NATURE IN SINGAPORE 2009 **2**: 421–429
Date of Publication: 19 November 2009

EFFECTS OF TRENCHING ON SHELL SIZE AND DENSITY OF *TURBO BRUNNEUS* (GASTROPODA: TURBINIDAE) AND *MONODONTA LABIO* (GASTROPODA: TROCHIDAE) AT LABRADOR BEACH, SINGAPORE

Cedric Kai Wei Tan
Department of Biological Sciences, National University of Singapore,
14 Science Drive, Singapore 117543, Republic of Singapore
Email: U0502369@nus.edu.sg

ABSTRACT

Gastropods are of particular interest on rocky shores because they are highly abundant and possess varied abilities to adapt to the harsh conditions of the rocky intertidal habitat. *Turbo brunneus* and *Monodonta labio* are two gastropods commonly found at Labrador Beach, Singapore. Here, the results of sampling of their shell sizes and shell densities are presented. ANOVA revealed significantly lower densities of *Turbo brunneus* and *Monodonta labio* at the site that underwent trenching compared to the other sites that did not undergo trenching ($P < 0.01$). This could be because of the change in substrate composition from the trenching event. The density of *Turbo brunneus* decreased from the high shore height to the low shore height (high: 2.0 ± 0.30 per m^2; middle: 1.08 ± 0.17 per m^2; low: 0.85 ± 0.13 per m^2) as well as with increased distance from the jetty (nearest jetty: 2.06 ± 0.28 per m^2, furthest from jetty: 0.5 8± 0.22 per m^2). Moreover, *Turbo brunneus* and *Monodonta labio* showed niche exclusion. High densities of *Turbo brunneus* were found together with low densities of *Monodonta labio* and vice versa. Larger *Turbo brunneus* were found at a section where trenching was conducted from 2006 till the end of 2007 (shell height: 3.51 ± 0.06 mm), as compared to other sections not directly affected by the trenching (MANOVA, d.f. = 1, 2, F = 5.00, P = 0.0022). Preliminary analyses of shell heights and widths revealed that shells of *Turbo brunneus* and *Monodonta labio* have isometric growth trends.

INTRODUCTION

Intertidal communities on rocky shores experience diurnal variations in air and seawater exposure and are therefore subjected to abiotic and biotic stresses. These environmental stresses vary along the vertical shorelines at which organisms on the lower shore heights are submerged in water for a longer duration than organisms higher up on the shore. Abiotic stresses owing to emersion, e.g., heat exposure and desiccation, create harsh conditions in the higher intertidal area and therefore are crucial in defining the upper distribution limit of intertidal organisms (Newell, 1970; Taylor, 1982; Raffaelli & Hawkins, 1996). Lower down the shore, abiotic conditions are more stable owing to longer immersion periods. Biological factors such as interspecific competition and predation determine the lower distribution limit of intertidal species. Different organisms with different adaptations for survival will thus reside at different shore heights, leading to the creation of a vertical zonation of the intertidal area (Purchon & Enoch, 1953; Vohta, 1971; Benson, 2002).

Gastropods are a major class of organisms that resides in the intertidal habitat (Esqueda et al., 2000). Because of their imposex capability and ability to accumulate toxins, gastropods are often used as bioindicators of the condition of the intertidal zone (Daka et al., 2006; Gomez-Ariza et al., 2006). Moreover, gastropods vary morphologically in relation to their surroundings. On the same rocky shore, individuals of the same species may have different morphologies as a result of different microhabitats (DeWolf et al., 1997; Britton, 1995). Gastropods also help curb macroalgae growth (Guerry, 2008; Thomas et al., 2008) and are an essential part of the diets of many molluscivorous intertidal animals (Creswell, 1990; Castell, 1997; Burkepile, 2007) Forming a significant proportion of intertidal organisms, being bioindicators, exhibiting morphological variation, and being part of the intertidal food chain are just some of the reasons why gastropods are of the more well-studied organisms in rocky intertidal habitats. These are also the exact reasons as to why it is crucial to understand how human interference affect their abundance and growth.

Singapore's Labrador Nature Reserve hosts many gastropods including *Turbo brunneus* and *Monodonta labio*. *Turbo brunneus* is known for its high abundance and its high market value for its foot and shell (Devaraj, 1996; Castell & Sweatman, 1997; Dorairaj & Soundararajan, 1998). *Monodonta labio* is a herbivorous gastropod found commonly in the Pacific region (Vermeij, 1971; Takada, 1995; Slack-Smith & Bryce, 2004). Both of these organisms graze on algae from the rocks (Takada, 1995; Ramesh, 2008) and therefore may compete with each other for the same niche, influencing the distribution of the two shells when they both occupy the same habitat.

In 2006, trenching was carried out on a section of Labrador Beach in order to install a service cable under the seabed (Chou, 2006). Sheet pilings were installed between the third and fourth quarters of 2006, parallel to the excavation path to restrict the damage done to the intertidal habitat. Trenching works lasted for a year, from the fourth quarter of 2006 to the fourth quarter of 2007 after which the trench was then filled. The sheet pilings, however, were not removed until the end of the first quarter of 2008. This study thus aimed to investigate the possibility that such a construction had affected the distribution and sizes of *Turbo brunneus* and *Monodonta lineata*.

There were two primary objectives in this study: (1) to sample the distributions of *Turbo brunneus* and *Monodonta labio* with respect to the area affected by trenching, and (2) to sample the size variation of the two shells with reference to the trenched area. Secondary objectives were: (1) to investigate how population densities of the gastropods vary with shore height, and (2) to examine the relationship between shell heights and shell widths for these two gastropods.

MATERIAL AND METHODS

Experimental design. – Labrador Beach (1°16.0′N, 103°48.0′E) is the only remaining rocky shore found on mainland Singapore (Fig. 1). The shore was vertically divided into three height zones, each 10 m wide, using transect tapes. The mean shore height of each was identified as: high (H) 1.0–1.9 m, middle (M) 0.3–1.0 m, low (L) 0.2–0.3 m. The shore was also horizontally divided into four 60 m long sectors, sections A–D with section A nearest the jetty (Fig. 2). Section C once hosted the service trench and one sheet piling. The other sheet piling was located at section D. Section D had only two sampling transects (High and Middle levels) due to the irregular curved-shape of the shoreline. This gave eleven 60 × 10 m (length × width) transects for sampling as shown in Fig. 2.

Sixteen quadrats (1 × 1 m) were used to sample each transect. The quadrats were placed based on a set of random numbers generated, then the number of *Turbo brunneus* and *Monodonta labio* in each quadrat was counted and recorded. For each quadrat, measurements of the height and width of all the shells were recorded (dial vernier calipers ± 0.01 mm). These two parameters were used as an indication of overall shell size.

Ten photographs of the substrate of each transect were taken and processed using Adobe Photoshop CS3 to scale and size images. The photos were then analyzed using Coral Point Count version 3.0 (CPCe) to determine the average substrate composition in each transect. Substrate types were defined according to Table 1.

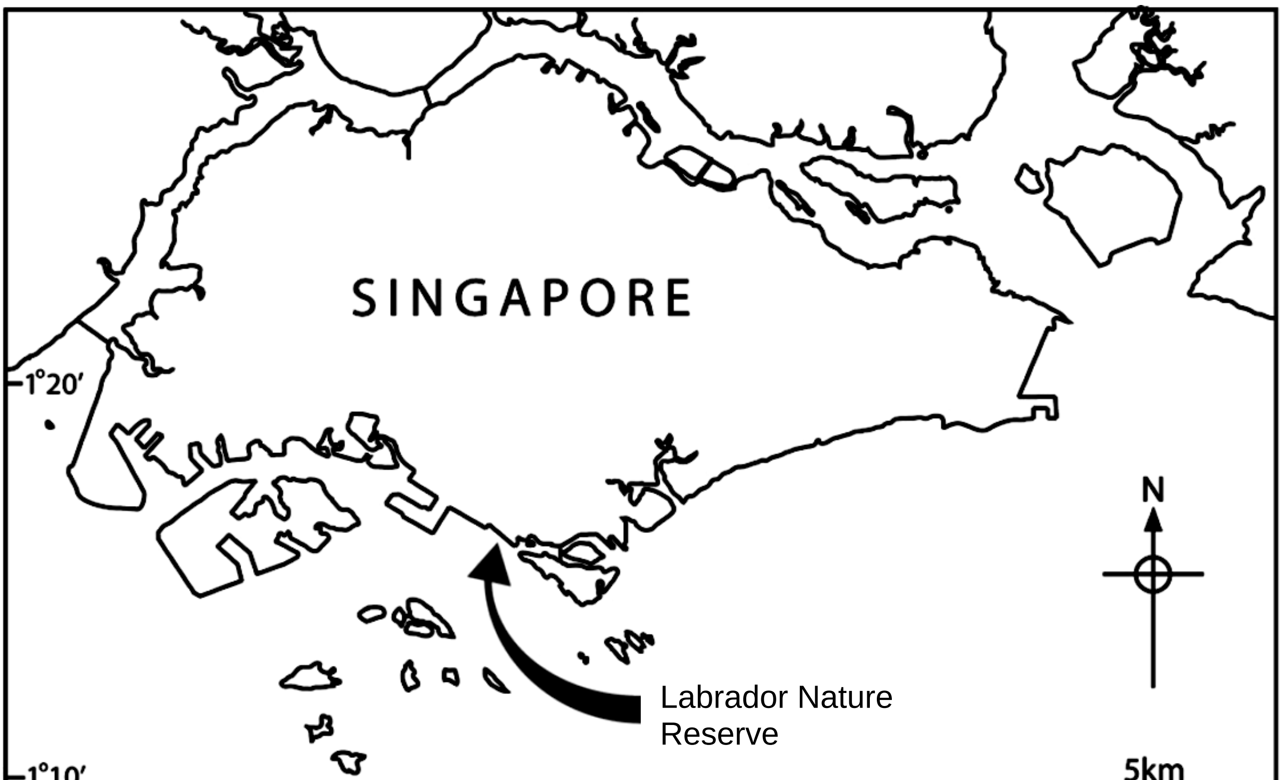


Fig. 1. Position of Labrador Nature Reserve in Singapore (Huang et al., 2006).

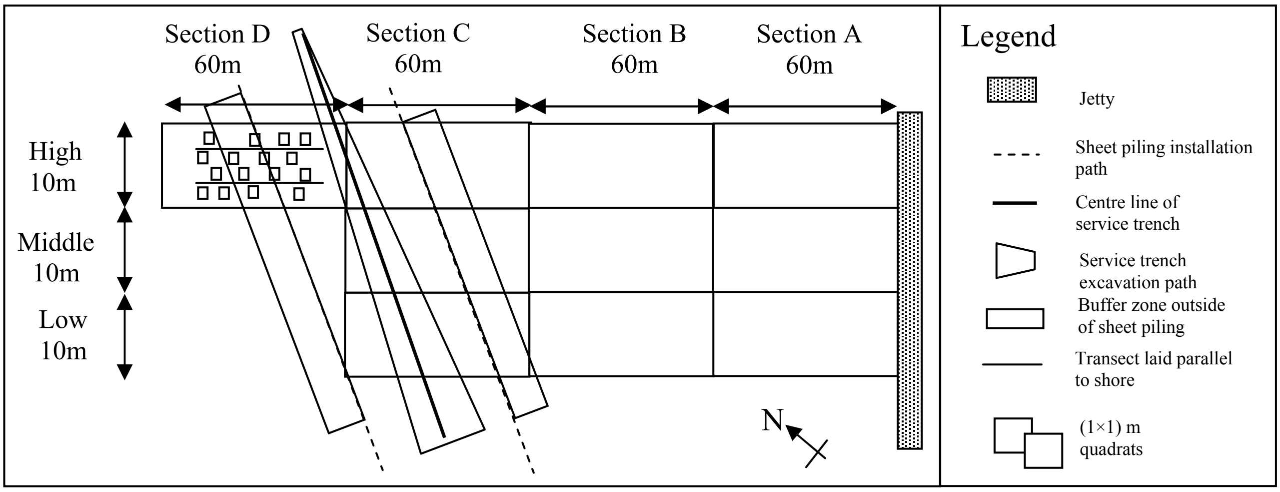


Fig. 2. Division of the shore into 11 transects for sampling. The transects measured 60 m long and 10 m wide. Section A started from the side of the jetty. Sixteen quadrats were laid in each transect for sampling of the gastropods.

Representatives of both species collected were identified and preserved in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore. They were *Monodonta labio* (ZRC.MOL.2880) and *Turbo brunneus* (ZRC.MOL.2881).

Statistical analysis. – two-way analysis of variance (ANOVA) and post-hoc Student-Newman-Keuls (SNK) tests were performed to determine whether shell density differs with shore height or with distance from the jetty. A multivariate analysis of variance (MANOVA) and post-hoc Student-Newman-Keuls (SNK) tests were performed for each of shell species, to determine the relationship between shell heights and widths with shore height and/or horizontal sectors. All data fulfilled the assumptions of normality and homogeneity of variances. All statistical analyses were performed using GMAV 5 (Institute of Marine Ecology, Sydney, Australia) and STATISTICA 5.0 (Stat-Soft).

For each shell, a scatter plot of shell height versus shell width was constructed with Microsoft Excel version 11.3.5 to determine how these two parameters are related. The best-fitted regression line was constructed with the R^2 value calculated. R^2 value is the proportion of the variance of y that can be explained by x (Bernard, 2006).

RESULTS

A total of 232 *Turbo brunneus* and 87 *Monodonta labio* were observed in all 176 quadrats. The interaction effects between shore height and horizontal sectors on the measured parameters could not be analysed as sampling transects were unbalanced (i.e., Section D had only two out of three transects sampled owing to an irregular shoreline).

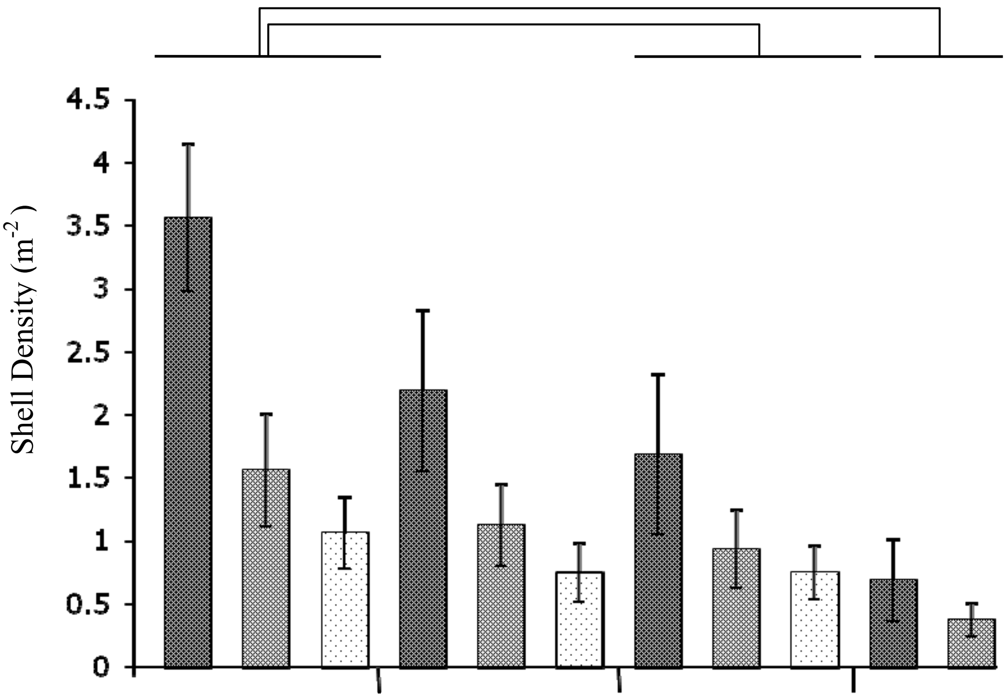
Densities of gastropods. – there were highly significant differences in the mean densities of *Turbo brunneus* among the horizontal sectors (ANOVA, d.f. = 3, F = 5.01, P = 0.0024) and the shore height (ANOVA, d.f. = 2, F = 8.78, P = 0.0002). Post-hoc SNK tests for the three shore heights (i.e. high, middle and low) indicated the occurrence of higher densities of *Turbo brunneus* at the high shore height as compared to the middle and low shore height. Also, section A had significantly higher densities of these shells than section C and D (Fig. 3a).

Densities of *Monodonta labio* were significantly different among the four horizontal sectors (ANOVA, d.f. = 3, F = 4.25, P = 0.0063) but not the shore heights (ANOVA, d.f. = 2, F = 2.44, P = 0.09). Post-hoc SNK tests for horizontal sectors revealed higher densities of *Monodonta labio* at section D compared to the other sections (Fig. 3b).

Table 1. Categories and definition of substrate types encountered.

Substrate	Definition
Silt	Fine grains (< 0.625mm)
Sand	Small grains (0.625–2.000 mm)
Pebbles	Small pieces of non-carbonate rock (2–64 mm)
Rock	Large angular sharp pieces of non-carbonate rock (> 64mm)
Rubble	Any broken pieces of dead coral skeleton, more irregularly shaped than rocks
Seagrass	Any seagrass species
Macroalgae	Any macroalgae species

(a) *Turbo brunneus*



(b) Monodonta labio

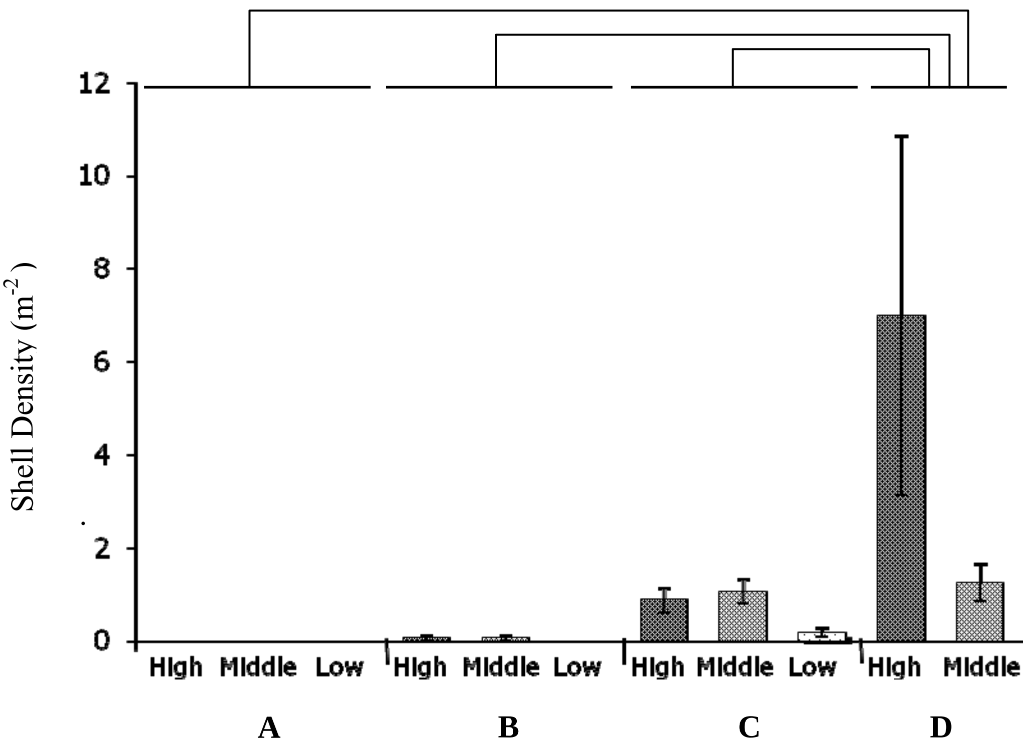
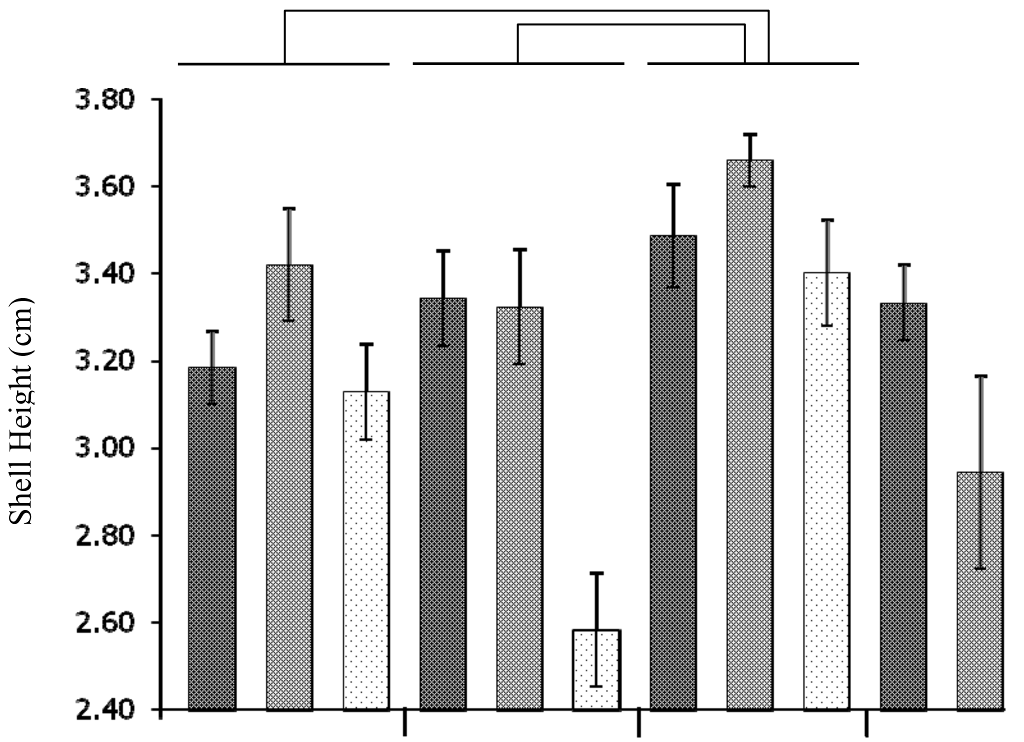


Fig. 3. Effect of shore heights and horizontal sections on the densities of (a) *Turbo brunneus* and (b) *Monodonta labio*. Error bars denote standard errors. Parameters that are significantly different (SNK tests; $P<0.05$) are linked by horizontal lines.

(a) *Turbo brunneus*



(b) Monodonta labio

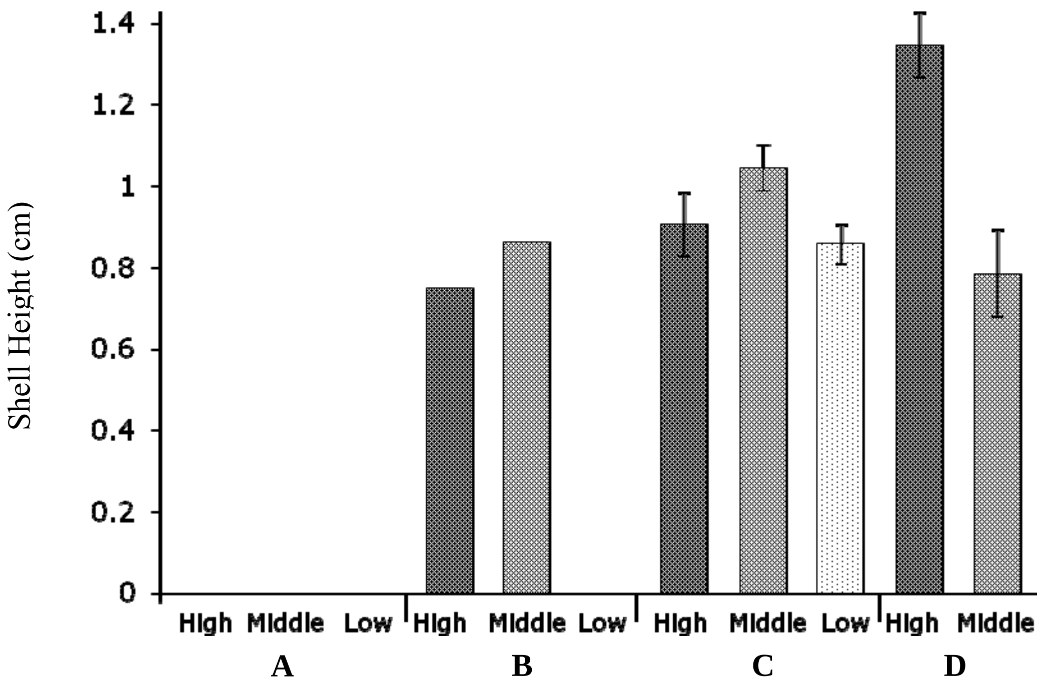


Fig. 4. Effect of shore heights and horizontal sections on the sizes of (a) *Turbo brunneus*, and (b) *Monodonta labio*. Error bars denote standard errors. Two barcharts of *Monodonta labio* do not have standard errors as they measurements of only one shell. Parameters that are significantly different (SNK tests; $P<0.05$) are linked by horizontal lines.

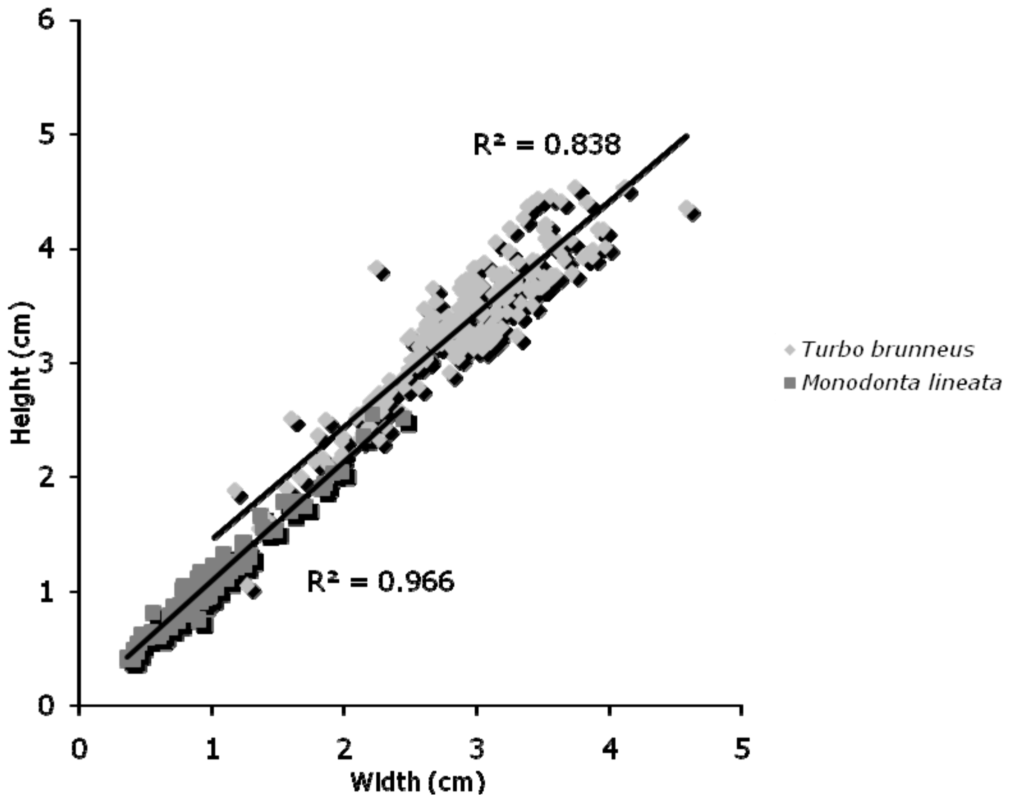


Fig. 5. Scatterplot of shell height versus shell width for *Turbo brunneus* and *Monodonta labio.* The best fit trend line was drawn and R^2 value of the line was calculated.

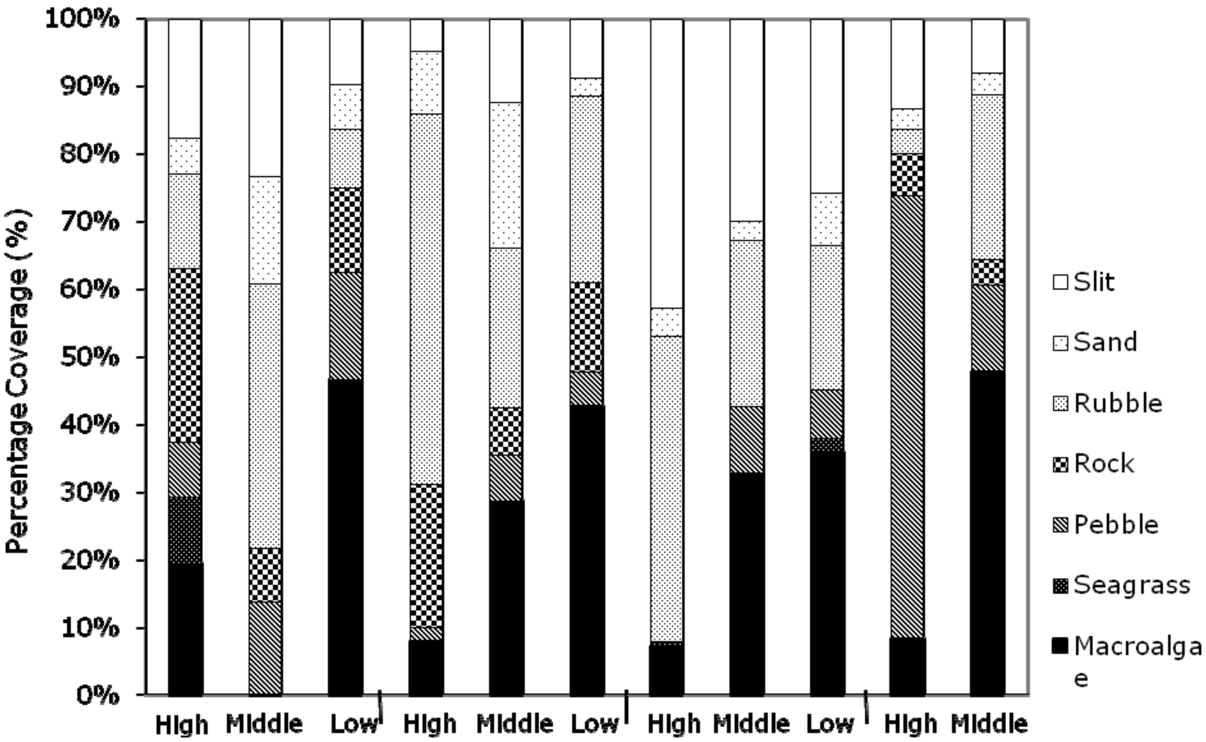


Fig. 6. Substrate composition of each of the eleven transects.

Shell sizes of gastropods. – as shown in Fig. 5, the shell heights of both *Turbo brunneus* and *Monodonta labio* were linearly related to their shell widths (R^2 = 0.838 and R^2 = 0.966, respectively). Moreover, MANOVA tests revealed similar results for shell heights and shell width, indicating that either one of these parameters can sufficiently represent the shell size. Therefore, only the MANOVA results on shell heights are presented here.

For *Turbo brunneus* shell height, MANOVA indicated significant differences for the main effects of shore height and horizontal sectors (MANOVA, d.f. = 1, 2, F = 6.74, P = 0.0014; MANOVA, d.f. = 1, 2, F = 5.00, P = 0.0022, respectively). Shell heights for *Turbo brunneus* were significantly smaller at the low shore height than at middle and high shore height. At section C, shell heights were larger than that at sections A and B (Fig. 4a).

Shell heights of *Monodonta labio* did not differ significantly among the shore heights or horizontal sectors (MANOVA, d.f. = 1, 2, F = 0.19, P = 0.82; MANOVA, d.f. = 1, 2, F = 0.84, P = 0.43, respectively).

DISCUSSION

Variations in gastropods' densities. – the substrate at section C could explain the relatively low densities of the two gastropods. Rock was not present at section C (Fig. 6) and this absence was owed to the trenching which dug through the substrate in order to lay down a power cable (Ng et al., unpublished data). In a rocky area, crevices formed by spaces between adjacent rocks and within rocks increase the surface area for grazing and act as hiding places for the gastropods (McGuinness & Underwood, 1986; Denadai & Amarai, 1999). Therefore, with few rocks at section C, the substrate was probably less attractive to both shells and their densities would be low. This inference is, however, based on a cross-sectional survey. In order to accurately determine the effects of the trenching event, one would have to conduct the survey on gastropods before and after the trenching event. Still, a significantly lower density of both shells ($P < 0.001$) at section C relative to the other sections, is a good indication that the density of shells have been affected by the trenching project.

Individuals of *Turbo brunneus* and *Monodonta labio* were found sympatrically, even though when one species is higher in density, the other would be lower in density. This is probably owed to their similar diets. *Turbo brunneus* feed on algae (Ramesh, 2008) while *Monodonta labio* feed on decaying organic matter derived mostly from algae (Takada, 1995). These gastropods were also observed to be foraging during the samplings. As such, competition for food could be a possible explanation for the population segregation as seen at Labrador Beach. Another factor attributed to this segregation could be the differential exposure to wave action at the different horizontal sectors. Earlier studies showed that larger *Littorina* species were found at the more exposed shores (DeWolf, 1997; Eschweiler et al., 2008). Owing to the irregular shoreline at Labrador beach, Section D hosts a bay and therefore is less exposed to wave energy. The smaller-sized *Monodonta labio* (shell height 1.12 ± 0.46 mm) were found at section D as they may be more protected in a sheltered shore. On the other hand, a larger number of *Turbo brunneus* (shell height 3.29 ± 0.60 mm) are found at sections A–C as they were larger and have higher tolerance to exposed shores.

Segregation of the populations of *Turbo brunneus* and *Monodonta labio* can thus be attributed to substrate differences, competition for food, and adaptability to shores with differential exposure to waves. However, all these factors are suggested reasons for their distribution, and thus warrant further studies.

A higher density of *Turbo brunneus* observed at the higher shore height compared to middle and low shore heights at Labrador Beach is typical of gastropod distribution patterns. Biological factors as such predation determine the lower limit of these gastropods (Newell, 1970; Raffaelli & Hawkins, 1996). Hence, they are found in higher concentration on the higher littoral zone (i.e., higher shore height). Huang et al. (2006) showed that visitor pressure decreased from section A to D and this might explain the decreasing *Turbo brunneus* density in the same direction. This trend is consistent with previous studies that show that human impacts enhance the abundances of certain gastropods (Keough et al., 1993; Addessi, 1994; Keough & Quinn, 1998).

Variations in sizes. – it is interesting to note that shell sizes of *Turbo brunneus* in section C (shell height: 3.51 ± 0.06 mm) are significantly different from those in sections A and B (shell height: 3.19 ± 0.08 and 3.20 ± 0.08 mm, respectively). *Turbo brunneus* individuals in section C were located nearest the trenching site and thus faced certain environmental conditions that cause them to grow larger. As discussed above, the poor rock composition in section C could be the reason for the lack of sites for refuge and thus increased exposure to wave shock. Therefore, a larger shell size would confer higher adaptability to the greater wave action exposure (DeWolf, 1997; Ríos-Jara, 2004; Eschweiler et al., 2008).

Shell sizes found at the low shore height of section B were significantly smaller than all other zones. Studies done on a related shell, *Turbo sarmaticus* showed that the types of diet can affect shell growth and hence shell size (Foster, 1999). Hence, a possible explanation could be the deficiency of specific algal species for the shell size growth observed in section B. However, a survey of the different types of macroalgae was not performed in this study and hence the incidence of smaller sized *Turbo brunneus* shells cannot be quantified.

Correlation of growth with shell height and width. – from the scatterplot of shell height versus shell width, a strong correlation exists between the shell height and width for *Turbo brunneus* and *Monodonta labio*. This suggests that both gastropods have an isometric growth whereby an increase in shell height corresponds to a proportional increase in shell width. This result for the two particular gastropods has not been recorded in other studies but the same trend occurs in other shells such as *Monodonta dama* (Ismail, 2006). The ratio of shell height to shell width decreases with an increase in shell size. This may indicate that these two *gastropods* become less elongate with age. For a detailed understanding of their growth patterns, a time-based study that follows the growth of the shells can be conducted. The results from this one-time sampling would serve as preliminary information of the *gastropods*' growth pattern.

CONCLUSIONS

In summary, the trenching project resulted in the low densities of *Monodonta labio* and *Turbo brunneus* occurring in the affected area. The density patterns of *Monodonta labio* and *Turbo brunneus* at Labrador Beach could be owed to competition with each other or their varied abilities to adapt to different environments. Sizes of *Turbo brunneus* differ possibly with the degree of exposure to wave energy. There was no significant difference in the sizes of *Monodonta labio* with the differing shore height and horizontal sectors. The linear relationship between shell height and shell width suggests an isometric growth pattern of the two *gastropods*.

ACKNOWLEDGEMENTS

For their assistance in the field, I thank Mohamad Faizal, Nick Yeo, William Lee, Boo Hongrui, and Jimmy Chan. For their help in statistical analysis and editing of drafts, I thank Peter Todd, Neo Mei Lin, and Justin Loh. Last but not least, my thanks go to Ng Shu Zhen, Sew Wei Xin, and Su Wai Tara for their invaluable insights into this project. This research was conducted under the National Parks Research Permit No: NP/RP861 A.

LITERATURE CITED

Addessi, L., 1994. Human disturbance and long-term changes on a rocky intertidal community. *Ecological Application*, **4**(4): 786–797.

Benson, K. R., 2002. The study of vertical zonation on rocky intertidal shores — a historical perspective. *Integrative and Comparative Biology*, **42**(4): 776–779.

Bernard, R., 2006. Regression and correlation methods. In: Bernard, R. (ed.), *Fundamentals of Biostatistics.* Duxbury, Belmont. 478 pp.

Britton, J. C., 1995. The relationship between position on shore and shell ornamentation in 2-size dependent morphotypes of *Littorina striat*, with an estimate of evaporative water-loss in these morphotypes and in *Melarhaphe neritoides*. *Hydrobiologia*, **309**(1–3): 129–142.

Burkepile, D. E. & M. E. Hay, 2007. Predator release of the gastropod *Cyphoma gibbosum* increases predation on gorgonian corals. *Oecologia*, **154**(1): 167–173.

Castell, L. L. & H. P. A. Sweatman, 1997. Predator-prey interactions among some intertidal gastropods on the Great Barrier Reef. *Journal of Zoology*, **241**(1): 145–159.

Chou, L. M., 2006. *Biodiversity Impact Assessment of the Coastal Area at Labrador Nature Reserve*. Report submitted to Maritime and Port Authority of Singapore . 69 pp.

Creswell, P. D., 1990. Handling times, prey size and species selection by *Cancer novaezelandiae* (Jacquinot, 1853) feeding on molluscan prey. *Journal of Experimental Marine Biology and Ecology*, **140**(1–2): 13–28.

Daka, E. R., I. Ifidi & S. A. Braide, 2006. Accumulation of heavy metals from single and mixed metal solutions by the gastropod mollusc *Tympanotonus fuscatus linnaeus* from a Niger Delta estuary: Implications for biomonitoring. *African Journal of Biotechnology*, **5**(20): 1954–1962.

Denadai, M. R. & A. C. Z. Amarai, 1999. A comparative study of intertidal molluscan communities in sandy beaches. Sao Sebastiao Channel, Sao Paulo State, Brazil. *Bulletin of Marine Science*, **65**(1): 91–103.

Devaraj, M., 1996. Sea-farming and conservation of molluscan resources of India. In: Gangwar, B, K. Chandra & K. Andaman (eds.). *Island Ecosystem and Sustainable Development*. Annamalai University, Chidambaram, India. Pp. 71–78.

DeWolf, H., T. Backeljau, R. Medeiros & R. Verhagen, 1997. Microgeographical shell variation in *Littorina striata*, a planktonic developing periwinkle. *Marine Biology*, **129**(2): 331–342.

Dorairaj, K. & R. Soundararajan, 1998. Status of molluscan resources of the Andaman Islands. In: Gangwar, B., K. Chandra & K. Andaman (eds.). *Island Ecosystem and Sustainable Development*. Science Association, Port Blair, India. Pp. 106–115.

Eschweiler, N., M. Molis, C. Buschbaum, 2008. Habitat-specific size structure variations in periwinkle populations (*Littorina littorea*) caused by biotic factors. *Helgoland Marine Research*. Pp. 1–9.

Esqueda, M. C., E. Rios-Jara, J. E. Michel-Morfin & V. Landa-Jaime, 2000. The vertical distribution and abundance of gastropods and bivalves from rocky beaches of Cuastecomate Bay, Jalisco. México. *Revista de Biologia Tropical*, **48**(4): 765–775.

Foster, G. G., A. N. Hodgson & M. Balarin, 1999. Effect of diet on growth rate and reproductive fitness of *Turbo sarmaticus* (Mollusca : Vetigastropoda : Turbinidae). *Marine Biology*, **134**(2): 307–315.

Gomez-Ariza, J. L., M. M. Santos, E. Morales, I. Giraldez, D. Sanchez-Rodas, N. Vieira, J. F. Kemp, J. P. Boon & C. C. Ten-Hallers-Tjabbes, 2006. Organotin contamination in the Atlantic Ocean off the Iberian Peninsula in relation to shipping. *Chemosphere*, **64**(7): 1100–1108.

Guerry, A. D., 2008. Interactive effects of grazing and enrichment on diversity; Conceptual implications of a rocky intertidal experiment. *Oikos*, **117**(8): 1185–1196.

Huang, D., L. M. Chou, P. A. Todd, K. H. Ang, P. Y. Boon, L. Cheng & H. Ling, 2006. Effects of shore height and visitor presurre on the diversity and distribution of four intertidal taxa at Labrador beach, Singapore. *Raffles Bulletin of Zoology*, **54**(2): 477–484.

Ismail, N. S. & A. Z. Elkarmi, 2006. Age, growth and shell morphometrics of the gastropod *Monodonta dama* (Neritidae:Prosobranchia) from the Gulf of Aqaba, Red Sea. *Pakistan Journal of Biological Sciences*, **9**(5): 843–847.

Keough, M. J. & G. P. Quinn, 1998. Effects of periodic disturbances from trampling on rocky intertidal algal beds. *Ecological Application*, **8**(1): 141–161.

Keough, M. J., G. P. Quinn & A. King, 1993. Correlations between human collecting and intertidal mollusk population on rocky shores. *Conservation Biology*, **7**(2): 378–390.

Krumbein, W. C. & L. L. Sloss, 1951. *Stratigraphy and Sedimentation*. W. H. Freeman & Co., San Francisco.

Lim, S. S. L., P. K. L. Ng, L. W. H. Tan & Y. C. Wee, 1994. *Rhythm of the sea: the life and Times of Labrador Beach*. Nanyang Technological University & National University of Singapore, Singapore. 160 pp.

McGuinness, K. A. & A. J. Underwood, 1986. Habitat structures and the nature of communities on intertidal boulders. *Journal of Experimental Marine Biology & Ecology*, **104**(1–3): 97–123

Newell, R. C., 1970. *Biology of Intertidal Animals*. American Elsevier Publishing Company Inc., New York. 555 pp.

Ng, K. L. Peter, S. Lim, L. K. Wang & L. Tan, 2007. *Private Lives: An Exposé of Singapore's Shores*. Raffles Museum of Biodiversity Research, Singapore. 141 pp.

Ng, S. Z., W. X. Sew & W. T. Su, unpublished. Effects of Trenching on Labrador Intertidal Habitat. SP2172 report.

Purchon R. D. & I. Enoch, 1953. Zonation of the marine fauna and flora on a rocky shore near Singapore. *Bulletin of Raffles Museum*, **25**: 46–65.

Raffaelli, D. & S. J. Hawkins, 1996. *Intertidal Ecology*. Chapman and Hall, London. 356 pp.

Ramesh, R. & S. Ravichandran, 2008. Feeding Biology with Reference to Algal Preferance and Scanning Electron Microscopy Studies on the Radula of *Turbo brunneus*. *Trends in Applied Sciences Research*, **3**(2): 189–195.

Ramírez, R., F. Tuya, P. Sánchez-Jerez, C. Fernández-Gil, O. Bergasa, R. J. Haroun & J. J. Hernández-Brito, 2005. Population structure and spatial distribution of the gastropod molluscs *Osilinus atrata* and *Osilinus sauciatus* in the rocky intertidal zone of the Canary Islands (Central East Atlantic). *Ciencias Marinas*, **31**(4): 697–706.

Ríos-Jara, E., C. C. Hernandez Cedillo, E. J. Carrillo & I. E. Padilla, 2004. Variations in density, shell-size and growth with shore height and wave exposure of the rocky intertidal snail, *Calyptraea spirata* (Forbes, 1852), in the tropical Mexican Pacific. *Journal of Shellfish Research*, **23**(2): 545–552.

Ronald, V. T. & D. Frances, 1998. *Elements of Marine Biology*. Butterworth-Heinemann, United Kingdom. 277 pp.

Slack-Smith, S. M. & C. W. Bryce, 2004. A survey of the benthic molluscs of Dampier Archipelago, *Western Australia Records of the Western Australian Museum*, **66** (Supplement): 221–245.

Takada, Y., 1995. Variations of growth rate with tidal level in the gastropod *Monodonta labio* on a boulder shore. *Marine Biology Progress Series*, **117**(1): 103–110.

Tan, L. W. H. & P. K. L. Ng, 2001. *A Guide to Seashore Life*. Singapore Science Centre, Singapore. 159 pp.

Taylor, P. R., 1982. Environmental resistance and the ecology of coexisting hermit crabs: thermal tolerance. *Journal of Experimental Marine Biology and Ecology*, **57**: 229–236.

Thomas W., W. Melissa & A. V. Mathew, 2008. Population structure of turbinid gastropods on wave-exposed subtidal reefs: effects of density, body size and algae on grazing behaviour. *Marine Ecology Progress Series*, **362**: 169–179.

Todd, P. A. & L. M . Chua, 2005. A tale of survival: Labrador Park, Singapore. *Coral Reefs*, **24**(3): 391.

Vermeij G. J., 1971. Temperature relationships of some tropical Pacific intertidal gastropods. *Marine Biology*, **10**(4): 308–314.

Vohra, F. C., 1971. Zonation on a tropical sandy shore. *The Journal of Animal Ecology*, **40**(3): 679–708.

Winer, B. J., 1971. *Statistical Principles in Experimental Design*. McGraw-Hill. Tokyo. 907 pp.