

## THE INTERTIDAL MOLLUSCS OF PULAU SEMAKAU: PRELIMINARY RESULTS OF “PROJECT SEMAKAU”

S. K. Tan and R. K. H. Yeo

*Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore,  
Block S6, Science Drive 2, #03-01, Singapore 117546, Republic of Singapore*

*Email: [dbstsk@nus.edu.sg](mailto:dbstsk@nus.edu.sg), [ronyeo@nus.edu.sg](mailto:ronyeo@nus.edu.sg)*

### ABSTRACT

“Project Semakau” is a community involvement and conservation project led by the Raffles Museum of Biodiversity Research (RMBR). One of the main objectives of this project is to document the biodiversity of Pulau Semakau, Singapore. A total of 258 species of molluscs were recorded through extensive surveys in the mangrove and intertidal areas. The results presented here provide an insight to the intertidal malacofauna diversity of the island, and establishes a baseline for future studies.

### INTRODUCTION

Pulau Semakau (or Semakau Island) lies about 10 km south of Singapore Island. The island is an offshore landfill (also known as Semakau Landfill) created by enclosing the sea between two islands, Pulau Sakeng, and Pulau Semakau. Construction work for the development of the Semakau Landfill began in 1995 and during the construction of the infrastructure, much care was taken in the design to minimise the environmental impact on the surroundings. More than 400,000 new mangrove plants were also planted to replace those lost to the landfill area (see also Chou et al., 2004; Tan et al., 2010). The measures to protect and restore the natural ecosystems are very successful and today, Semakau Landfill is a model for environmental protection and conservation (Chou & Tun, 2007; Ng, 2009). It was opened to the public in 2005.

“Project Semakau” is a community involvement and conservation project led by the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore (NUS), and sponsored by the Hongkong and Shanghai Banking Corporation Limited (HSBC). Most of the participants are volunteers — employees of the HSBC, undergraduates from the NUS, and the Nanyang Technological University (NTU), students from various secondary schools, and members of the public. The project aims to realise and enhance the island’s value as a nature education and conservation site. One of the main objectives is to obtain data on the island’s biodiversity via comprehensive surveys. It has been nearly two years since the launch of “Project Semakau” on 14 Nov.2008. The preliminary results of the intertidal mollusc diversity thus far recorded are presented.

### MATERIAL AND METHODS

The “Project Semakau” mollusc surveys covered much of the original coastline of the island. Efforts of the volunteers were concentrated mainly on the western and northwestern side of Pulau Semakau, southwards from Tanjong Romos, and eastwards to the rock bund adjacent to the NEA office (see Fig. 1). Additional random sampling was undertaken farther south at the rock bund and muddy sand areas exposed at low tide of the ‘Phase 2’ lagoon. Surveys were generally arranged to coincide with low tides. Habitats surveyed include seagrass meadows, muddy or sandy flats, fringing coral reefs, and the reef flat. Towards the landward side, the mangrove areas were also surveyed, but to a lesser extent, and mangrove samplings were largely restricted to the fringes, and along the streams in the mangrove forest.

Molluscs encountered in the field were provisionally identified, if possible, and photographed and/or collected for verification. Habitat and location data were documented. Voucher specimens were collected for the majority of species recorded. Exceptions are indicated with an asterisk (\*; see Tables 1–4), these being represented and identified with only photographs. Living animals were not observed for some shelled mollusc species throughout the surveys, and these records of ‘dead’ shells (empty or inhabited by hermit crabs) are denoted with dagger symbols. Freshly ‘dead’ specimens that are likely to be found living are indicated by a single dagger (†) whilst the badly weathered or specimens in a sub-fossilised state are indicated with double daggers (††). All specimens obtained were cleaned of excess mud, algae, and other encrustations, and preserved dry or wet. Wet specimens were either preserved directly in 75% ethanol or fixed in 10% formalin solution for one to two weeks before transferring to 75% ethanol for permanent storage.

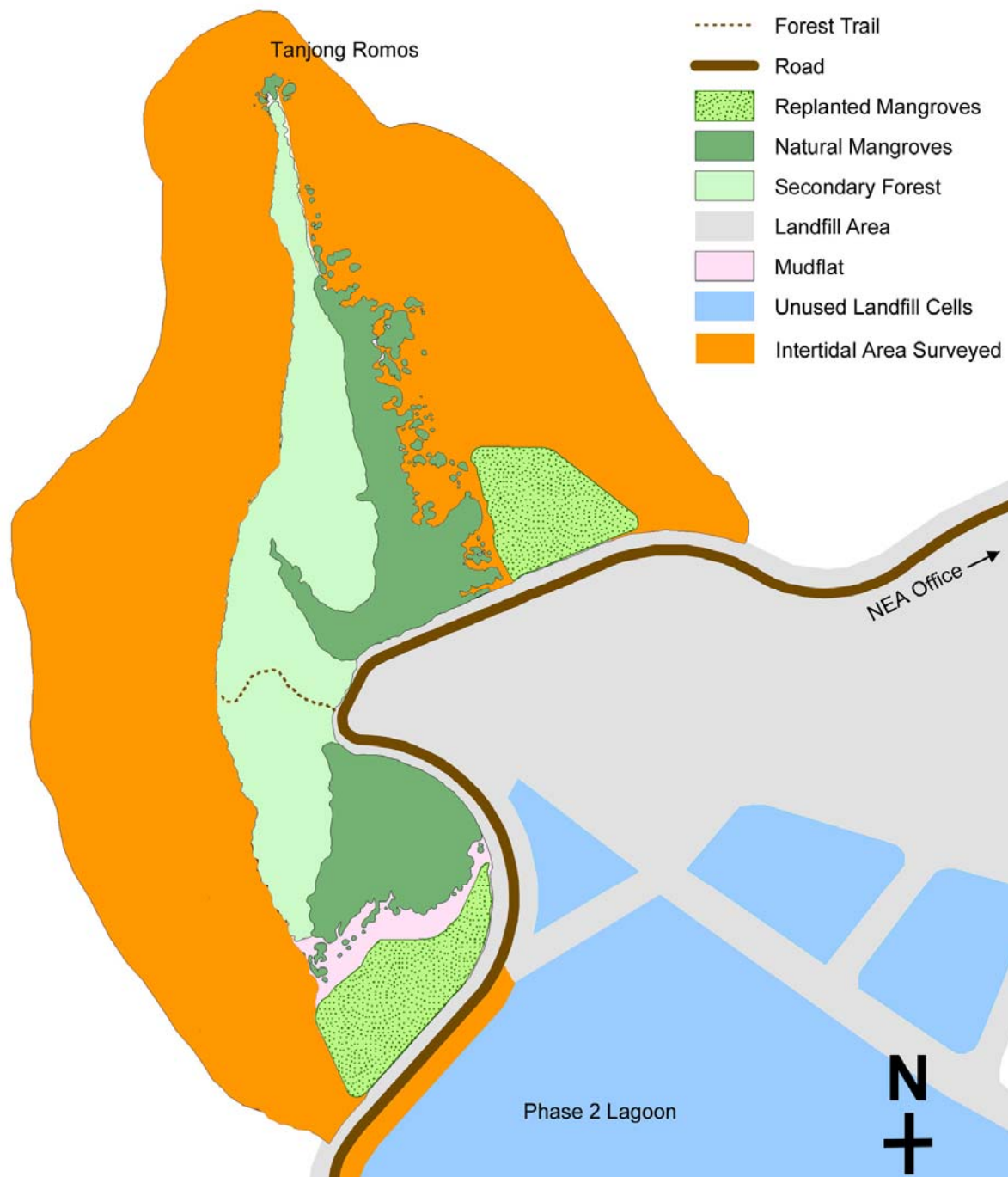


Fig. 1. Sectional map of Pulau Semakau showing the areas covered by the “Project Semakau” surveys.

Identifications were mainly based on the references listed: Brandt (1974), Nielsen (1976), Tantanasiwong (1978), Abbott & Dance (1982), Cernohorsky (1984), Houbrick (1985, 1992), Reid (1986, 2007), Lamprell & Whitehead (1992), Wilson (1993, 1994), Houart (1996), Lamprell & Healy (1998), Poutiers (1998a, 1998b), Kabat (2000), Tan & Chou (2000), Swennen et al. (2001), Raven (2002), Vongpanich & Matsukuma (2004), Dharma (2005), Lützen & Nielsen (2005), Taylor & Glover (2005), Debelius & Kuitert (2007), García & Oliver (2008), Gosliner et al. (2008), Sartori et al. (2008), Simone & Wilkinson (2008), Tan & Clements (2008), Valentich-Scott & Tongkerd (2008), Chan (2009), Jensen (2009), Lam & Morton (2009), ter Poorten (2009), Wong (2009), and Dayrat (2010). Several species included in the tables have not been positively identified, and unidentifiable species were omitted. Taxa that were identified to genera, but not to species, are shown with “species” behind the generic name. Quotation marks indicate uncertain generic placements. Tentative identifications are indicated by a “cf.” (confer, or compare in Latin) before the species name. The “Project Semakau” voucher collection will be lodged in the Zoological Reference Collection (ZRC) of the RMBR at the conclusion of the project.

## RESULTS

A total of 258 mollusc species consisting of one polyplacophora species, 97 bivalvia species (30 families), 155 gastropoda (48 families), and five cephalopoda (five families) have been recorded by the “Project Semakau” surveys thus far (see Tables 1–4). The intertidal habitats of Pulau Semakau surveyed are loosely defined as MG = mangroves, including part of the rock bund area (with distinctly mangrove attributes) that face the mangrove forest directly; CR = coral rubble areas on the reef flat, and the fringing coral reefs; SG = seagrass meadows; RB = man-made rock bund/seawall, and walls around the pier; MS = muddy sand areas of the reef and the sandy intertidal flats. A plus symbol (+) indicates the respective habitat(s) where the species was collected or observed. Relative abundance of the individual species is not shown because species diversity was the main aim of the study.

Table 1. Polyplacophora recorded by “Project Semakau” surveys.

Family	Species	MG	CR	SG	RB	MS
Ischnochitonidae	“ <i>Lepidozona</i> ” species		+	+		

Table 2. Bivalvia recorded by “Project Semakau” surveys.

Family	Species	MG	CR	SG	RB	MS
Arcidae	<i>Acar plicata</i> (Dillwyn, 1817)		+			
	<i>Anadara antiquata</i> (Linnaeus, 1758)	+	+	+		
	<i>Arca avellana</i> Lamarck, 1819		+			
	<i>Barbatia fusca</i> (Bruguière, 1789)		+		+	
	<i>Barbatia plicata</i> (Dillwyn, 1817)		+			
	<i>Barbatia</i> species		+			
Cardiidae	<i>Corculum cardissa</i> (Linnaeus, 1758)		+			+
	<i>Fragum</i> species		+			
	<i>Fragum unedo</i> (Linnaeus, 1758)		+			+
	<i>Fulvia papyracea</i> (Bruguière, 1789)†					+
	<i>Vasticardium flavum</i> (Linnaeus, 1758)	+	+	+		+
	<i>Vasticardium pectiniforme</i> (Born, 1780)		+	+		
Carditidae	<i>Cardita variegata</i> (Bruguière, 1792)†		+			
Chamidae	<i>Chama asperella</i> Lamarck, 1819		+			
	<i>Chama brassica</i> Reeve, 1847		+			
	<i>Chama pacifica</i> Broderip, 1835		+			
	<i>Chama</i> species		+		+	
Corbulidae	<i>Corbula crassa</i> Hinds, 1843					+
	<i>Corbula</i> cf. <i>scaphoides</i> Hinds, 1843†					+
Cyrenidae	<i>Geloina erosa</i> (Solander, 1786)†	+				
Galeommatidae	<i>Galeomma ambigua</i> (Deshayes, 1856)		+			+
	<i>Pseudogaleomma japonica</i> (A. Adams, 1862)		+			
	<i>Scintilla cuvieri</i> Deshayes, 1856		+			
	<i>Scintilla ovulina</i> Deshayes, 1856			+		
	<i>Scintilla rosea</i> Deshayes, 1856		+			
	<i>Scintilla</i> species		+			
Gryphaeidae	<i>Parahyotissa</i> cf. <i>numisma</i> (Lamarck, 1819)†		+			
Isognomonidae	<i>Isognomon ephippium</i> (Linnaeus, 1758)	+				
	<i>Isognomon isognomon</i> (Linnaeus, 1758)		+	+	+	
	<i>Isognomon legumen</i> Gmelin, 1791				+	
Limidae	“ <i>Ctenoides</i> ” species††		+			
	<i>Lima vulgaris</i> (Link, 1807)		+			
	<i>Limaria basilanica</i> (Adams & Reeve, 1850)†		+			

## Tan &amp; Yeo: Intertidal Molluscs of Pulau Semakau

Family	Species	MG	CR	SG	RB	MS
Lucinidae	<i>Anodontia ovum</i> (Reeve, 1850)†			+		
	<i>Anodontia philippiana</i> (Reeve, 1850)††	+	+			
	<i>Austriella corrugata</i> (Deshayes, 1843)†	+				
	“ <i>Divaricella</i> ” species†					+
Mactridae	<i>Lutraria australis</i> Reeve, 1854††					+
	<i>Mactra mera</i> Reeve, 1854			+		+
Malleidae	<i>Malleus albus</i> Lamarck, 1819		+	+		
	<i>Malleus malleus</i> (Linnaeus, 1758)		+			
	<i>Malleus regula</i> (Forsskål, 1775)		+	+	+	
	<i>Vulsella vulsella</i> (Linnaeus, 1758)		+			
Mesodesmatidae	<i>Paphies striata</i> (Gmelin, 1791)					+
Mytilidae	<i>Brachidontes</i> species				+	
	<i>Leiosolenus malaccanus</i> (Reeve, 1858)		+			
	<i>Lithophaga teres</i> (Philippi, 1846)		+			
	<i>Modiolus philippinarum</i> (Hanley, 1843)			+		
	<i>Modiolus</i> cf. <i>micropterus</i> Deshayes, 1836		+		+	
	<i>Modiolus</i> species					+
	<i>Septifer bilocularis</i> (Linnaeus, 1758)		+		+	
<i>Septifer</i> cf. <i>excisus</i> (Wiegmann, 1837)				+		
Noetiidae	<i>Striarca symmetrica</i> (Reeve, 1844)		+			
	“ <i>Verilarca</i> ” species				+	
Ostreidae	<i>Dendostrea folium</i> (Linnaeus, 1758)	+				
	<i>Dendostrea sandvichensis</i> (Sowerby in Reeve, 1871)		+			
	<i>Planostrea pestigris</i> (Hanley, 1846)		+			
	<i>Saccostrea cucullata</i> (Born, 1778)	+	+		+	
Pectinidae	<i>Comptopallium radula</i> (Linnaeus, 1758)		+			
Pinnidae	<i>Pinna bicolor</i> Gmelin, 1791			+		+
Placunidae	<i>Placuna ephippium</i> (Philippson in Retzius, 1788)					+
	<i>Placuna placenta</i> (Linnaeus, 1758)	+		+		+
Plicatulidae	<i>Plicatula australis</i> Lamarck, 1819		+			
	<i>Plicatula chinensis</i> Mörch, 1853		+			
Pteriidae	<i>Pinctada albina sugillata</i> (Reeve, 1857)		+			
	<i>Pinctada fucata</i> (Gould, 1850)		+			
	<i>Pinctada</i> cf. <i>maxima</i> (Jameson, 1901)††		+			
	<i>Pinctada</i> species		+			
Semelidae	<i>Semele carnicolor</i> (Hanley, 1847)†		+			
Solenidae	<i>Solen</i> species†					+
Spondylidae	<i>Spondylus</i> cf. <i>cuneus</i> Reeve, 1856		+			
	<i>Spondylus nicobaricus</i> Schreibers, 1793		+			
	<i>Spondylus versicolor</i> Schreibers, 1793		+			
Tellinidae	<i>Macalia bruguieri</i> (Hanley, 1844)†	+				
	<i>Scutarcopagia linguafelis</i> (Linnaeus, 1758)†					+
	<i>Tellina</i> cf. <i>capsoides</i> Lamarck, 1818†	+				
	<i>Tellina</i> cf. <i>inflata</i> Gmelin, 1791†		+	+		
	<i>Tellina remies</i> Linnaeus, 1758†		+			
	<i>Tellina</i> species†		+			+
	<i>Tellina staurella</i> Lamarck, 1818†		+			
<i>Tellina virgata</i> Linnaeus, 1758	+		+		+	

Family	Species	MG	CR	SG	RB	MS
Teredinidae	"Teredo" species††	+				
Trapeziidae	<i>Coralliophaga coralliophaga</i> (Gmelin, 1791)		+			
	<i>Trapezium sublaevigatum</i> (Lamarck, 1819)	+			+	
Tridacnidae	<i>Hippopus hippopus</i> (Linnaeus, 1758)††		+			+
	<i>Tridacna crocea</i> Lamarck, 1819		+			
	<i>Tridacna squamosa</i> Lamarck, 1819*		+			
Veneridae	<i>Anomalocardia squamosa</i> (Linnaeus, 1758)	+				
	<i>Circe tumefacta</i> Sowerby, 1851		+	+		+
	<i>Dosinia amphidesmoides</i> (Reeve, 1850)†		+			
	<i>Gafrarium pectinatum</i> (Linnaeus, 1758)					+
	<i>Gafrarium tumidum</i> (Röding, 1798)		+			+
	<i>Periglypta puerpera</i> (Linnaeus, 1771)†		+			
	<i>Pitar citrinus</i> (Lamarck, 1818)		+	+		+
	<i>Placamen chlorotica</i> (Philippi, 1849)					+
	<i>Ruditapes variegatus</i> (Sowerby, 1852)†		+			+
<i>Tapes literatus</i> (Linnaeus, 1758)†			+		+	

Table 3. Gastropoda recorded by "Project Semakau" surveys.

Family	Species	MG	CR	SG	RB	MS
Acmaeidae	<i>Acmaea pygmaea</i> (Dunker, 1882)				+	
	<i>Patelloida saccharinoides</i> Habe & Kosuge, 1966				+	
Aglajidae	<i>Chelidonura pallida</i> Risbec, 1951*		+			+
	<i>Philinopsis pilsbryi</i> (Eliot, 1900)*		+			+
Aplysiidae	<i>Aplysia extraordinaria</i> (Allan, 1932)*			+		
	<i>Bursatella leachii</i> de Blainville, 1817*		+			
	<i>Phyllaplysia</i> species			+		
	<i>Stylocheilus striatus</i> (Quoy & Gaimard, 1832)*		+			
Assimineidae	<i>Assiminea brevicula</i> (Pfeiffer, 1854)	+				
Batillariidae	<i>Batillaria zonalis</i> (Bruguière, 1789)	+			+	+
Bornellidae	<i>Bornella stellifer</i> (A. Adams & Reeve, 1848)*		+	+		
Buccinidae	<i>Cantharus fumosus</i> (Dilwyn, 1817)		+			
	<i>Engina armillata</i> (Reeve, 1846)				+	
	<i>Nassaria acuminata</i> (Reeve, 1844)†		+			
Calliostomatidae	<i>Calliostoma scobinatum</i> (A. Adams, 1863)††		+			
Calyptraeidae	<i>Crepidula walshi</i> (Reeve, 1859)*		+			
Cerithiidae	<i>Cerithium coralium</i> Kiener, 1841	+				+
	<i>Cerithium dialeucum</i> Philippi, 1849†		+			
	<i>Cerithium torresi</i> Smith, 1884†					+
	<i>Cerithium traillii</i> Sowerby, 1835		+			
	<i>Cerithium zonatum</i> (Wood, 1828)		+	+		+
	<i>Clypeomorus batillariaeformis</i> Habe & Kosuge, 1966					+
	<i>Clypeomorus bifasciata</i> (Sowerby, 1855)					+
	<i>Clypeomorus pellucida</i> (Hombron & Jacquinot, 1852)	+				
	<i>Rhinoclavis aspera</i> (Linnaeus, 1758)††					+
	<i>Rhinoclavis sinensis</i> (Gmelin, 1791)		+	+		
	<i>Rhinoclavis vertagus</i> (Linnaeus, 1758)††		+			
Chromodorididae	<i>Ceratosoma sinuatum</i> (van Hasselt, 1824)*		+	+		
	<i>Chromodoris lineolata</i> (van Hasselt, 1824)*		+			

## Tan &amp; Yeo: Intertidal Molluscs of Pulau Semakau

Family	Species	MG	CR	SG	RB	MS
	<i>Glossodoris atromarginata</i> (Cuvier, 1804)*		+			
Columbellidae	<i>Euplica scripta</i> (Lamarck, 1822)		+	+		
	<i>Mitrella</i> species				+	
	<i>Parametaria philippinarum</i> (Reeve, 1843)		+		+	+
	<i>Pardalina testudinaria</i> (Link, 1807)		+			
	<i>Pictocolumbella ocellata</i> (Link, 1807)	+	+		+	
	<i>Pseudanachis basedowi</i> Hedly, 1918	+				
Cypraeidae	<i>Cypraea arabica</i> Linnaeus, 1758		+		+	
	<i>Cypraea cylindrica</i> Born, 1778††		+			
	<i>Cypraea erronea</i> Linnaeus, 1758		+			
	<i>Cypraea ovum</i> Linnaeus, 1758		+		+	
	<i>Cypraea quadrimaculata</i> Gray, 1824		+			
Dendrodorididae	<i>Dendrodoris denisoni</i> (Angas, 1864)*		+	+		
	<i>Dendrodoris tuberculosa</i> (Quoy & Gaimard, 1832)*		+	+		
Discodorididae	<i>Discodoris boholiensis</i> Bergh, 1877*		+			
Dorididae	<i>Asteronotus cespitosus</i> (van Hasselt, 1824)*		+			
	<i>Atagama intacta</i> (Kelaart, 1858)*		+			
	<i>Jorunna funebris</i> (Kelaart, 1858)*		+	+		
	<i>Platydorid scabra</i> (Cuvier, 1804)*		+	+		
	<i>Sebadoris</i> cf. <i>fragilis</i> (Alder & Hancock, 1864)*		+			
Ellobiidae	<i>Cassidula nucleus</i> (Gmelin, 1791)	+				
	<i>Ellobium aurismidae</i> (Linnaeus, 1758)	+				
	<i>Laemodonta</i> species	+				
	<i>Melampus</i> species	+				
	<i>Pythia trigona</i> (Troschel, 1838)	+				
Elysiidae	<i>Elysia ornata</i> (Swainson, 1840)*		+			
	<i>Thuridilla ratna</i> (Marcus, 1965)*		+			
Facelinidae	<i>Pteraeolidia ianthina</i> (Angas, 1864)*		+			
Fissurellidae	<i>Diodora singaporensis</i> (Reeve, 1850)		+			
	<i>Scutus unguis</i> (Linnaeus, 1758)				+	
Gymnodorididae	<i>Gymnodoris rubropapulosa</i> (Bergh, 1905)*		+			
Haminoeidae	<i>Haminoea tenera</i> (A. Adams, 1850)	+				
Limapontiidae	<i>Costasiella paweli</i> Ichikawa, 1993*		+			
Littorinidae	<i>Echinolittorina malaccana</i> (Philippi, 1847)				+	
	<i>Echinolittorina melanacme</i> (Smith, 1876)				+	
	<i>Littoraria</i> cf. <i>articulata</i> (Philippi, 1846)	+			+	
	<i>Littoraria carinifera</i> (Menke, 1830)	+				
	<i>Littoraria intermedia</i> (Philippi, 1846)	+				
	<i>Littoraria melanostoma</i> (Gray, 1839)	+				
	<i>Littoraria pallelescens</i> (Philippi, 1846)	+				
	<i>Littoraria vespacea</i> Reid, 1986	+				
Melongenidae	<i>Pugilina cochlidium</i> (Linnaeus, 1758)	+				+
Mitridae	<i>Mitra proscissa</i> Reeve, 1844		+			
	<i>Pterygia dactylus</i> (Linnaeus, 1767)††		+			
Muricidae	<i>Chicoreus brunneus</i> (Link, 1807)		+		+	
	<i>Chicoreus capucinus</i> (Lamarck, 1822)	+				
	<i>Chicoreus torrefactus</i> (Sowerby, 1841)		+		+	
	<i>Cronia margariticola</i> (Broderip, 1833)	+	+		+	

Family	Species	MG	CR	SG	RB	MS
	<i>Drupella rugosa</i> (Born, 1778)††		+			
	<i>Ergalatax contracta</i> (Reeve, 1846)		+			
	<i>Mancinella echinata</i> (Blainville, 1832)		+			
	<i>Morula fusca</i> (Küster, 1858)	+				
	<i>Morula musiva</i> (Kiener, 1835)	+	+		+	
	<i>Morula spinosa</i> (H. & A. Adams, 1853)		+			
	<i>Thais bitubercularis</i> (Lamarck, 1822)	+			+	
	<i>Thais muricoides</i> (Blainville, 1832)				+	
Nassariidae	<i>Nassarius crenoliratus</i> (A. Adams, 1852)		+	+		+
	<i>Nassarius jacksonianus</i> (Quoy & Gaimard, 1833)	+				
	<i>Nassarius limnaeiformis</i> (Dunker, 1847)		+			+
	<i>Nassarius livescens</i> (Philippi, 1849)			+		+
	<i>Nassarius mitralis</i> (A. Adams, 1852)	+				
	<i>Nassarius nodifer</i> (Powys, 1835)					+
	<i>Nassarius olivaceus</i> (Bruguière, 1789)	+				+
	<i>Nassarius pauperus</i> (Gould, 1850)†		+			
	<i>Nassarius pullus</i> (Linnaeus, 1758)					+
Naticidae	<i>Natica gualteriana</i> Récluz, 1844*		+			
	<i>Natica tigrina</i> (Röding, 1798)*					+
	<i>Naticarius zonalis</i> (Récluz, 1850)		+	+		+
	<i>Polinices mammilla</i> (Linnaeus, 1758)					+
	<i>Polinices peselephanti</i> (Link, 1807)††					+
	<i>Tanea lineata</i> (Röding, 1798)†					+
Neritidae	<i>Clithon faba</i> (Sowerby, 1836)	+				
	<i>Clithon oualaniensis</i> (Lesson, 1831)	+				
	<i>Nerita albicilla</i> Linnaeus, 1758				+	
	<i>Nerita articulata</i> Gould, 1847	+				
	<i>Nerita chamaeleon</i> Linnaeus, 1758	+	+		+	
	<i>Nerita grayana</i> Récluz, 1843					
	<i>Nerita histrio</i> Linnaeus, 1758	+			+	
	<i>Nerita planospira</i> Anton, 1839	+				
	<i>Nerita polita</i> Linnaeus, 1758	+				
	<i>Nerita undata</i> Linnaeus, 1758				+	
	<i>Neritina siquijorensis</i> (Récluz, 1843)	+				
Onchidiidae	<i>Peronia verruculata</i> (Cuvier, 1830)	+			+	
	“ <i>Platyvindex</i> ” species*	+				
Olividae	<i>Oliva mustelina</i> Lamarck, 1811					+
Phyllidiidae	<i>Phyllidia varicosa</i> Lamarck, 1801*		+			
	<i>Phyllidiella nigra</i> (van Hasselt, 1824)*		+			
	<i>Phyllidiella pustulosa</i> (Cuvier, 1804)*		+			
Plakobrachidae	<i>Plakobranthus ocellatus</i> van Hasselt, 1824*					+
Planaxidae	<i>Planaxis sulcatus</i> (Born, 1778)		+		+	
Pleurobranchidae	<i>Pleurobranchus forskalii</i> (Ruppell & Leuckart, 1828)*		+	+		
Potamididae	<i>Cerithidea alata</i> (Philippi, 1847)	+				
	<i>Cerithidea cingulata</i> (Gmelin, 1791)	+				+
	<i>Cerithidea microptera</i> (Kiener, 1842)	+				+
	<i>Cerithidea obtusa</i> (Lamarck, 1822)	+				
	<i>Cerithidea quadrata</i> Reeve, 1866	+				

Family	Species	MG	CR	SG	RB	MS
	<i>Telescopium telescopium</i> (Linnaeus, 1758)	+				
	<i>Terebralia palustris</i> (Linnaeus, 1767)	+				
	<i>Terebralia sulcata</i> Born, 1778	+				
Pyramidellidae	<i>Otopleura auriscati</i> (Dillwyn, 1817)	+		+		+
	<i>Pyramidella ventricosa</i> Guerin, 1831		+			+
Ranellidae	<i>Gyrineum natator</i> (Röding, 1798)				+	
Rissoiidae	“ <i>Zebinella</i> ” species†		+			
Siliquariidae	<i>Siliquaria ponderosa</i> (Mörch, 1860)††		+			
Siphonariidae	<i>Siphonaria guamensis</i> Quoy & Gaimard, 1833		+		+	
	<i>Siphonaria laciniosa</i> (Linnaeus, 1758)		+		+	
Strombidae	<i>Lambis lambis</i> (Linnaeus, 1758)*		+	+		
	<i>Strombus marginatus robustus</i> Sowerby, 1875					+
	<i>Strombus turturella</i> (Röding, 1798)	+		+		+
	<i>Strombus urceus</i> Linnaeus, 1758		+	+		+
	<i>Strombus variabilis</i> Swainson, 1820					+
	<i>Strombus vittatus apicatus</i> Man in't Veld & Visser, 1993					+
Triviidae	<i>Trivia oryza</i> (Lamarck, 1811)†		+			
Trochidae	<i>Chrysostoma paradoxum</i> (Born, 1780)		+			
	<i>Clanculus</i> cf. <i>granosus</i> Brazier, 1877		+		+	
	<i>Euchelus atratus</i> (Gmelin, 1791)		+		+	
	<i>Euchelus quadricarinatus</i> (Holten, 1802)	+			+	
	<i>Monodonta labio</i> (Linnaeus, 1758)	+			+	
	<i>Trochus maculatus</i> Linnaeus, 1758		+		+	
	<i>Trochus niloticus</i> Linnaeus, 1767		+			
Turbinidae	<i>Angaria delphinus</i> (Linnaeus, 1758)		+			
	<i>Astralium calcar</i> (Linnaeus, 1758)		+			
	<i>Turbo bruneus</i> (Röding, 1798)		+		+	
	<i>Turbo intercostalis</i> Menke, 1846	+	+		+	
Vermetidae	<i>Vermetus</i> species*		+		+	
Volutidae	<i>Cymbiola nobilis</i> (Lightfoot, 1786)		+	+		+

Table 4. Cephalopoda recorded by “Project Semakau” surveys.

Family	Species	MG	CR	SG	RB	MS
Idiosepiidae	<i>Idiosepia</i> species			+		
Loliginidae	<i>Sepioteuthis lessoniana</i> Férussac, 1831		+	+		
Nautilidae	<i>Nautilus pompilius</i> Linnaeus, 1758††	+				
Octopodidae	<i>Octopus</i> species		+			
Sepiidae	<i>Sepia</i> cf. <i>papuensis</i> Hoyle, 1885					+

## DISCUSSION

As the surveys aim to document the intertidal mollusc species diversity, the subtidal regions and offshore areas were not investigated. Unsurprisingly, most species listed are known to inhabit the intertidal zone. Several species appear elusive with no living members observed throughout the surveys (see species indicated with †, ††). Further sampling over time will elucidate whether the species indicated with †† are still extant on Pulau Semakau. Nevertheless, the absence of living animals does not suggest rarity of the indicated species. Moreover, equipment for sampling the infaunal molluscs was not employed. It is thus unsurprising that many of the infaunal species, such as the lucinid and tellinid bivalves for example, are represented only by empty shells. An accurate determination of the abundance and conservation status of each species recorded would require more studies.



A cuttlebone from the freshly predated remains of a cuttlefish on a sandbank was collected and provisionally identified as *Sepia cf. papuensis* — a new record and possible range extension, if confirmed. However, more comparative material is needed to confirm the identity of this odd cuttlebone. Additionally, a few species, such as *Plakobranthus ocellatus*, *Limaria basilanica*, *Scintilla ovulina*, and *Dosinia amphidesmoides*, are not listed in the recent checklist by Tan & Woo (2010), and this paper is likely the first published report of their occurrence in Singapore.

The find of a complete *Nautilus pompilius* shell is one of the highlights of the surveys. *Nautilus pompilius* shells have been found infrequently on Singapore's beaches, but specimens in good condition are extremely rare. The animals typically inhabit waters more than 200 m deep off reefs (Norman & Lu, 2000), and although this species has a wide distribution in the Indo-West Pacific (see Dunning, 1998), no living population is as yet known from Singapore waters. However, the gas-filled chambers of an empty shell carried by the currents can drift for hundreds or even thousands of kilometres (Teichert, 1970), and the origin of this *Nautilus pompilius* remains indeterminate.

Interestingly, the surveys recorded twelve species, or 30%, of the thirty-eight species (excluding two terrestrial camaenids) mentioned in the second edition of the Singapore Red Data Book (Davison et al., 2008). Eight species, namely *Pinna bicolor*, *Trochus niloticus*, *Nerita planospira*, *Clithon oualaniensis*, *Lambis lambis*, *Strombus urceus*, *Cypraea arabica*, and *Cymbiola nobilis*, are listed as nationally vulnerable and four, *Tridacna squamosa*, *Scutus unguis*, *Cerithium traillii*, *Trivia oryza*, are listed as nationally endangered (see Davison et al., 2008). This suggests that Pulau Semakau can be a bastion for conservation efforts in Singapore despite the recent developments and ongoing activities of the landfill. The results of "Project Semakau" serve to provide an insight to the species diversity of the intertidal areas of Pulau Semakau. As there are no prior studies of a comparable scale on Pulau Semakau, or the other southern islands of Singapore, the information garnered enables the establishment of a baseline for future work. The "Project Semakau" data will be inventoried and later made publicly available online.

#### ACKNOWLEDGEMENTS

The activities of "Project Semakau" were made possible by the generous sponsorship from the Hongkong and Shanghai Banking Corporation (HSBC) Singapore. Thanks are due to all our colleagues involved with the project, especially L. K. Wang, for their support. Too many to name are the enthusiastic volunteers who deserve a big "Thank you!". The "Project Semakau" surveys would not have been possible without their participation and efforts. We would also like to thank Y. Feng for the GIS map. The anonymous reviewer is gratefully acknowledged for improvements to this paper.

#### LITERATURE CITED

- Abbott, R. T. & S. P. Dance, 1982. *Compendium of Seashells*. E. P. Dutton, New York. x + 411 pp.
- Brandt, R. A. M., 1974. The non-marine Mollusca of Thailand. *Archiv für Molluskenkunde*, **105**: i–iv + 1–423.
- Cernohorsky, W. O., 1984. *Systematics of the Family Nassariidae (Mollusca: Gastropoda)*. Auckland Institute and Museum, Auckland. 356 pp.
- Chan, S. Y., 2009. The Melongenidae (Mollusca: Gastropoda) of Singapore. *Nature in Singapore*, **2**: 63–67.
- Chou, L. M., J. Y. Yu & T. L. Loh, 2004. Impacts of sedimentation on soft-bottom benthic communities in the southern islands of Singapore. *Hydrobiologia*, **515**(1–3): 91–106.
- Chou, L. M. & K. P. P. Tun, 2007. Conserving reefs beside a marine landfill in Singapore. *Coral Reefs*, **26**(3): 719.
- Davidson, G. W. H., P. K. L. Ng & H. C. Ho (eds.), 2008. *The Singapore Red Data Book: Threatened Plants and Animals of Singapore*. 2nd Edition. The Nature Society (Singapore), Singapore. 285 pp.
- Dayrat, B., 2010. A Monographic Revision of Basal Discodorid Sea Slugs (Mollusca: Gastropoda: Nudibranchia: Doridina). *Proceedings of the California Academy of Sciences*, Series 4, **6**(Supplement 1): 1–403.
- Debelius, H. & R. H. Kuitert, 2007. *Nudibranchs of the world*. IKAN-Unterwasserarchiv, Frankfurt. 360 pp.
- Dharma, B., 2005. *Recent & Fossil Indonesian Shells*. ConchBooks, Hackenheim, 424 pp.
- Dunning, M. C., 1998. Nautilidae (Cephalopods). In: Carpenter, K. E. & V. H. Niem (eds.). *FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 2*. Rome, FAO. Pp. 709–711.
- García, A. A. & P. G. Oliver, 2008. Species discrimination in seven species of *Barbatia* (Bivalvia: Arcoidea) from Thailand with a redescription of *B. grayana* (Dunker, 1858). *Raffles Bulletin of Zoology*, Supplement **18**: 7–23.
- Gosliner, T. M., D. W. Behrens & Á. Valdés 2008. *Indo-Pacific nudibranchs and sea slugs: a field guide to the World's most diverse fauna*. Sea Challengers/California Academy of Sciences: Gig Harbor/San Francisco, 426 pp.
- Houart, R., 1996. Results of the Rumphius Biohistorical Expedition to Ambon (1990). Part 5. Mollusca, Gastropoda, Muricidae. *Zoologische Mededelingen*, **70**(26): 377–397.
- Houbrick, R. S., 1985. Genus *Clypeomorus* Jousseaume (Cerithiidae: Prosobranchia). *Smithsonian Contributions to Zoology*, **403**: i–iii + 1–130.
- Houbrick, R. S., 1992. Monograph of the Genus *Cerithium* Bruguière in the Indo-Pacific (Cerithiidae: Prosobranchia). *Smithsonian Contributions to Zoology*, **510**: i–iv + 1–211.

- Jensen, K. R., 2009. Sacoglossa (Mollusca: Gastropoda: Opisthobranchia) from Singapore. *Raffles Bulletin of Zoology*, Supplement **22**: 207–223.
- Kabat, A. R., 2000. Results of the Rumphius Biohistorical Expedition to Ambon (1990). Part 10. Mollusca, Gastropoda, Naticidae. *Zoologische Mededelingen*, **73**(25): 345–380.
- Lam, K. & B. Morton, 2009. Oysters (Bivalvia: Ostreidae and Gryphaeidae) recorded from Malaysia and Singapore. *The Raffles Bulletin of Zoology*, **57**(2): 481–494.
- Lamprell, K. & J. Healy, 1998. *Bivalves of Australia. Volume 2*. Backhuys Publishers, Leiden. 288 pp.
- Lamprell, K. & T. Whitehead, 1992. *Bivalves of Australia. Volume 1*. Crawford House Press, Bathurst, New South Wales. 182 pp.
- Lützen, J. & C. Nielsen, 2005. Galeommatid bivalves from Phuket, Thailand. *Zoological Journal of the Linnean Society*, **144**: 261–308.
- Ng, M. F. C., 2009. *Habitats in Harmony: The Story of Semakau Landfill*. National Environment Agency, Singapore. 118 pp.
- Nielsen, C., 1976. An illustrated checklist of bivalves from PMBC beach with a reef-flat at Phuket, Thailand. *Phuket Marine Biological Center, Research Bulletin*, **9**: 1–7 + 17 pls.
- Norman, M. D. & C. C. Lu, 2000. Preliminary checklist of the Cephalopods of the South China Sea. *The Raffles Bulletin of Zoology*, Supplement **8**: 539–567
- Poorten, J. J. ter, 2009. The Cardiidae of the Panglao Marine Biodiversity Project 2004 and the Panglao 2005 Deep-Sea Cruise with descriptions of four new species (Bivalvia). *Vita Malacologica*, **8**: 9–96.
- Poutiers, J. M., 1998a. Bivalves (Acephala, Lamellibranchia, Pelecypoda). In: Carpenter, K. E. & V. H. Niem (Eds.). *FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Vol. 1*. FAO, Rome. Pp. 123–362.
- Poutiers, J. M., 1998b. Gastropods. In: Carpenter, K. E. & V. H. Niem (Eds.). *FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 1*. FAO, Rome. Pp. 363–648.
- Raven, J. G. M., 2002. Notes on molluscs from NW Borneo. 1. Stromboidea (Gastropoda, Strombidae, Rostellariidae, Seraphidae). *Vita Malacologica*, **1**: 3–32.
- Reid, D. G., 1986. *The Littorinid Molluscs of Mangrove Forests in the Indo-Pacific Region: The Genus Littoraria (Mollusca: Gastropoda: Littorinidae)*. British Museum (Natural History), London. i–xv + 228 pp.
- Reid, D. G., 2007. The genus *Echinolittorina* Habe, 1956 (Gastropoda: Littorinidae) in the Indo-West Pacific Ocean. *Zootaxa*, **1420**: 1–161.
- Sachidhanandam, U., R. C. Willan & L. M. Chou, 2000. Checklist of the nudibranchs (Opisthobranchia: Nudibranchia) of the South China Sea. *The Raffles Bulletin of Zoology*, Supplement **8**: 495–513.
- Sartori, A. F., C. Printragoon, P. M. Mikkelsen & R. Bieler, 2008. Siphonal structure in the Veneridae (Bivalvia: Heterodonta) with an assessment of its phylogenetic application and a review of venerids of the Gulf of Thailand. *Raffles Bulletin of Zoology*, Supplement **18**: 103–125.
- Simone, L. R. L. & S. Wilkinson, 2008. Comparative morphological study of some Tellinidae from Thailand (Bivalvia: Tellinoidea). *Raffles Bulletin of Zoology*, Supplement **18**: 151–190.
- Swennen, C., R. G. Moolenbeek, N. Ruttanadakul, H. Hobbelink, H. Dekker & S. Hajisamae, 2001. The Molluscs of the Southern Gulf of Thailand. *Thai Studies in Biodiversity*, **4**: 1–210.
- Tan, H. T. W., L. M. Chou, D. C. J. Yeo & P. K. L. Ng, 2010. *The Natural Heritage of Singapore*. 3<sup>rd</sup> Edition. Prentice Hall/Pearson South Asia Pte Ltd, Singapore. i–ix + 323 pp.
- Tan, K. S. & L. M. Chou, 2000. *A Guide to Common Seashells of Singapore*. Singapore Science Centre, Singapore. 168 pp.
- Tan, S. K. & R. Clements, 2008. Taxonomy and distribution of the Neritidae (Mollusca: Gastropoda) in Singapore. *Zoological Studies*, **47**(4): 481–494.
- Tan, S. K. & H. P. M. Woo, 2010. *A Preliminary Checklist of the Molluscs of Singapore*. Raffles Museum of Biodiversity Research, National University of Singapore, Singapore. 78 pp.
- Tantanasiriwong, R., 1978. An illustrated checklist of marine shelled gastropods from Phuket island, adjacent mainland and offshore islands, western peninsular Thailand. *Phuket Marine Biological Center, Research Bulletin*, **21**: 1–63.
- Taylor, J. D. & E. A. Glover, 2005. Cryptic diversity of chemosymbiotic bivalves: a systematic revision of worldwide *Anodontia* (Mollusca: Bivalvia: Lucinidae). *Systematics and Biodiversity*, **3**(3): 281–338.
- Teichert, C., 1970. Drifted Nautilus shells in the Bay of Bengal. *Journal of Paleontology*, **44**(6): 1129–1130
- Valentich-Scott, P. & P. Tongkerd, 2008. Coral-boring bivalve molluscs of southeastern Thailand, with the description of a new species. *Raffles Bulletin of Zoology*, Supplement **18**: 191–216.
- Vongpanich, V. & A. Matsukuma, 2004. Family Noetiidae in Thailand. *Phuket Marine Biological Centre, Research Bulletin*, **65**: 31–44.
- Wilson, B. R., 1993. *Australian Marine Shells: Prosobranch Gastropods. Part 1*. Odyssey Publishing, Western Australia. 408 pp.
- Wilson, B. R., 1994. *Australian Marine Shells: Prosobranch Gastropods. Part 2 (Neogastropods)*. Odyssey Publishing, Western Australia. 370 pp.
- Wong, H. W., 2009. The Mactridae of East Coast Park, Singapore. *Nature in Singapore*, **2**: 283–296.