Malayan Nature Journal 2006, **59(1)**, *93 – 102*

Algal and Invertebrate Diversity of the Intertidal Zone at Labrador Nature Reserve, Singapore

D. HUANG[1], L.M. CHOU[1], P.A. TODD[1], K.H. ANG[1], P.Y. BOON[1] and L. CHENG[1]

Abstract: The intertidal zone at Labrador Nature Reserve is mainland Singapore's only remaining rocky shore. The last ecological study of this beach, a qualitative survey focused mainly on molluscs and cirrepeds, was conducted almost 40 years ago. With much of Singapore's shoreline threatened by coastal development, documenting the biodiversity of this unique beach has become increasingly important. We sampled four key marine taxa, i.e. macroalgae, Anthozoa, Crustacea and Mollusca in relation to four intertidal zones, approximately spanning high to low spring tide marks. In total, 28 genera of macroalgae, 14 genera of anthozoans, at least 25 genera of crustaceans and 27 genera of molluscs were recorded. Results are compared to previous findings and discussed in the context of coastal development and industrial activities within the vicinity of the beach.

Keywords: Intertidal, tropics, rocky shore, diversity, Labrador Nature Reserve, Singapore.

INTRODUCTION

Rocky shores have received considerable attention, primarily due to their high incidence along coastlines and accessibility (Roughgarden et al. 1988; Farrell et al. 1991). To date, most studies had focused on temperate regions, with the few studies of tropical shores having been conducted some distance away from the equator (e.g. Sutherland 1990; Coates 1995). Comparisons of rocky shores between the tropics and higher latitudes have revealed key ecological differences. In contrast to temperate rocky intertidal communities, Menge and Lubchenco (1981) sampled much lower abundances of noncrustose algae and sessile animals, with indistinguishable vertical zonation patterns, and Lubchenco et al. (1984) found that seasonal and annual variations in community structure are minute at a tropical shore in Panama. Singapore, situated at the southern tip of Peninsula Malaysia ~1° north of the equator, represents an excellent opportunity to examine rocky shores at extremely low latitudes.

Previous studies of Singapore's rocky shores were mostly qualitative and limited in scope (Purchon and Enoch 1954; Chuang 1961; Ewing-Chow 1966; Lee 1966; Chuang 1973). One site, only comprehensively surveyed ~40 years ago (Ewing-

[1] Department of Biological Sciences, National University of Singapore, Kent Ridge, Singapore 117543, Republic of Singapore.

Chow 1966), is Labrador Nature Reserve's intertidal zone — the last remaining natural rocky shore on mainland Singapore (Nirmala 1989; Lim et al. 1994; Todd and Chou 2005). Despite being the first attempt at describing the beach's entire intertidal diversity, Ewing-Chow (1966) focused on molluscs and cirripeds, with only general notes made on macroalgae and corals. Two other rocky shore sites that had previously been studied, i.e. Tanjong Gul and Tanjong Teritip (Ewing-Chow 1966; Lee 1966), have both been lost to land reclamation (Nirmala 1989; Chou 1996). As Singapore continues to develop, more of its natural shoreline comes under threat (Hilton and Manning 1995; Todd and Chou 2005), hence the importance of documenting the biodiversity of what remains. Such information will facilitate the development of viable management strategies for the local natural heritage that still exists.

The intertidal zone at Labrador Nature Reserve (1° 16.0' N, 103° 48.0' E) is a 300m-long (i.e. parallel to the coast) rock and coral rubble shore with a fringing coral reef (Lim et al. 1994) situated at the western edge of the park (Fig 1). The beach was probably more than twice this size before the eastern half was reclaimed prior to 1959 (Chia 1992). A large area to the west (Pasir Panjang) was reclaimed between 1972 and 1981 but, anecdotally, this stretch did not have the same rocky shore characteristics. The Labrador intertidal has experienced several other major developments, for example, Pasir Panjang Power Station, built at the western margin of the beach's current boundaries, became operational in 1952 (Ang 1992). The power station was decommissioned in the 1990s but its concrete foundations still remain. To the east, a British Petroleum (BP) oil tanker jetty, likely built at a similar

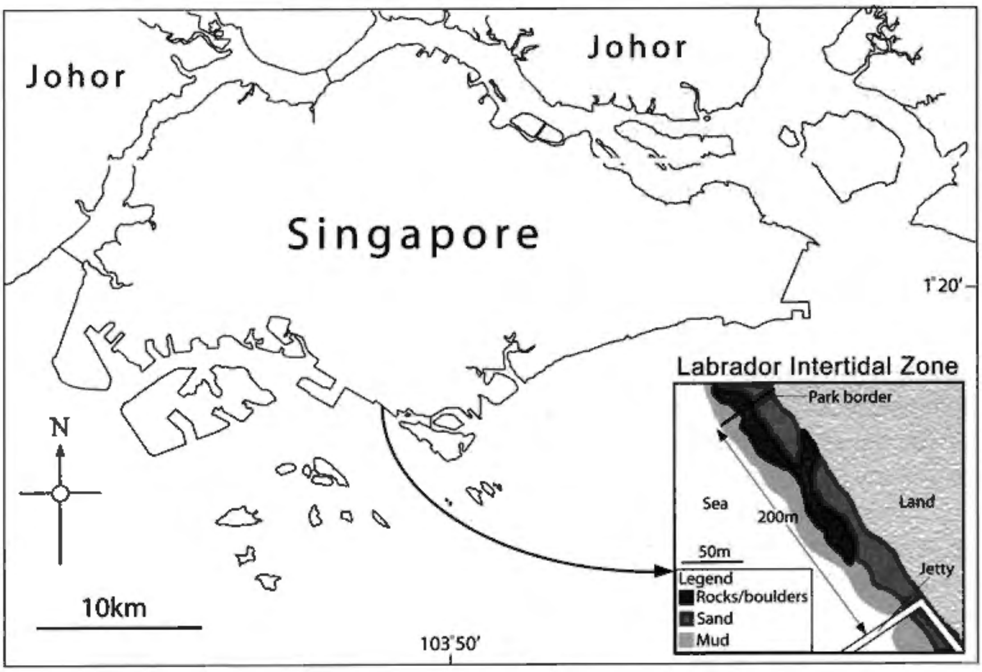

Figure 1. Map of Singapore showing the intertidal zone at Labrador Nature Reserve, the study site.

time (1954) to the BP refinery that it supplied, was shut down in 1995 (Lim 1997). Despite the impacts these projects have had (Ewing-Chow 1966; Todd and Chou 2005; Huang et al. in press), the beach at Labrador Park has been acknowledged for its high diversity (Lim et al. 1994; Tan and Ng 2001). It has also captured the attention of several volunteer conservation groups that have been regularly patrolling the beach with park rangers to halt illegal collection of marine organisms from the reserve (Basu 2005; Teo 2005).

This study aims to provide a semi-quantitative description of the diversity of macroalgae, anthozoans, crustaceans and molluscs at the Labrador shore. These taxa were selected based on their ecological importance in the intertidal environment. Macroalgae, as a major primary producer, forms much of the basis for intertidal food webs (Littler et al. 1989; Trono 1997), while crustaceans and molluscs play important roles in structuring rocky shore assemblages (Gladstone 2002; Schreider et al. 2003) and often exhibit complex relationships with algal populations and anthozoans (Tsuchiya and Yonaha 1992; Stachowicz and Hay 1996). Anthozoans are of particular concern as visitor pressure has been shown to adversely affect their diversity (Liddle and Kay 1987, Huang et al. in press). Here we provide information on the abundance and spatial variability of the four taxa within a low to high shore gradient.

MATERIALS AND METHODS

Data were collected using a stratified random sampling design (Chalmers and Parker 1989) between December 2004 and March 2005. A 200m-long section of the shore (i.e. parallel to the coast) was divided into four zones parallel to the shoreline, approximately spanning high to low spring tide marks. Each zone was 10m wide and separated from the adjacent zone by a 1m buffer area that was not sampled. The cross-staff method (Hawkins and Jones 1992) was used to determine the heights of each of the zones based on published tide tables (Maritime and Port Authority of Singapore 2003, 2004), i.e. High (H) 1.0–1.9m, Middle (M) 0.3–1.0m, Low (L) 0.2–0.3m and Very low (VL) 0.1–0.2m.

We conducted pilot studies to generate cumulative species curves (Hawkins and Jones 1992), and found that 30 quadrats per zone, each 1.0m × 1.0m, were needed to capture a representative proportion of the macroalgae population, while 60, 21 and 30 quadrats, each 0.5m × 0.5m, were required for the anthozoan, crustacean and mollusc populations respectively. The very low shore zone was only sampled for anthozoan diversity. Random number tables were used to generate coordinates where quadrats were to be placed, which were then positioned using fiberglass tape measures.

The abundance of macroalgae and colonial anthozoans within each quadrat was quantified as percentage cover (C) while that of solitary anthozoan polyps, crustaceans and molluscs was quantified as number of individuals (N). Abundance data were then divided into six levels using a categorization scale (Crisp and Southward 1958), i.e. abundant ($C \geq 20\%$; $N \geq 50$), common ($5\% \leq C < 20\%$; $10 \leq N < 50$), frequent ($1\% \leq C < 5\%$; $1 \leq N < 10$), occasional ($0.1\% \leq C < 1.0\%$; $0.1 \leq N < 1.0$), rare ($C < 0.1\%$; $N < 0.1$) and absent.

RESULTS AND DISCUSSION

In total, 28 genera of macroalgae, 14 genera of anthozoans (including 11 genera of hard corals), at least 25 genera of crustaceans and 27 genera of molluscs were observed within the respective quadrats. The relative abundances of sampled taxa and their vertical distribution are listed in Tables 1(a) to 1(d).

This study expanded the list of species found at Labrador shore by Ewing-Chow (1966). Besides the macroalgae, anthozoans and crustaceans not sampled previously, we recorded 15 additional genera of gastropods (*Cellana*, *Petalloida*, *Diadora*, *Angaria*, *Batillaria*, *Truncatella*, *Strombus*, *Lambis*, *Thais*, *Columbellida*, *Mitra*, *Vexillium*, *Bulla*, *Alysia* and *Siphonaria*), while seven genera noted by Ewing-Chow (1966) were not found (*Planaxis*, *Pyrene*, *Tectarius*, *Ligia*, *Acmaea*, *Conus* and *Melongena*).

The high shore zone was dominated by the green algae *Bryopsis* sp., banded bead anemone *Epiactis* sp., barnacles, amphipods and the false limpet *Siphonaria* sp. These are organisms generally considered well adapted to the hot and dry upper shore environment with fluctuating temperature and salinity (Chuang 1973; Tan and Ng 2001). *Bryopsis* sp. appeared to exhibit temporal variation during the four-month sampling period. Mass blooms recorded in December 2004 gave way to a

Table 1(a). Abundance of anthozoans in four shore zones.

Taxon	High shore	Middle shore	Low shore	Very low shore
Epiactis	3	3	0	0
Phymanthus	0	0	0	1
Zoanthus	0	3	3	2
Montipora	0	0	0	1
Turbinaria	0	0	0	1
Favia	0	0	0	1
Favites	0	1	1	1
Goniastrea	0	0	2	0
Leptastrea	0	0	0	2
Oulastrea crispata	0	0	1	1
Platygyra	0	0	0	2
Galaxea	0	0	0	1
Goniopora	0	0	2	2
Porites	0	0	1	1

Key:
5 = Abundant
4 = Common
3 = Frequent
2 = Occasional
1 = Rare
0 = Absent

Table 1(b). Abundance of macroalgae in three shore zones.

Taxon	High shore	Middle shore	Low shore
Brachytrichia	3	2	0
Avrainvillea	0	1	2
Acetabularia	1	2	2
Bryopsis	4	5	4
Borgesenia forbesii	0	2	2
Chlorodesmis	0	2	2
Chaetomorpha	2	2	1
Caulerpa lentillifera	1	0	3
Caulerpa surrulata	0	1	2
Caulerpa racemosa	0	0	2
Caulerpa sertularioides	0	2	2
Caulerpa taxifolia	1	2	2
Caulerpa verticillata	0	0	1
Enteromorpha	2	2	2
Halimeda	2	2	3
Neomeris vanbosseae	0	1	2
Microdictyon	0	2	2
Udotea	0	1	2
Ulva	2	2	3
Valonia	0	2	0
Acanthophora	1	2	2
Amphiroa	0	0	2
Bostrychia	2	1	0
Gracilaria	3	4	4
Halymenia	0	2	0
Hypnea	0	0	2
Laurencia	1	3	2
Colpomenia	0	1	1
Dictyopteris	0	0	1
Dictyota	0	2	2
Padina	0	2	2
Sargassum	3	3	1
Stypopodium	0	2	2

Key:

5 = Abundant
4 = Common
3 = Frequent
2 = Occasional
1 = Rare
0 = Absent

Table 1(c). Abundance of crustaceans in three shore zones. Taxa observed at the beach, but not recorded within quadrats, were *Tetraclita, Thalamita, Acteaodes, Neodorippe callida, Ocypode ceratophthalama, Cryptodromia pileifera,* and Order Stomatopoda.

Taxon	High shore	Middle shore	Low shore
Leptodius	3	3	3
Pilodius	2	3	3
Atergatis	0	2	0
Baruna	0	2	2
Actumnus	0	2	2
Pilumnus	0	2	3
Metopograpsus	2	2	0
Nanosesarma	2	0	2
Ilyoplax	0	0	2
Macrophthalamus	2	3	2
Halicarcinus	0	3	2
Paratymolus	0	2	0
Portunus	0	2	0
Diogenes	2	4	4
Petrolisthes	0	3	2
Porcellana	0	0	2
Alpheus	0	3	3
Synalpheus	0	2	2
Periclimenes	0	0	3
Nikoides	0	0	2
Balanus	5	0	0
Chthamalus	3	0	0
Order Amphipoda	4	4	3
Order Isopoda	2	3	3
Order Tanaida	3	3	4

Key:

5 = Abundant
4 = Common
3 = Frequent
2 = Occasional
1 = Rare
0 = Absent

Table 1(d). Abundance of molluscs in three shore zones.

Taxon	High shore	Middle shore	Low shore
Cellana	2	2	2
Patelloida	2	0	0
Diodora	0	2	2
Turbo	2	3	3
Trochus	0	3	2
Angaria	2	2	2
Monodonta	0	3	0
Euchelus	2	3	3
Nerita	2	3	3
Cerithium	3	3	4
Batillaria	2	0	2
Littoraria	2	0	2
Truncatella	2	2	0
Strombus	2	0	0
Lambis	0	2	0
Cypraea	0	2	2
Morula	2	3	3
Thais	2	2	2
Columbellida	3	3	3
Mitra	0	2	2
Vexillium	2	4	2
Bulla	0	2	0
Aplysia	2	3	0
Onchidium	2	2	0
Siphonaria	5	0	0
Family Ostreidae	0	3	2
Family Chitonidae	0	2	2

Key:

5 = Abundant
4 = Common
3 = Frequent
2 = Occasional
1 = Rare
0 = Absent

marked fall in abundance during February and March 2005, suggesting that reproduction and recruitment of *Bryopsis* sp. varies seasonally (Underwood 1981). However, as this hypothesis was not specifically tested, and such temporal patterns have rarely been examined in tropical intertidal algae, the phenomenon warrants further investigation.

The middle and low shore zones were occupied by most of the other organisms observed, corresponding with the findings of Ewing-Chow (1966). The upper range of hard corals was higher (middle shore zone) than in Ewing-Chow (1966), who only found them in the lower zones and described no overlap between corals and gastropods. Coral richness was highest in the very low zone at the edge of the fringing reef.

The two industrial facilities that were operational at Labrador in the 1960s caused sedimentation and localised thermal elevation, resulting in a reduction of hard coral species richness from ~30 to eight (*Favia speciosa*, *Favites spectabilis*, *Goniastrea pectinata*, *Goniopora lobata*, *Oulastrea crispata*, *Platygyra daedalea*, *Porites lutea* and *Trachyphyllia geoffroyi*) in 1968 (Chuang 1973). Since then, the oil facility and power station have ceased to operate (both in the 1990s), and we determined that the number of hard corals has increased to at least 11. Four genera (*Turbinaria*, *Montipora*, *Leptastrea* and *Galaxea*) not listed in Chuang (1973) were identified, whereas *Trachyphyllia geoffroyi*, present on the earlier list, were not found.

The temporal taxonomic variation at the Labrador intertidal during the past 40 years is probably associated with the industrial activity and coastal projects within the vicinity of the beach (Ewing-Chow 1966; Chuang 1973; Todd and Chou 2005). It has been recommended that conservation of important habitats and species diversity be promoted as a national goal in Singapore, even when confronted with pressing development needs (Chia 1992). The rocky shore at Labrador escaped reclamation plans in 1990 (Nathan 1993) and is now protected under Labrador Park's Nature Reserve status. The findings of this research provide a solid baseline for future studies of Labrador beach and will contribute to management strategies for this unique portion of Singapore's coastline.

ACKNOWLEDGEMENTS

We thank the following from the National University of Singapore (NUS) for assisting in taxonomic identification: Jani Thuaibah Isa Tanzil, Dionne Teo, Dr. Tan Swee Hee, A/P Peter Ng Kee Lin, Dr. Tan Koh Siang and Reuben Clements Gopalasamy. Additional thanks to the members of the Marine Biology Laboratory, NUS, for their support. This research was conducted under the National Parks Research Permit No: NP/RP456 M.

REFERENCES

Ang, L. 1992. PUB to build S$4bn power station in Tuas. *Business Times* (24 August 1992), Singapore.

Basu, R. 2005. Sea warriors with a passion to preserve. *The Straits Times* (31 January 2005), Singapore.

Chalmers, N. and P. Parker. 1989. *The OU Project Guide*. Shropshire: Field Studies Council.

Chia, L.S. 1992. *Singapore's Urban Coastal Area: Strategies for Management*. Manila: International Center for Living Aquatic Resources Management Technical Report No. 31.
Chou, L.M. 1996. Response of Singapore reefs to land reclamation. *Galaxea* 13: 85–92.
Chuang, S.H. 1961. *On Malayan Shores*. Singapore: Muwu Shosa.
Chuang, S.H. 1973. Life of the seashore. In *Animal Life and Nature in Singapore*, ed. S.H. Chuang, 150–174. Singapore: Singapore University Press.
Coates, M. 1995. Macroinvertebrate species assemblages of rocky intertidal habitats within Keppel Bay, Queensland. *Proceedings of the Royal Society of Queensland* 105: 43–54.
Crisp, D.J. and A.J. Southward. 1958. The distribution of intertidal organisms along the coasts of the English Channel. *Journal of the Marine Biology Association of the U.K.* 37: 157–208.
Ewing-Chow, J.M. 1966. A study of the littoral fauna on rocky shores at Labrador and Tanjong Gul – Singapore, with a note on universal zonation. Honours thesis (unpublished). Singapore: National University of Singapore.
Farrell, T.M., D. Bracher and J. Roughgarden. 1991. Cross-shelf transport cause recruitment to intertidal populations in central California. *Limnology and Oceanography* 36: 279–288.
Gladstone, W. 2002. The potential value of indicator groups in the selection of marine reserves. *Biological Conservation* 104: 211–220.
Hawkins, S.J. and H.D. Jones. 1992. *Marine Field Course Guide 1: Rocky Shores*. London: Immel Publishing Ltd.
Hilton, J.H. and S.S. Manning. 1995. Conversion of coastal habitats in Singapore: indications of unsustainable development. *Environmental Conservation* 22: 307–322.
Huang, D., P.A. Todd, L.M. Chou, K.H. Ang, P.Y. Boon, L. Cheng, H. Ling and W.-J. Lee. In press. Effects of shore height and visitor pressure on the diversity and distribution of four intertidal taxa at Labrador beach, Singapore. *Raffles Bulletin of Zoology*.
Lee, S.K. 1966. The natural history of the shore flora and fauna off Tanjong Teritip, Singapore. *Malayan Nature Journal* 19: 259–274.
Liddle, M.J. and A.M. Kay. 1987. Resistance, survival and recovery of trampled corals on the Great Barrier Reef. *Biological Conservation* 42: 1–18.
Lim, R. 1997. Sale of BP's Pasir Panjang refinery may have hit snag. *The Straits Times* (14 July 1997), Singapore.
Lim, S.S.L., P.K.L. Ng, L.W.H. Tan and Y.C. Wee. 1994. *Rhythm of the Sea: the Life and Times of Labrador Beach*. Singapore: Nanyang Technological University and National University of Singapore.
Littler, D.S., M.M. Littler, K.E. Bucher and J.N. Norris. 1989. *Marine plants of the Caribbean*. Washington, D.C.: Smithsonian Institution Press.
Lubchenco, J., B.A. Menge, S.D. Garrity, P.J. Lubchenco, L.R. Ashkenas, S.D. Gaines, R. Emlet, L. Lucas and S. Strauss. 1984. Structure, persistence, and role of consumers in a tropical rocky intertidal community (Taboguilla Island, Bay of Panama). *Journal of Experimental Marine Biology and Ecology* 78: 23–73.
Maritime and Port Authority. 2003, 2004. *Year 2004/2005 Singapore Tide Tables*. Singapore: Hydrographic Department, Maritime and Port Authority.
Menge, B.A. and J. Lubchenco. 1981. Community organization in temperate and tropical rocky intertidal habitats: prey refuges in relation to consumer pressure gradient. *Ecological Monographs* 51: 429–450.
Nathan, D. 1993. PSA plans 'will not harm Labrador Park'. *The Straits Times* (14 October 1993), Singapore.
Nirmala, M. 1989. When conservationists do not see people for the trees. *The Straits Times* (26 November 1989), Singapore.
Purchon, R.D. and I. Enoch. 1954. Zonation of the marine fauna and flora on a rocky shore near Singapore. *The Bulletin of the Raffles Museum* 25: 47–65.
Roughgarden, J., S.D. Gaines and H. Possingham. 1988. Recruitment dynamics in complex life cycles. *Science* 241: 1460–1466.
Schreider, M.J., T.M. Glasby and A.J. Underwood. 2003. Effects of height on the shore and complexity of habitat on abundances of amphipods on rocky shores in New South Wales, Australia. *Journal of Experimental Marine Biology and Ecology* 293: 57–71.

Stachowicz, J.J. and M.E. Hay. 1996. Facultative mutualism between an herbivorous crab and a coralline alga: advantages of eating noxious seaweeds. *Oecologia* 105: 377–387.

Sutherland, J.P. 1990. Recruitment regulates demographic variation in a tropical intertidal barnacle. *Ecology* 71: 955–972.

Tan, L.W.H. and P.K.L. Ng. 2001. *A Guide to Seashore Life*. Singapore: Singapore Science Centre.

Teo, J. 2005. Volunteers patrol park to stop illegal coral collectors. *The Straits Times* (26 January 2005), Singapore.

Todd, P.A. and L.M. Chou. 2005. A tale of survival: Labrador Park, Singapore. *Coral Reefs* 24: 391.

Trono, G.C. 1997. *Field Guide and Atlas of the Seaweed Resources of The Philippines*. Makati City: Bookmark, Inc.

Tsuchiya, M. and C. Yonaha. 1992. Community organization of associates of the scleractinian coral *Pocillopora damicornis*: effects of colony size and interactions among the obligate symbionts. *Galaxea* 11: 29–56.