higher in sheltered areas, mainly in mixed seagrass bed dominated by* Halophila *spp. and with high sediment organic content. The densities were relatively very low in areas dominated by the tape seagrass,* Enhalus acoroides. *The species studied also showed distinct temporal variation in abundance. The abundance value was seasonally varied with highest density recorded during the wet monsoon season (*$p<0.05$*). The densities were otherwise very low during the dry season, except for a slight peak in July. Since the conch is a very important fishery species within the Johor Straits and regulations on their harvesting is still lacking, this information would be very important for their sustainable management.*

Keywords: Abundance; conch; density; population dynamics; seagrass; Strombidae

ABSTRAK

Kelimpahan organisma bentik marin selalunya menunjukkan corak taburan tertentu, yang umumnya dipengaruhi oleh faktor fizikal dan biologi khusus kepada sesuatu habitat. Dalam kajian ini, variasi reruang dan temporal bagi kelimpahan siput gonggong, Strombus canarium *Linnaeus 1758, spesies gastropod marin yang penting secara komersil, telah dikaji. Penilaian ke atas kelimpahan siput di hamparan rumput laut Merambong, Malaysia, telah dijalankan melalui kaedah jalur transek. Stesen kajian telah dipilih secara rawak dan parameter persekitaran habitat direkodkan. Spesies yang dikaji menunjukkan pola taburan reruang yang jelas. Kelimpahan siput secara signifikannya lebih tinggi di kawasan yang terlindung, terutamanya di hamparan rumput laut yang didominasi oleh* Halophila *spp. dan dengan kandungan organik sedimen yang tinggi. Kepadatan siput secara relatifnya lebih rendah di kawasan yang didominasi oleh rumput laut jenis pita,* Enhalus acoroides. *Spesies yang dikaji juga menunjukkan variasi temporal yang jelas dalam kelimpahannya. Nilai kelimpahan didapati berbeza mengikut musim dengan nilai kepadatan tertinggi direkodkan semasa musim hujan (*$p<0.05$*). Kepadatan siput sebaliknya adalah lebih rendah semasa musim panas, kecuali sedikit peningkatan pada bulan Julai. Memandangkan siput gonggong adalah spesies perikanan yang penting di selat Johor dan setakat ini tiada peraturan khusus dalam penangkapannya, maklumat daripada kajian ini adalah sangat penting bagi pengurusan mapan siput tersebut.*

Kata kunci: Dinamik populasi; kelimpahan; kepadatan; rumput laut; Strombidae; siput

INTRODUCTION

Marine benthic organism often exhibit distinct pattern in distribution throughout their geographical range, which were evidence in both spatial as well as temporal scale. The patterns of distribution were largely determined by the habitat characteristics, which include the physical, as well as the biological environments (Alfaro & Carpenter 1999; Navarrete 1996; Underwood & Petraitis 1993). Combinations of physical and biological characteristics were generally involved where in most occasions not one factor alone can explain the distributional patterns of a species (Connell 1983; Navarrete 1996; Underwood & Petraitis 1993). Determination of these factors and how organisms react when changes in environmental condition occurs, are very important for management of the marine resources.

Gastropods from the family Strombidae are group of commercially important marine snails, which occurred throughout the tropical and subtropical regions (Abbott 1960). Many authors have reported significant variations in spatial and temporal distribution and abundance of some species within this family (Catterall & Poiner 1983; Randall 1964; Stoner et al. 1992; Wada et al. 1983). Studies on the Caribbean species found the *Strombus* there were generally patchily distributed, where large number of individuals can be found in certain areas, while none in adjacent areas with seemingly similar characteristics. Within the family, coordinated migrations normally occurred, particularly during the breeding season, resulting in large congregation of conch at certain areas across their habitat range (Berg 1975; Hesse 1979; Kuwamura et al. 1983; Stoner & Ray 1993). This behavioral characteristics probably very important traits for the species (Stoner & Ray 1993), however little is known of the nature or ecological significance of the aggregations.

Within the Indo-pacific region, the dog conch, *Strombus canarium* Linnaeus, 1758 is probably the most important species of the family Strombidae. This species normally present in large numbers, particularly within the shallow near-shore seagrass bed ecosystem (Amini 1986; Cob et al. 2008; Erlambang & Siregar 1995; Lauranceau 2001; Libutaque 2000; Sudtongkong & Intacharoen 2011). Compared with their Caribbean cousins (*Strombus gigas*), there were currently very few studies dealing with the ecology of this species (Amini 1986; Cob et al. 2008, 2009; Erlambang & Siregar 1995). Much information such as their distribution pattern, habitat preferences and habitat range were still remained unknown. The objective of the current study was to determine the spatial and temporal variations in abundance of *S. canarium* population in their natural habitat. This information is very important for conservation and for better management of this species.

MATERIALS AND METHODS

Merambong Shoal, located within the West Johor Straits has been selected as the study site for this research (Figure 1). It is a subtidal shoal with depth of -1.5 to –2.7 m MSL and is only accessible during period of extreme low tides. The shoal measured about 1 to 1.2 km in length and 100 to 200 m in width when exposed and of calcareous sandy mud substrate (Japar Sidik & Muta Harah 2003). The shoal was densely populated with seagrasses where ten species have been recorded, with *Enhalus acoroides*, *Halophila ovalis* and *Halophila spinulosa* were among the most dominant species (Japar Sidik & Muta Harah 2003). It is most probably the largest single seagrass bed in Peninsular Malaysia and supports the highest species number for any locality in either Peninsular Malaysia or Malaysia (Japar Sidik et al. 1996).

Investigation on the conch spatial distribution was conducted between November 2005 and January 2006. A transect belt of 5 × 1 m was used for the sampling and adopting a random sampling approach. The transect line was deployed randomly and the number of conch present within the transect area was recorded. The location of the sampling station was recorded using a GPS and were then mapped using GARMIN® Mapsource computer software. Environmental parameters most associate with the stations such as the specific seagrass species coverage and sediment organic content were recorded. Data were then analyzed using multivariate (principle component analysis/PCA) analysis against the conch density.

Temporal variations in conch abundance were analyzed from January to December 2005. Monthly conch densities were assessed using a transect belt of 30 × 2 m, which were randomly deployed and all conch present

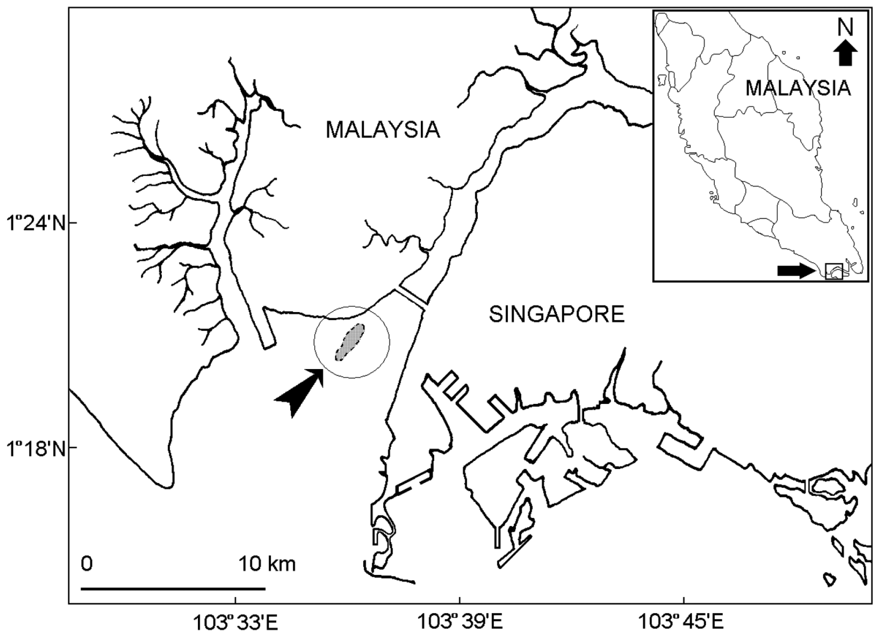

FIGURE 1. The sampling sites, Merambong Shoal, Johor Straits, Johor, Malaysia

within the transect area were sampled. Variations in conch density (monthly and seasonally) were then analyzed. Water quality parameters including temperature, salinity, dissolved oxygen, pH and conductivity were also recorded during each visit, using a properly calibrated Hydro Lab (Model: Surveyor 4A, Hydrolab Corporation, USA).

Data Analysis

Prior to any statistical analyses, data distributions were tested for normality and homogeneity of variances. The abundance data were then compared using one way-ANOVA with station and season as factor. Ordination of sampling stations on the basis of habitat descriptors was achieved using principal component analysis (PCA). The correlation matrix was used because the independent variables were measured in different units. Analyses were conducted with untransformed data as transformations did not improve the distribution of residuals and correlation coefficients.

Results

Spatial Variations in Abundance

The conch density ranged between 0 and 13 ind/m^2, with overall mean density of 4.27 ± 0.69 ind/m^2 (N = 33). The pattern of conch distribution along the shoal area is presented in Figure 2. Generally they were more abundant at middle-northern areas compared with the southern areas and more abundant on the western areas than the eastern areas of the shoal. For analytical purposes, the shoal area was therefore divided into northern, middle and southern sections. The abundance data was normally distributed (Anderson-Darling, p>0.05) and variance significantly homogeneous (Bartlett's test, p>0.05). Analysis of variance followed by Tukey's test showed that the conch densities in stations at the middle and northern area of the shoal were significantly higher compared with stations on the southern end of the shoal (p<0.5). Comparison of conch densities between the

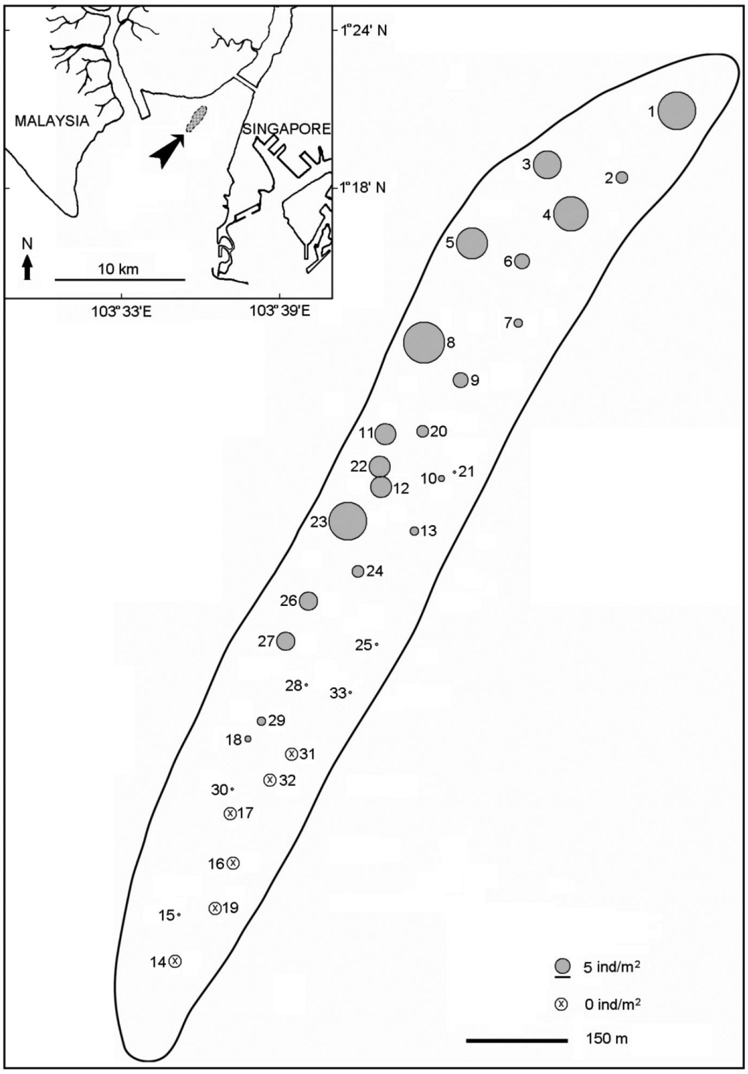

FIGURE 2. Spatial distribution and abundance of *Strombus canarium* at Merambong Shoal

eastern and western sides of the shoal was also conducted. The pooled data also normally distributed and fulfilled the assumption of homogeneity of variance ($p>0.05$). A two-sampled t-test was conducted where the mean conch densities at stations on the eastern side of the shoal (6.17 ± 1.30) was significantly higher than the western side of the shoal (1.00 ± 0.41) ($p<0.05$).

The sampling stations were ordinated with PCA using 5 different habitat descriptors i.e. the seagrass coverage (*Enhalus*, *Halophila*, *Halodule* and *Thalassia* percentage coverage) and sediment organic content (%LOI). Prior to ordination the sampling stations were classified into groups based on conch densities i.e. low (<1ind.m^2), mid and high (>5 ind/m^2) conch density. The first two principal components described 88.27% of the cumulative variance, with Axes-1 and 2 accounted for 58.20 and 30.07%, respectively, of variations of the whole matrix (Table 1). The factor loadings of the descriptors in the first 3 principal component axes were presented in Table 2. High scores in axis-1 (PC1) represent high *Halophila* coverage, high sediment organic content, and low *Enhalus* coverage. High score in axis-2 (PC2) on the other hand represent high *Thalassia* coverage and low *Enhalus* coverage.

There were large spread of points (stations) along axis-1 and 2, suggesting considerable variations in habitat (seagrass microhabitat) characteristics within the study areas (Figure 3). The figure shows very good separation between stations with low and high conch density, indicating conch specific preference for suitable habitats. Most stations with high conch density showed positive PC1 values, which indicate high preference for habitat with high *Halophila* coverage and high sediment organic content. Stations with low conch density on the other hand mostly showed negative PC1 values, i.e. reflecting habitat with high *Enhalus* coverage.

TEMPORAL VARIATIONS IN ABUNDANCE

The environmental parameters at the sampling sites, which include the meteorological data (rain), are presented in Table 3. The mean monthly conch density ranged widely, from 1.11 ± 0.29 ind/m^2 in June to 8.56 ± 0.92 ind/m^2 in November, with mean annual density of 3.71 ± 0.48 ind/m^2. The conch showed higher densities in January, November and December, with a slight peak in July (Figure 4). All monthly density data were normally distributed (Anderson-Darling test, $p>0.05$) and met the assumptions of homogeneity of variance (Bartlett's test, $p>0.05$), thus one way analysis of variance (ANOVA) was conducted, followed by Tukey's post-hoc test. There was a significant different in mean conch densities between month ($p<0.05$). Tukey's test was therefore conducted and presented in Table 4. The significant different occurred due to the higher mean conch density in November, December and January samples ($p<0.05$). The mean conch density in November was significantly higher than others except for December ($p<0.05$); the mean conch density in December was significantly higher than other months except for January, February and November ($p<0.05$); and the mean conch density in January was significantly higher than others except for February, July and December ($p<0.05$).

The monthly density recorded from this study indicated a probable seasonal variation in conch abundance. Therefore the abundance data were pooled and compared between seasons i.e. northeast monsoon, from October to April (wet season) and southwest monsoon, from May to September (dry season) (Morton & Blackmore 2001). The density data for both seasons were normally distributed (Anderson-Darling, $p>0.05$) and fulfilled the assumption of homogeneity of variance (Bartlett's test, $p>0.05$). There was significantly higher conch density during wet season compared with dry

TABLE 1. Eigenvalues and percentage of variation described by each axes

Axes	Eigenvalues	% variance	Cumulative % of variance
1	2.07	58.20	58.20
2	1.07	30.07	88.27
3	0.24	6.76	95.02
4	0.11	3.05	98.07
5	0.07	1.93	100.00

TABLE 2. Eigen vectors for variables used in PCA of environmental (seagrass and organic content) data, indicating the strengths of the correlations between variables and the principle components (axes)

	PC1	PC2	PC3
Enhalus % cover	-0.76	-0.61	0.16
Thalassia % cover	-0.51	0.84	0.16
Halophila % cover	0.98	0.00	-0.02
Halodule % cover	0.57	-0.07	0.31
Organic content (%LOI)	0.73	-0.12	0.64

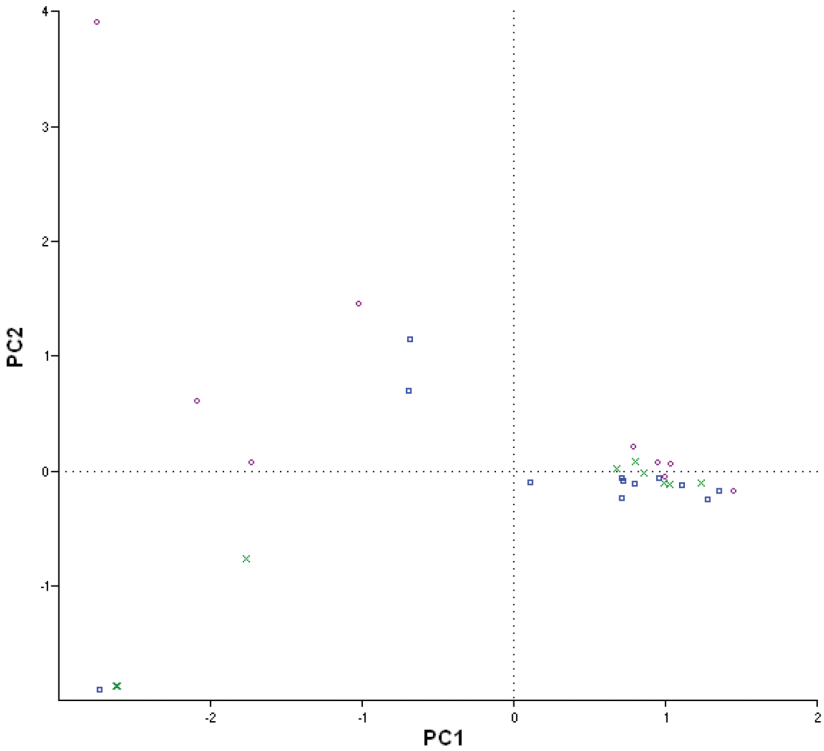

FIGURE 3. The distribution of 30 sampling stations randomly selected across the shoal, against the first two principal component axes in Table 2. Legend: circle = stations with conch density <1 ind/m^2; cross = conch density 2 – 4 ind/m^2; square = conch density > 5 ind/m^2

TABLE 3. The environmental parameters of the sampling station recorded throughout 2005. Monthly rainfall data was supplied by the Malaysian Meteorological Service, recorded at Hospital Johor Bahru weather station

Months	Salinity (psu)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (mS)	Rainfall (mm)
JAN	30.02	28.65	5.51	7.67	45.37	297.42
FEB	30.56	28.96	4.85	7.58	46.28	148.22
MAR	30.75	29.64	4.92	7.87	44.13	252.29
APR	30.46	29.95	4.98	7.66	45.61	257.88
MAY	29.41	30.05	4.65	7.78	45.57	193.13
JUN	29.24	30.01	4.84	7.91	46.5	135.86
JUL	29.22	29.35	5.13	8.02	44.88	200.20
AUG	29.15	29.1	5.56	8.14	43.08	204.51
SEP	29.54	29.26	5.14	7.9	43.08	199.82
OCT	29.74	29.15	5.62	7.745	44.16	228.54
NOV	30.15	29.35	5.75	7.765	44.68	250.35
DEC	29.99	28.88	5.61	7.75	47.55	338.89

season (t-test, p<0.05). The mean conch densities for wet- and dry-seasons were 4.97 ± 0.67 and 1.96 ± 0.28 ind/m^2, respectively.

Correlation analysis between conch abundance and various environmental parameters is presented in Table 5. There was significant negative correlation between density and seawater temperature (r = -0.66, p< 0.05); and positive correlation between conch density and dissolved oxygen levels (r = 0.64, p<0.05), and between conch density and monthly rainfall (r = 0.62, p< 0.05).

DISCUSSION

SPATIAL DISTRIBUTION AND HABITAT PREFERENCES

The *Strombus canarium* in this study was generally widely distributed along the shoal, but clearly showed preference towards specific areas. In general they were relatively more abundant in sheltered areas, i.e. towards the northern and western sides of the shoal compared with those facing the open seas. Observations found that conch density was higher at mixed *Halophila* bed of

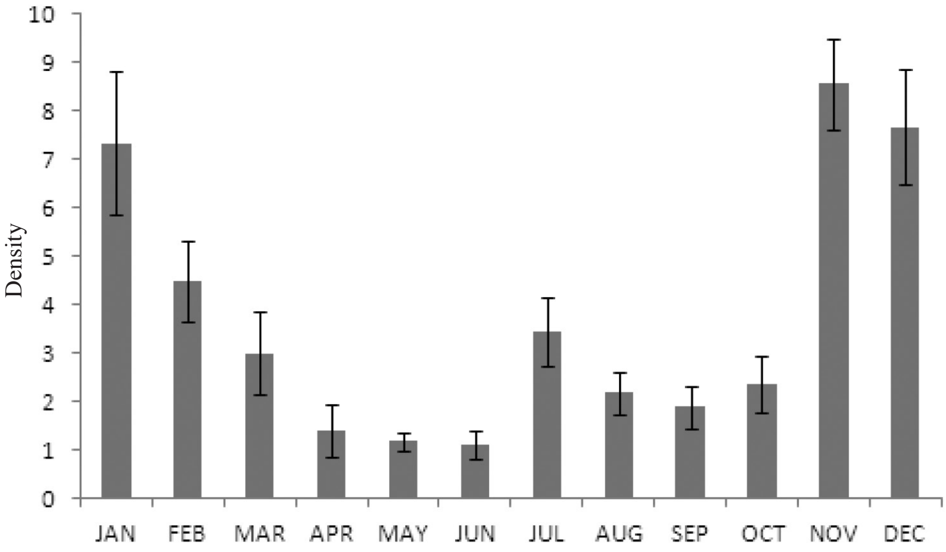

FIGURE 4. *Strombus canarium* monthly density (ind/m^2) at Merambng shoal, Johor Straits

TABLE 4. Tukeys pairwise comparisons for monthly density data (N = 3). Asterisks (*) denotes significant different and zero (O) denotes not significantly differs, at p = 0.05 probability levels

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Feb	O										
Mar	*	O									
Apr	*	O	O								
May	*	O	O	O							
Jun	*	O	O	O	O						
Jul	O	O	O	O	O	O					
Aug	*	O	O	O	O	O	O				
Sep	*	O	O	O	O	O	O	O			
Oct	*	O	O	O	O	O	O	O	O		
Nov	*	*	*	*	*	*	*	*	*	*	
Dec	O	O	*	*	*	*	*	*	*	*	O

TABLE 5. Pearson correlations between *Strombus canarium* density and the environmental parameters, at Merambong seagrass bed, Johor. Asterisks (*) denotes a significant different at α = 0.05

	Pearson correlation	p-value
Salinity (PSU)	0.35	0.26
Temperature (°C)	-0.65	0.02*
Dissolved Oxygen (mg/L)	0.64	0.02*
Conductivity (mS)	0.31	0.33
pH	-0.35	0.26
Rainfall (mm)	0.62	0.03*

low coverage and very low densities in areas with thick *Enhalus* meadows. Therefore pattern of conch distribution might also due to the different in seagrass standing crop across the shoal areas, which need further investigations. In addition, the conch was patchily distributed, where they normally occurred in groups/ local colonies. Often the boundaries of these colonies however were difficult to be drawn because of the low conch density and habitat overlapping.

The patchiness in conch distribution has been reported by several authors (Berg 1975; Catterall & Poiner 1983; Hesse 1979; Stoner & Waite 1991), which seems as a general characteristic of the family. In fact, aggregation tends to be the norm in most benthic marine invertebrate distribution (Heip 1975; Poiner 1977; Scheibling 1980). Catterall and Poiner (1983) described four types of aggregations in *S. luhuanus*: group of mixed age class, juvenile, mating and clusters. The first three were common for *S. canarium* studied, but aggregation in clusters was never been observed. Cluster aggregation or clumping has also been reported in *S. gigas* and like mass burying, it might be related with dormant period during winter in the subtropical areas (Hesse 1979).

TEMPORAL VARIATION IN ABUNDANCE

Strombus canarium also showed a seasonal variation in abundance where significantly higher density was recorded during the wet season. The conch density was otherwise very low during the other months, except for a small peak during the month of July. There was no account of abundant data in literature for the species from Merambong shoal, thus comparisons were made with other locality. In Bintan Island, Indonesia highest density of *S. canarium* occurred between May and October each year (Amini 1986; Erlambang 1996), which was completely in contrast with the current study. In terms of abundance, the density values recorded here is quite similar with other studies (Amini 1986; Erlambang 1996) and was also comparable with other *Strombus* species, such as *S. luhuanus* (Poiner & Catterall 1988; Wada et al. 1983).

The lower density recorded during dry season could be attributed either to conch burial behavior and / or migration to deeper water, as was described for other *Strombus* species (Hesse 1979). The *S. canarium* studied however was rarely found deeply buried, unless when they were in stress, as was observed in laboratory culture condition when the water quality deteriorated (pers. observ.). Adult conch do periodically bury into the substrate. But in normal burying condition, although the shell almost completely buried, parts of the anterior siphonal canal and conch eyes still visible to experienced observers during the species counts. Therefore burying behavior is most likely not the main reason behind the low abundance during Southwest Monsoon (dry season) for the species studied.

Nevertheless, mass burial has been reported in sub-tropical species (*S. gigas*, *S. costtus* and *S. pugilis*) particularly during winter. They can lay dormant in the sediment for considerable periods during winter before emerged and congregate during the summer reproductive season (Hesse 1979; Perchade 1970). This behavior appears to signal a dormant condition, during a period of adverse condition (winter), in the species (Hesse 1979; Perchade 1970). However mass burial was not observed during this study and has never been reported for any other tropical *Strombus* species.

Adult *S. canarium* has wide habitat range (Abbott 1960). There is high possibility that some of the population might venture into deeper areas and migrate back to the shoal during reproductive season. Study on *S. gigas* reported adult conchs appeared to range for several kilometers and could move around at a rate between 50 and 100 m daily (Hesse 1979). However, *S. canarium* migratory behavior in this study cannot be followed due to the difficulty of capture outside the shoal area. In addition underwater observation was almost impossible due to the very poor visibility of the seawater. Even tagged individuals were never recovered on the shoal area, which was in favor of the hypothesis that they had migrated to deeper waters.

Reproduction might be the main reason behind this seasonal variation in abundance. Numerous studies on *Strombus* have reported migratory behavior related to reproduction (Catterall & Poiner 1983; Kuwamura et al. 1983; Randall 1964; Stoner et al. 1992; Wada et al. 1983). *Strombus gigas* moves inshore to shallow areas and aggregate at the beginning of spawning season and return to deeper habitats afterward (Stoner et al. 1992). Aggregations during spawning season are important for successful reproduction in *Strombus* species, which was density-dependent (Stoner & Ray-Culp 2000). The study on queen conch reported incidence of reproductive failure in low population density (Stoner & Ray-Culp 2000).

Apart from that since conch were harvested during the high season (November to March), low abundance in the following months (April to June) might also be due to human predation. Unfortunately direct impact of gathering to the population was not thoroughly studied. Nevertheless the impact might be minimal. There was limited collecting time as access to the shoal only available during spring low tide, which was limited for only a few hours and span only for a few days in a month. The number of collectors involved also considerably low and there was no specific tool or fishing gear involved. In addition only adult conch exposed on the surface was collected while the buried and the subtidal escaped. According to Poiner and Catterall (1988), both the size and age-dependent burying and the partly subtidal distribution provide refugia which buffer the *Strombus* populations from human predation. They found no significant impact of traditional fishery on *S. luhuanus* in Papua New Guinea although collecting activity occurred all year round.

CONCLUSION

Strombus canarium population studied at the Merambong Shoal showed patchy distribution. They normally present in local colonies and were generally more abundant in sheltered areas compared with those facing open seas. The population also showed very distinct seasonal variation in abundance where significantly higher density was recorded during wet (northeast monsoon) season. The lower density during dry season could be attributed to migration of adult conchs to deeper areas, which however need further studies.

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