Journal of Sustainability Science and Management
Volume 14 Number 1, February 2019 : 1-10
e-ISSN: 2672-7226

EFFECTS OF TEMPERATURE ON FOOD CONSUMPTION OF JUVENILES DOG CONCH, *Laevistrombus canarium* (LINNAEUS, 1758) IN LABORATORY CONDITION

WAN NURUL HUSNA WAN HASSAN[1*], NURUL AMIN SM[2], MAZLAN ABD GHAFFAR[1,3,4] AND ZAIDI CHE COB[1,3]

[1]*School of Environmental and Natural Resources Science, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.*
[2]*Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia.*
[3]*Marine Ecosystem Research Centre, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.*
[4]*Institute of Marine Biotechnology, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia*

**Corresponding author: p63421h@gmail.com*

Abstract: The dog conch, *Laevistrombus canarium* (Linnaeus, 1758) is one of the economically important marine molluscs that have high market value, particularly in the Southeast Asian region. This study investigates food consumption and assimilation by the juvenile conch at different temperature regimes (22, 26, 30 and 34°C). Live samples of the juvenile conch were collected on several occasions between December 2013 to May 2105 at Merambong shoal, Johor Straits, Malaysia. They were acclimatized for one week in stocking aquaria with well-aerated seawater at 30 PSU, 26°C and fed with commercial marine sinking pellets. Prior to experimentation, the gastric emptying levels of the samples were standardized by allowing them to feed until satiation, followed by 24 hrs starvation. All treatments were carried out in ten replicates of similar sized aquarium (20 x 15 x 15 cm) containing 4L of aerated seawater. The conch food consumption rate was significantly different ($p<0.05$) between different temperature regimes. The food absorption efficiency was also affected by different temperature regimes ($P<0.05$), and ranged between 50.14% to 73.76%. The food energy absorbed were then calculated, which showed significant variations between temperatures ($P<0.05$). Based on these calculations, higher food consumption and assimilation were recorded at 26°C followed by 30, 34 and 22°C. Results from this study allow us to predict the optimal temperature regimes (26°C) for the culture of these marine sea snail *L. canarium.* Further studies are indeed, needed to provide a better insight on the effect of climate change parameters on these species.

KEYWORDS: *Laevistrombus canarium,* conch, feeding, absorption efficiency, temperature regimes.

Introduction

Laevistrombus canarium (Linnaeus 1758) is an important gastropod mollusc generally known as dog conch or locally known as 'siput gonggong'. According to Abbott (1960), this marine conch is originated from the coastal waters of Indo-Pacific region and is widely distributed from southern India to Melanesia, extending north to the Ryukus in Japan and south to Queensland, Australia and New Caledonia. This gastropod species in Peninsular Malaysia are mainly found in the Johor Straits (Cob *et al.,* 2008) and other areas such as Pulau Tinggi and Pulau Besar, in eastern Johor, and in Port Dickson and Teluk Kemang in Negeri Sembilan. Dog conch lives on muddy sand bottoms among algae and seagrass beds on peninsular and continental shores (Poutiers, 1998). This mollusc species is essential as a staple food, especially for local communities (Poutiers, 1998; Arularasan *et al.,* 2010), as well as other uses as ornaments or decorative (Latiolais *et al.,* 2006) and fishing equipment.

Amini (1986), Erlambang and Siregar (1995) and Cob *et al.* (2009a) reported that this species is relatively less known and not extensively studied as compared to the commercially important conch from other region such as the queen conch, *Lobatus gigas,* the milk conch, *Lobatus costatus* and the fighting conch, *Strombus pugilis*. Knowledge on various physiological parameters such as food consumption, food absorption efficiency and food energy absorbed are therefore extremely vital and urgently useful. To date, information regarding the food consumption and assimilation of this marine species are very scarce and limited.

Doxa *et al.,* (2013) stated that feeding is vital for all physiological parameters, thus understanding the feeding behavior is crucial for the successful adaptation, maintenance and welfare of the animals especially in captivity. In addition, according to Staikou and Lazaridou-Dimitriadou (1989), ingestion and assimilation are important phases of energy transport from one trophic level to another and many gastropods, being primary consumers, play an essential role in the ecosystem functioning. Therefore, it is crucial to conduct a quantitative study on food consumption and assimilation in snails in order to evaluate their role in an ecosystem (Mason, 1970; Charrier & Daguzan, 1980; Staikou & Lazaridou-Dimitriadou*,* 1989).

Among the environmental variables, many studies have reported temperature as the most important extrinsic factor affecting the physiological states of ectotherms (Fry, 1971; Daoud *et al.,* 2007; Jahangir *et al.,* 2011). Therefore, it was hypothesized that temperature plays a significant role in the physiology and growth of *L. canarium*, particularly in the food consumption and assimilation efficiency. Optimal temperature conditions for growth might considerably vary between different life stages such as larvae, veligers, juvenile, sub-adult and adult. Moreover, the parameter component of the energy budget at different life stages might have large influence on the proportion of ingested energy that can be devoted to growth (Vernberg & Piyatiratitivorakul, 1998). However, impacts of temperatures on the energetics of the juvenile stage have not been thoroughly studied. Advantage working with juveniles is that the interference from gonad development (gametogenesis) and other reproductive factors can be excluded, thus less complicated (Bashevkin & Pechenik, 2015).

The Merambong shoal is located in the western part of the Straits of Johor, Malaysia. This seagrass bed shoal is one of the most important and most extensive seagrass habitats particularly in Peninsular Malaysia. This dense seagrass meadow provides a suitable place for breeding, as a nursery, for protection and as a feeding ground, for marine animals (Bujang, 1994, Bujang *et al.,* 2001; Bujang & Zakaria, 2003). The *L. canarium* has high market value and is in high demand in many parts of Southeast Asia, and it is now undergoing rapid development for introduction into aquaculture. Thus, information regarding the food consumption and assimilation efficiency, and factors controlling them are urgently needed. The objectives of this study are therefore to investigate the food consumption, food absorption efficiency and food energy absorbed by juvenile of *L. canarium* at different temperature regimes.

Materials and Methods

Field Sampling and Collection

Live samples of juvenile *L. canarium* were collected on several occasions between December 2013 to May 2015 at Merambong shoal, Johor Straits (01°19′N, 103°35′E) (Figure 1). The juvenile stage can easily be identified by several criterias, such as shell thickness, shell flaring (outward growth of the outer columella lip) and the thickness of the flared lip (CFMC, 1999; Cob *et al.,* 2009b).

Acclimatization

Upon returning to the Marine Science wet lab, Universiti Kebangsaan Malaysia, the gastropods were acclimatized in stocking aquaria with well-aerated seawater (salinity: 30 PSU, ambient temperature: 26°C) for one week prior to experimentation. During acclimation, marine sinking pellets were offered daily to *L. canarium* as food. The seawater was changed once every three days to prevent accumulation of metabolic wastes and dead individuals were removed when encountered. Prior to laboratory experimentation, gastric emptying levels of the snails were standardized by allowing them to feed on pellets to satiation and then starving them for 24 hours. Samples were selected based on their health and activeness. The shell length and body weight were recorded and then snails were transferred to experiment tanks with four different temperature regimes (22°C, 26°C, 30° and 34°C). The test temperature regimes were selected following suggestion by IPCC, (2007). The shell length was measured to the nearest 0.01 mm using a vernier caliper and the body weight to the nearest 0.01 g using a digital scale.

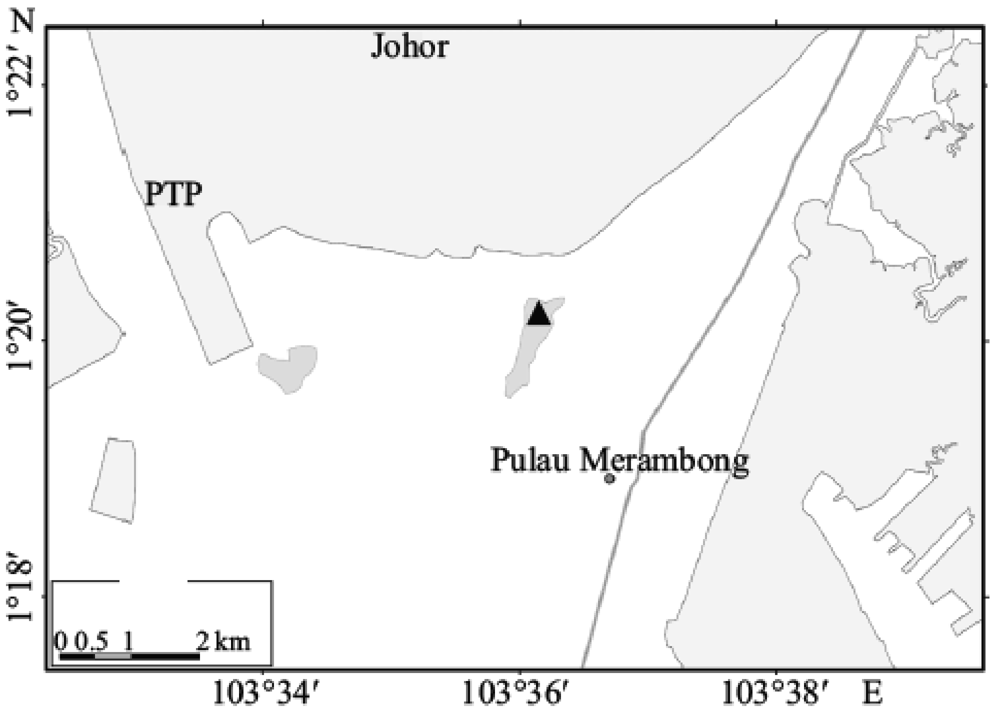

Figure 1: The study area (black triangle). Samples collection was conducted at the Merambong Shoal, Johor Straits, Malaysia.

Experimental design

Forty *L. canarium* juveniles with shell length between 33.00 to 49.00 mm and body weight between 4.16 to 10.69 g were used for this experiment. The experimental setup is as shown in Figure 2 (Tank 1 to Tank 10 as experimental tanks, while T0 act as a control tank). Each sample (one sample per tank) were placed in aquaria with similar sized (20 x 15 x 15 cm) containing 4 L of well aerated and filtered seawater (0.45 µm). Control tank, T0 with animal but no foods was also set up to obtain a correction factor for each experiment. Screen of 1.00 mm mesh size were fitted at the inflow and outflow of each tank, which prevent the food and faeces from escaping. Each tank was provided with uniform quantity (102.24 ± 0.44 mg) of marine sinking pellets (HIKARI MARINE MARINE-S-™, crude protein min 48%) and the conchs were allowed to feed within 24 h period. The food selection of the gastropod is caused by the qualitative composition of the food and its quantitative accessibility as well as by the dietary needs of the gastropods (Calow 1970; Van der Steen *et al.* 1973; Egonman 2007). After 24 h of feeding period, the seawater flow was stopped and the remaining uneaten pellets and faeces were collected and weighed. All weighing in this study were conducted to the nearest 0.1 mg using an analytical balance (A&D Company, Limited). The food consumption (FC) was calculated using the equation below (Britz, 1995):

$$FC\ (mg) = F - R$$

Where, FC = consumption (mg), F = initial food weight (mg) and R = weight of food remaining (mg) after feeding.

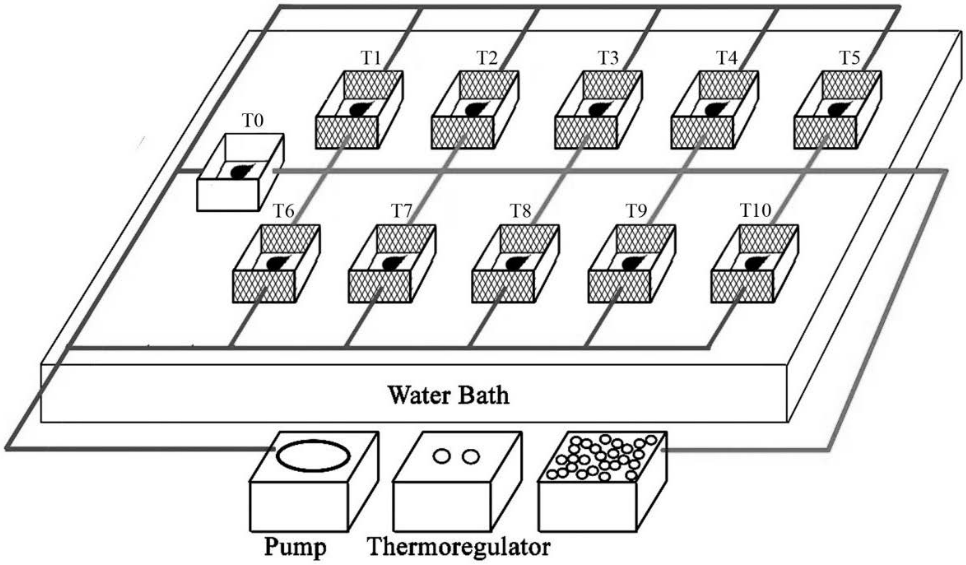

Figure 2: Experimental setup for juveniles *Laevistrombus canarium* food consumption study

The conch faeces were collected at every four hours up to the end of the experiment (the next 24 to 48h). The faecal pellets were collected using Pasteur pipettes and rinsed with filtered seawater (47 mm diameter, 0.45 µm, Whatman GF/F). The remaining salt adhered to the faeces were washed using distilled water (Smaal & Widdows, 1994), before drying in an oven to a constant weight at 60 °C for 24 h. The dried faeces were allowed to cool to room temperature in a desiccator and then re-weighed. Afterwards, they were ashed in a muffle furnace at 550 °C for 3 h, cooled to room temperaturein desiccators and finally re-weighed to estimate the organic content. Food absorption efficiency (AE) was determined by calculating the organic and inorganic (ash) content of the ingested food and faeces, following the method of Conover (1966) and Bayne and Newell (1983):

$$AE\ (\%) = (F-E)/[(1-E)F] \times 100$$

Where, F = ash-free dry weight: dry weight ratio of food (g), and E = ash-free dry weight: dry weight ratio of the feaces (g).

The energy content of the food was determined by using bomb calorimetry (PARR6100, Parr Instrument Co.). Each sample was pounded to a fine powder using pestle and mortar. The conversion factors was 1 g dry pellet weight = 16469.46 J. The food energy absorbed was measured following Widdows and Johson (1988) and Sobral and Widdows (1997).

$$EA\ (J\ h^{-1}) = FC \times AE \times E$$

Where, EA = food energy absorbed (J h^{-1}), FC = food consumption rate (g h^{-1}), AE = food absorption efficiency (%) and E = Energy content of food (J g^{-1}).

Data Analyses

Prior to any statistical analyses, data distributions were tested for normality and homogeneity of variances. Similarities in variance and covariance were tested using Bartlett's test for univariate. Differences in food consumption, food absorption efficiency and food energy absorb between the four temperature regimes were then further analyzed via the univariate method, i.e. one-way ANOVA, followed by an appropriate post-hoc analyses (Tukey test), at P=0.05 probability levels. Statistical analyses were conducted using MINITAB® 14.1 statistical software.

Results

There was a very significant effect of temperature regimes on food consumption in juveniles *L. canarium* (Figure 3, one-way ANOVA, $p<0.0001$, $F = 18.38$). Food consumption rate (FC) was highest at 26 °C followed by 30, 34 and 22 °C. The FC values of the conch cultured at 26 °C (3.54 ± 0.13 mg h^{-1}), 30 °C (3.45 ± 0.14 mg h^{-1}) and 34 °C (3.04 ± 0.26 mg h^{-1}) were significantly higher compared with 22°C (1.87 ± 0.15 mg h^{-1}).

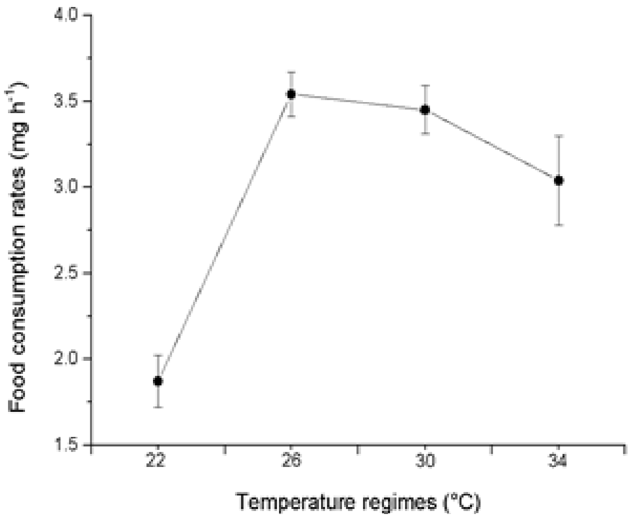

Figure 3: Food consumption rate (mg h^{-1}) of juveniles *Laevistrombus canarium* at different temperature regimes. Values are means ± SE (n=10).

The temperature regimes also showed highly significant effect on food absorption efficiency (AE) in the juveniles *L. canarium* (Figure 4, one-way ANOVA, $p<0.0001$, $F = 36.41$). The mean AE was highest at 26 °C followed by 30, 34 and 22 °C. The AE values of the conch cultured at 26 °C (73.76 ± 2.26 %) and 30 °C (73.28 ± 2.00 %) were significantly higher compared with 34 °C (52.40 ± 2.37%) and 22 °C (50.14 ± 1.87%).

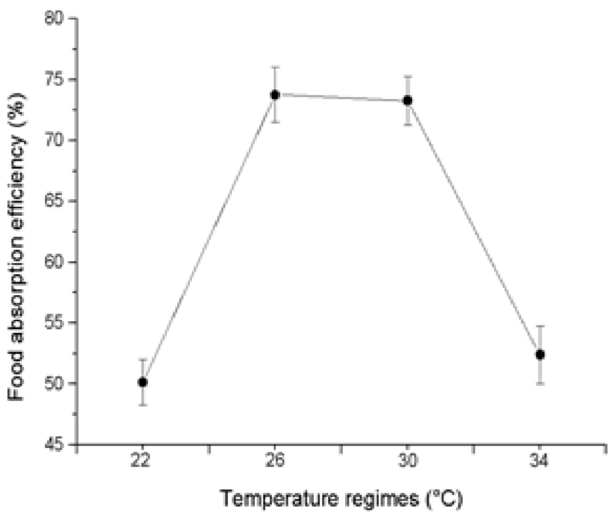

Figure 4: Food absorption efficiency (%) of juveniles *Laevistrombus canarium* at different temperature regimes. Values are means ± SE (n=10).

The food energy absorbed (EA) of juveniles *L. canarium* also varied significantly with different temperature regimes (Figure 5, one-way ANOVA, p<0.0001, F = 34.26). Highest EA was recorded at 26 °C, followed by 30, 34 and 22 °C. There was significant between treatments where EA at 26 and 30 °C were significantly higher compared with 22 and 34 °C (P<0.05). Apart from that the EA at 22 °C was significantly lower compared with 34 °C (P<0.05).

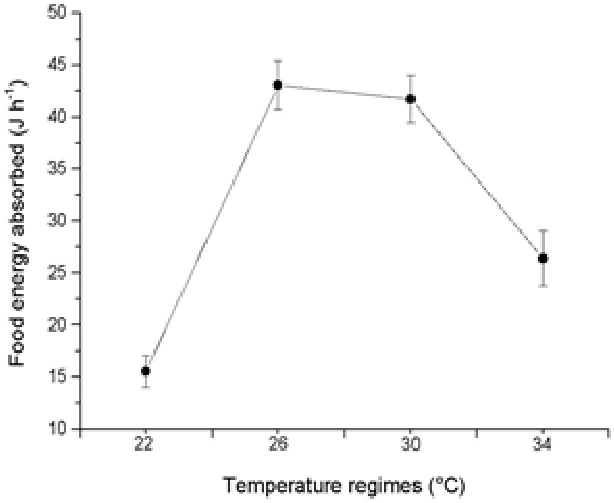

Figure 5: Food energy absorbed (J h^{-1}) of juveniles *Laevistrombus canarium* at different temperature regimes. Values are means ± SE (n=10).

Discussion

The present study has demonstrated a high food consumption and assimilation rates of juveniles *L. canariumat* 26 °C followed by 30, 34 and 22 °C. The *L. canarium* juveniles were slightly tolerant and readily acclimatized to the laboratory condition. Previous study by Kinne (1971) described that marine invertebrates have the capacity to modify their response to temperature through acclimatization thus increase their capacity to survive, reproduce or compete under new conditions. In the present study, the food consumption of juveniles at higher temperature regimes (26, 30 and 34 °C) was significantly higher than 22 °C (p<0.05). Staikou and Lazaridou-Dimitriadou (1989) described that increasing mean values of daily consumption and assimilation rate in juvenile snails may be due their high metabolic rate.

The variation of food absorption efficiency in juveniles *L. canarium* between 50.14 and 73.76% falls within the wide range of values reported for gastropods. Navarro *et al.* (2002) reported food absorption efficiency ranged between 47 and 83% in *C. giganteues,* while Peck *et al.* (1987) reported between 78 and 81% in *Haliotis tuberculata.* For carnivorous gastropods, higher values of absorption efficiencies have been reported such as between 82-98% for *Clioneli macina,* 81-97% and *Thais haemastoma* (Bayne & Newell, 1983), and 81-95% for *Concholepas concholepas* (Navarro & Torrijos, 1995). This could be related to the low concentration of ash in the marine sinking pellets used in the present study as compared with other types of food. In this study, the highest food absorption efficiency was recorded at 26°C, which may be related to the higher consumption rates and increased food residence time. This finding was in contrast with previous study by Navarro *et al.* (2002) who reported that temperature regimes have no effect on food absorption efficiency in *Chorus giganteus.*

The food energy absorbed by juveniles *L. canarium* increased with increasing temperature regimes. This finding could be related to the adaptation at higher temperature as the normal temperature ranged at field for this species is between 28 to 30 °C (Cob *et al.,* 2008). According to Sobral and Widdow (1997), temperature is one of the factors limiting marine animal's distribution, affecting their activity level and disturbing their energy balance. This present study found that food energy absorbed at 34°C was significantly higher than 22°C. This present finding is similarly with previous study by Bashevkin and Pechenik (2015) who demonstrated that the food energy absorbed by Crepidula fornicate was significantly depressed at low temperatures. In contrasts, Sobral and Widdow (1997) reported food energy absorbed by Ruditapes decussatus was lower at 32°C compared with 20°C. Navarro *et al.* (2002) also stated lower food energy absorption at higher temperature for *Chorus giganteus.*

According to Resgalla *et al.* (2007), a complete data of the effect of temperature on the physiological activities of mollusc is fundamental for the interpretation of production in natural environments. Dame (1996) stated that most aquatic organisms cannot regulate their body temperature in accordance with surrounding environment, thus most physiological and biochemical processes are temperature dependent. Navarro *et al.* (2006) showed that food consumption and assimilation rates are reliable tools for estimating the growth of juvenile gastropod molluscs without intervention from reproductive processes such as gametogenesis and spawning, which may produce corresponding increase and decrease in the biomass of individuals.

Conclusion

The optimum temperature regimes for food consumption and assimilation for juveniles L. canarium was between 26°C to 30°C. This study not only determined the optimal temperature regimes for the best culture practice of this marine edible sea snail, but more importantly allow us to evaluate their fate in an extreme temperature climate. However, more studies are still needed, particularly by adopting longer exposure times as well as higher temperature ranges, in order to better understand the effect of ocean climate change on the species.

Acknowledgements

This study was funded partly by research grant from the Ministry of Science, Technology and Innovation, Malaysia (MOSTI) through UKM fundamental research grant #FRGS/2/2014/STWN10/UKM/02/1 and Centre for Research and Innovation Management (CRIM) grant #AP-2012-013.

References

Abbott, R. T. (1960). The genus Strombus in the Indo-Pacific. *Indo-Pacific Mollusca.* 1(2):33-146.

Amini, S. (1986). Preliminary study on gonggong (*Strombus canarium*) in Bintan waters Riau. Jabatan Penelitian Perikanan Laut 36: 23-29 (in Indonesian with English abstract).

Arularasan,S., Lyla, P. S., Kesavan, K., & Khan, S. A. (2010). Recieps for the Mesogastropod-*Strombus canarium. Advance Journal of Food Science and Technology,* 2(1): 31-35.

Basheckin, S. M., & Pechenik J. A. (2015). The interactive influence of temperature and salinity on larval and juvenile growth in the gastropod *Crepidula fornicate* (L.). *Journal of Experimental Marine Biology and Ecology,* 490: 78-91.

Bayne, B. L., & Newel, R. C., (1983). Physiological energetics of marine mollusks In: Saleuddin ASM, Wilbur KM (eds) The Mollusca, Vol 4, Physiology, Part 1. Academic Press, New York, pp: 407-515.

Britz, P. (1995). The Nutritional Requirements of Haliotismidae and Development of a

Practical Diet for Abalone Aquaculture. PhD Thesis, Rhodes University, South Africa.

Bujang, J. S., Zakaria, M. H., Kanamoto, Z., & Mohd, P. A. (2001). Seagrass communities of the Straits of Malacca. In: Japar Sidik B, Arshad A, Tan S G, Daud S K, Jambari H A, Sugiyama S (Eds). Aquatic Resource and Environmental Studies of the Straits of Malacca: Current Research and Reviews. Universiti Putra Malaysia, Serdang. pp: 81-98.

Bujang, J. S., & Zakaria, M. H. (2003). The seagrasses of Malaysia. In: Green E P, Short F T eds. World Atlas of Seagrasses. California University Press, California. pp:152-160.

Bujang, J. S. (1994). Status of seagrass resources in Malaysia. In: Wilkinson C R, Sudara S, Chou L M eds. Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources, Volume 1. Australian Institute of Marine Science, Townsville, Australia. pp: 283-290.

Calow , P. (1974). Some observations on the locomotory strate- gies and their metabolic effects in two species of fresh- water gastropods, *Ancylus fluviatilis* (Mull.) and *Planorbis contortus* Linn. Oecologia, 16:149–161

CFMC. (1999). Queen conch stock assessment and management workshop. Caribbean Fishery Management Council (CFMC), National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Belize City. Charrier, M., & Daguzan J. (1980). Consommation Alimentai reproduction et bilanén ergétique chez Müller (Gastéropode pulmoné terrestre). *Ann Nutr Aliment,* 34: 147- 166.

Cob, Z. C., Arshad, A., Bujang, J. S., Amin, S. M. N., & Ghaffar, M. A. (2008). Growth, mortality, recruitment and yield-per recruit of *Strombus canarium* Linnaeus, 1758 (Megastropoda: Strombidae) from the west Johor straits, Malaysia. Research *Journal of Fisheries and Hydrobiology,* 3(2): 71-77.

Cob, Z. C., Arshad, A., Bujang, J. S., Ghaffar, M. A. (2009a). Age, growth, mortality and population structure of *Strombus canarium* (Gastropoda: Strombidae): variations in male and female sub populations. *Journal of Applied Sciences,* 9(18): 3287-3297.

Cob, Z. C., Arshad, A., Bujang, J. S., Ghaffar, M. A. (2009b). Seasonal variation in growth and survival of *Strombus canarium* (Linnaeus, 1758) larvae. Pakistan *Journal of Biological Sciences,* 12(9): 676-682.

Conover, R. J. (1966). Assimilation of organic matter by zooplankton. *Limnology and Oceanography,* 11: 338-354.

Dame, R. F. (1996). Ecology of Marine Bivalves an Ecosystem Approach. CRC Press, Boca Raton., pp: 19– 26.

Daoud, D., Chabot, D., Audet, C., & Lambert, Y. (2007). Temperature induced variation in oxygen consumption of juvenile and adult stages of the northern shrimp, *Pandalus borealis. Journal of Experimental Marine Biology and Ecology,* 347: 30-40.

Egonmwan, R. I. (2007). Food utilisation in a laboratory colony of the Giant African Land Snail (Swainson) (Pulmonata: Achatinidae). *Turkish Journal of Zoology,* 31: 265-270.

Erlambang, T., & Siregar Y. I. (1995). Ecological aspects and marketing of dog conch Strombus canarium Linné, 1758 at Bintan Island, Sumatra, Indonesia. *Special Publication Phuket Marine Biological Center.* 15: 129-131.

Doxa, C. K., Divanach, P., Maroudio, K. (2013). Consumption rates and digestibility of four food items by the marine gastropod Charonia seguenzae (Aradas& Benoit, 1870). *Journal of Experimental Marine Biology and Ecology,* 446: 10–16

Fry, F. E. J. (1971). The effect of environmental factors on the physiology of fish. Environmental Relations and Behavior. Hoar, S., Randall, D. (Eds.). Academic, New York., pp: 1–98.

IPCC. (2007): Climate Change 2007: Synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change [Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland. 104.

Jahangir, V. S., Novio, L. J. A., & Abtahi, B. (2011). The antagonistic effect of raised salinity on the aerobic performance of a rocky intertidal gastropod Nassarius deshayesianus (Issel, 1866) exposed to raised water temperature. *Journal of the Persion Gulf,* 2(6): 29–32.

Kinne, O. (1971). Salinity: Animals. Invertebrates. In: Kinne O (ed) Marine ecology Vol 1. Part 2. Wiley , London., pp; 821-996.

Latiolais, J. M., Taylor, M. S., Roy, K., & Hellberg, M. E. (2006). A molecular phylogenetic analysis of strombid gastropod morphological diversity. *Molecular Phylogenetics and Evolution,* 41(2): 436-444.

Mason, C. F. (1970). Food, feeding rates and assimilation in woodland snails. *Oecologia*, 4: 358-373.

Navarro, J. M., Leiva, G. E., Gallardo, C. S., & Varela C. (2002). Influence of diet and temperature on physiological energetics of Chorus giganteus (Gastropoda: Muricidae) during reproductive conditioning. *New Zealand Journal of Marine and Freshwater Research,* 36: 321-332.

Navarro, J. M., Urrutia, G. X., & Carrasco, C. (2006). Scope for growth versus actual growth in the juvenile predatory gastropod *Chorus giganteus. Journal of Marine Biological Association of the United Kindgom,* 8: 1423-1428.

Navarro, J. M., & Torrijos, R. A. (1995): Fisiologíaenergética de Concholepas concholepas (Bruguière, 1789) (Gastropoda: Muricidae) en la bahía de Yaldad, sur de Chile. *Revista Chilena de Historia Natural,* 68: 61-77.

Peck, L. S., Culley, M. B., & Helm, M. M. (1987). A laboratory energy budget for the ormer *Haliotis tuberculata. Journal of Experimental Marine Biology and Ecology,* 106: 103-123.

Poutiers, J. M. (1998). Gastropods. In: Carpenter K E, Niem V Heds. The Living Marine Resources of the Western Central Pacific. Food and Agriculture Organization of the United Nations (FAO), Rome., pp.363-646.

Resgalla, C. J., Brasil, E. D. S., & Salomão, L. C. (2007). The effect of temperature and salinity on the physiological rates of the mussel *Perna perna* (Linnaeus 1758). *Brazilian Archives of Biology and Technology,* 50 (3): 543-556.

Smaal, A. C., & Widdows, J. (1994). The scope for growth of bivalves as an integrated response parameter in biological monitoring. In: Kramer, K.L.M. (Ed.), Biomonitoring of Coastal Waters and Estuaries. CRC Press Inc., Boca Raton, pp. 247–268.

Sobral, P., & Widdows J. (1997). Influence of hypoxia and anoxia on the physiological responses of the clam *Ruditapes decussatus* from southern Portugal. *Marine Biology,* 127: 455–461.

Staikou, A., & Lazaridou-Dimitriadou, M. (1989). Feeding experiments on and energy flux in a natural population of the edible snail *Helix lucorum* L. (Gastropoda: Pulmonata: Stylommatophora) in Greece. *Malacologia*, 31: 217-227.

Van der Steen, W. J., Jager, J.C. and Tiemersma, D. (1973). The influence of food quality on feeding, reproduction and growth in the pond snail (L.) with some methodological comments. 76: 47-60.

Vernberg, F. J., & Piyatiratitivorakul, S. (1998). Effects of salinity and temperature on the bioenergetics of adult stages of the grass shrimp (*Palaemonetespugio holthuis*) from the North Inlet Estuary South Carolina. *Estuaries*, 21: 176–193.

Widdows, J., & Johnson, D. (1988). Physiological energetic of *Mytilus edulis*: Scope for growth. *Marine Ecology Progress Series* 46: 113-121.