

## A GENERIC ACCOUNT OF MARINE SOFT-BOTTOM BENTHIC BIVALVES OF SINGAPORE

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**ABSTRACT.** - Marine bivalves collected from various marine soft-bottom habitats (Sungei Buloh, Kallang Basin, Singapore River, Pulau Tekong, West Johore Straits and Pulau Semakau) in Singapore waters were studied from 1987 to 1993. A total of 26 families, 47 genera and 75 species were recorded. The genus *Bucardium* Gray, 1853 has not previously been reported from Singapore. The most commonly occurring bivalve was *Mytilopsis sallei* Recluz 1852. The overall distribution is non-uniform.

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### INTRODUCTION

Of previous work on bivalves in Singapore, the most recent is by Chuang & Goh (1992) who listed a total of 31 families and 61 genera. Purchon's (1981) survey of bivalves recorded 35 families, 81 genera and 103 species. His survey encompassed intertidal sands, market stalls, mangroves and benthic areas. Lim's (1963a) guide to the families of Malaysian bivalves that included specimens from Singapore, listed 55 families and 128 genera. In another publication (1963b), he listed bivalves from the Malayan seas and also mentioned edible species. Chuang (1961) listed 46 genera and 70 species that were found on Singapore shores and later (1972) listed 82 additional species, bringing the total to 152 species.

A survey by Chou & Khoo (1990) conducted over a four year period off Bedok yielded 12 genera of bivalves. Four of the genera overlap with those collected in this current study. Lee (1973) recorded 15 species of bivalves from the East Johore Straits. Three of these genera, *Perna* Philipsson 1788, *Anomalocardia* Schumacher, 1817 and *Modiolus* Lamarck, 1799, have been found in the current study. The Zoological Reference Collection of the National University of Singapore has specimens representing 44 families collected from both Singapore and Malaysia since the 1900s.

The present study is based on specimens collected by the Reef Ecology Study Team as part of the ASEAN-Australia Marine Science Project: Living Coastal Resources. This study is centered on soft-bottom benthic bivalves and the equipment used were grabs and dredges

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as compared to earlier works which were done along shallow coasts where collection was mostly by hand and sometimes even from trawling nets (Purchon, 1981).

Many of the sites that previous workers such as Chuang and Purchon have surveyed have now been buried by land reclamation. The surveys included in this study are from the following sites: Sungei [=river] Buloh (1988-1993), Singapore River (1987-1992), Kallang Basin (1987-1990), West Johore Straits (1987), Pulau [=island] Tekong (1987) and Pulau Semakau (1989-1993).

This study documents the present status of bivalves from marine soft-bottom habitats of Singapore.

Of the 75 species from 26 genera, 25 of them were identified down to specific level. These are noted in the Systematic Account.

### MATERIALS AND METHODS

**Locations.** - Six locations were studied: Sungei Buloh, Kallang Basin, Singapore River, Pulau Tekong, West Johore Straits and Pulau Semakau (Fig. 1).

Sungei Buloh was surveyed annually over a 6 year period from 1988 to 1993. Kallang Basin was surveyed annually over a period of 4 years from 1987 to 1990. Singapore River was surveyed over a 6 year period annually from 1987 to 1992. Pulau Tekong and West Johore Straits were each surveyed once during 1987. Pulau Semakau was surveyed annually over a 5 year period from 1989 to 1993.

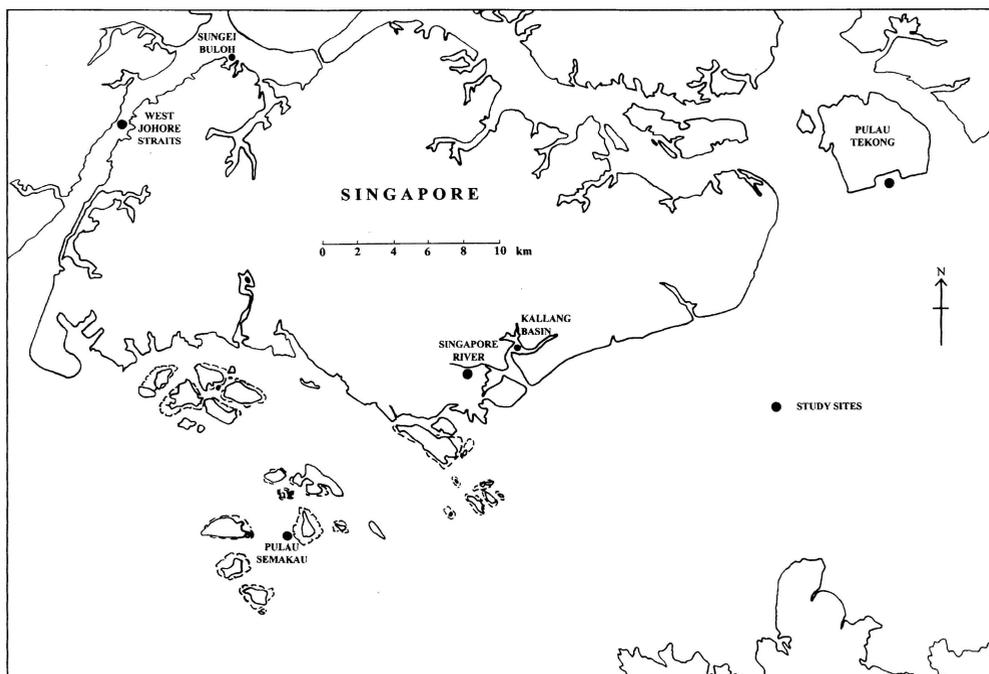


Fig. 1. Map of Singapore showing study sites.

Table 1. A systematic list of bivalves showing distribution in Singapore.

Genus	Locations					
	PS	SB	KB	PT	SR	WJS
<i>Anadara</i>	*	*				
<i>Anodontia</i>		*			*	
<i>Anomalocardia</i>		*	*		*	
<i>Anomia</i>		*				
<i>Arca</i>	*					
<i>Arcuatula</i>		*	*		*	
<i>Barbatia</i>			*	*		*
<i>Botula</i>				*		
<i>Bucardium</i>			*			
<i>Chama</i>	*			*		
<i>Chlamys</i>	*			*		
<i>Corbula</i>	*					
<i>Coralliophaga</i>		*				
<i>Crassatella</i>	*			*		
<i>Cultellus</i>	*		*	*	*	
<i>Decatopecten</i>	*					
<i>Diplodonta</i>	*	*				
<i>Dosinia</i>		*	*	*		*
<i>Gafrarium</i>				*		
<i>Gari</i>			*			
<i>Geloina</i>		*				
<i>Isognomon</i>	*			*		
<i>Irus</i>					*	
<i>Laternula</i>		*			*	
<i>Lithophaga</i>	*	*				
<i>Lucina</i>		*				*
<i>Mactra</i>		*	*		*	
<i>Marcia</i>		*		*	*	
<i>Modiolus</i>		*		*	*	
<i>Mytilopsis</i>	*	*	*		*	
<i>Musculus</i>	*					
<i>Mya</i>		*	*			
<i>Nucula</i>	*			*		*
<i>Nuculana</i>				*		
<i>Ostrea</i>				*	*	
<i>Paphia</i>		*	*	*	*	*
<i>Perna</i>		*			*	
<i>Placamen</i>			*	*	*	
<i>Pitar</i>		*			*	*
<i>Pododesmus</i>	*					
<i>Saccostrea</i>				*		
<i>Solen</i>	*	*	*	*	*	
<i>Tagelus</i>		*				
<i>Tapes</i>		*				
<i>Tellina</i>		*	*	*		*
<i>Vulsella</i>	*					
<i>Yoldia</i>	*					

Note: PS= Pulau Semakau, SB= Sungei Buloh, KB= Kallang Basin, PT= Pulau Tekong, SR= Singapore River, WJS= West Johore Straits

**Sampling Methods.** - The methods used in the surveys are modifications of those described in English et al (1994). Two kinds of grabs were used, the Smith-McIntyre grab and the Ekman grab. At the various sampling locations either one of the grabs was used and the number of replicates depended upon which grab was used. In the earlier years of the project the Ekman grab was utilized until replaced midway by the Smith-McIntyre grab.

An Ockelmann's sledge was used to sample the epifauna. The Naturalist's Rectangular dredge was also used at some locations. Both the sledge and dredge have a 50cm long polypropylene net bag with a stretched-mesh bag size of 3cm attached to it. The dredge and sledge when used were towed along the riverbed or seabed at a speed of one knot for ten minutes.

**Sorting, Fixation and Preservation.** - Samples were fixed for 24 hours in 10% buffered formalin and sorted using 2mm and 1mm mesh-sized sieves. All specimens were eventually transferred into 70% alcohol.

**Identification.** - Identification was done using mainly the references of Lim (1963a), Chai (1966), Abbott & Dance (1982) and Oliver (1992). Specimens were identified down to the generic level and the number of species in each genera was noted. Specimens were counted, placed into glass bottles, labelled, assigned reference numbers and later catalogued and stored at the Zoological Reference Collection (ZRC), School of Biological Sciences, National University of Singapore (NUS).

## SYSTEMATIC ACCOUNT

### CLASS BIVALVIA

#### FAMILY ANOMIIDAE RAFINESQUE, 1815

##### Genus *Anadara* Gray, 1847

**Definition.**- Shells small to medium in size. Equivalve or inequivalve. Outline quadrate to rectangular. Sculpture of broad ribs. Hinge strong with teeth in single series. Inner margin crenulate. Periostracum sometimes with bristles or lamellae.

**Material examined.**- ZRC1991.17914, ZRC1991.12784, ZRC1991.13662-13663, ZRC1991.12793-12798, ZRC1991.17974-17978, ZRC1991.12197 (Sungei Buloh), ZRC1992.5569 (Pulau Semakau).

**Remarks.**- *A. auriculata* (Lamarck, 1819) was the only species from this genus that was collected in the sample.

##### Genus *Anomia* Linnaeus, 1758

**Definition.**- Shells small to medium in size. Inequivalve. Outline irregular. Subcircular. Upper valve thin and transparent. Attached to substrata.

**Material examined.**- ZRC1991.18037 (Sungei Buloh).

**Remarks.**- Only one indeterminable species was observed.

FAMILY ARCIDAE LAMARCK, 1809

**Genus *Arca* Linnaeus, 1758**

**Definition.**- Small to medium shells. Equivalve. Slightly to strongly inequilateral. Outline subrectangular. Posterior carina present. Byssus gape present. Sculpture of radial ribs or riblets. Hinge line straight; teeth numerous and uniform. Adductor scars subequal.

**Material examined.**- ZRC1992.5575, ZRC1991.6302, ZRC1991.6292-6294, ZRC1991.6118, ZRC1991.6284 (Pulau Semakau).

**Remarks.**- Two species were noted in the sample; *A. navicularis* Bruguire, 1792 and one indeterminable species.

**Genus *Barbatia* Gray, 1842**

**Definition.**- Small to medium sized shells. Equivalve. Generally inequilateral. Outline subrectangular or subquadrate. Byssal gape narrow. Posterior carina low. Sculpture of radial ribs. Periostracum sometimes with short hairs. Hinge line is usually curved; marginal teeth may be larger than the median teeth.

**Material examined.**- ZRC1992.5568, ZRC1992.5567, ZRC1990.6303-6304, ZRC1991.6285, ZRC1992.5581 (Pulau Semakau), ZRC1990.4105-4108, ZRC1990.16339, ZRC1990.4102-4104, ZRC1991.4186 (Pulau Tekong).

**Remarks.**- *B. complanata* Chemnitz 1784, *B. cf. decussata* (Sowerby 1833), and three indeterminable species were identified in this collection.

**Genus *Pododesmus* Philippi, 1837**

**Definition.**- Similar to *Anomia*, but upper valve with one large retractor scar.

**Material examined.**- ZRC1992.5574 (Pulau Semakau).

**Remarks.**- One indeterminable species was observed in the sample.

FAMILY CARDIIDAE LAMARCK, 1809

**Genus *Bucardium* Gray, 1853**

**Definition.**- Outline rounded or ovate-subcircular. Medium sized. Equivalve and inflated. Sculpture of radial ribs with raised calcareous ridges, arising from the margins.

**Material examined.**- ZRC1991.16416 (Pulau Tekong).

**Remarks.**- One indeterminable species was noted in this sample.

FAMILY CHAMIDAE LAMARCK, 1809

**Genus *Chama* Linnaeus, 1758**

**Definition.**- Small to medium in size. Cemented to substrate by left valve. Often thick. Outline variable. Upper valve flat or slightly convex; lower valve deeply concave. Ligament external. Sculpture sometimes lamellose or spicate but often eroded. Inner margins smooth or crenulate. Pallial sinus absent; line entire. Adductor scars subequal and large.

**Material examined.**- ZRC1990.4164 (Pulau Tekong), ZRC1993.1226, ZRC1992.5598 ZRC1992.5593, ZRC1992.5593, ZRC1994.4315, ZRC1992.5583 (Pulau Semakau).

**Remarks.**- Five indeterminable species were observed in this collection.

FAMILY CORBICULIDAE GRAY, 1847

**Genus *Geloina* Gray, 1842**

**Definition.**- Shell large. Equivalve. Three cardinal teeth per valve. One anterior and one posterior lateral tooth in left valve. Pallial line entire.

**Material examined.**- ZRC1990.3530 (Sungei Buloh).

**Remarks.**- Specimen was identified as *G. coaxans* (Gmelin,1791).

FAMILY CORBULIDAE LAMARCK, 1818

**Genus *Corbula* Bruguiere, 1797**

**Definition.**- Small. Solid. Inequivalve. Left valve smaller than right. Outline posteriorly rostrate or subtruncate. Sculpture of concentric lines or ridges. Pallial sinus shallow or absent.

**Material examined.**- ZRC1992.5591, ZRC1993.1219 (Pulau Semakau).

**Remarks.**- One indeterminable species was noted.

FAMILY CRASSATELLIDAE FERUSSAC, 1822

**Genus *Crassatella* Lamarck, 1799**

**Definition.**- Outline subtrapezoidal. Concentric ribbing present. Beaks thick and prosogyrous. Adductor muscle scars broad; anterior scar reniform and posterior scar ovate. Inner margins crenulate.

**Material examined.**- ZRC1990.2115-2116 (West Johore Straits), ZRC1991.6283, ZRC1991.6309, ZRC1991.6300, ZRC1991.6305-6308, ZRC1991.291, ZRC1992.5578, ZRC1992.5594, ZRC1993.1202 (Pulau Semakau), ZRC1991.15265, ZRC1990.4111-4155, ZRC1991.16356-16357, ZRC1990.4214, ZRC1991.16445 (Pulau Tekong).

**Remarks.**- All specimens were identified as *C. radiata* Sowerby 1833.

FAMILY CULTELLIDAE DAVIES, 1935

**Genus *Cultellus* Schumacher, 1817**

**Definition.**- Outline oblong. Rounded ends that gape. One cardinal in right valve and two in left.

**Material examined.**- ZRC1992.8601, ZRC1991.1332 (Singapore River), ZRC1991.8327, ZRC1991.6315, ZRC1991.6132, ZRC1993.962 (Pulau Semakau), ZRC1990.7792 (Kallang Basin), ZRC1991.15287 (Pulau Tekong).

**Remarks.**- One indeterminable species was observed in the collection.

FAMILY DRESSENIDAE GRAY IN TURTON, 1840

**Genus *Mytilopsis* Conrad, 1858**

**Definition.**- Outline mytiliform to quadrate. Beaks subterminal or terminal. Ligament inside. Hinge without teeth. Beak cavity bridged by septum. Periostracum well developed.

**Material examined.**- ZRC1991.9765-9771, ZRC1990.7964-7966, ZRC1990.7967-8029, ZRC1991.1351-1369, ZRC1991.1391-1399, ZRC1991.1388-1389, ZRC1991.1400-1408, ZRC1991.9265-9771, ZRC1991.9772-9773, ZRC1991.9983-9982, ZRC1991.9775-9982, ZRC1991.9738-9782, ZRC1992.8621-8623, ZRC1990.6267-6268, ZRC1990.6269-6276, ZRC1994.4316, ZRC1994.4317 (Singapore River), ZRC1991.6122-6129 (Pulau Semakau), ZRC1990.2220 (Sungei Buloh).

**Remarks.**- All specimens were identified as *M. sallei* Recluz, 1852.

FAMILY ISOGNOMONIDAE WOODRING, 1925

**Genus *Isognomon* Lightfoot, 1786**

**Definition.**- Shell compressed. Inequilateral. Beaks terminal. Byssal notch present immediately below the anterodorsal margin. Ligament in numerous shallow triangular pits. External surface smooth, lamellose or irregularly scaly. Adductor muscle scar single and concentric.

**Material examined.**- ZRC1991.1387, ZRC1991.9774 (Singapore River).

**Remarks.**- All specimens belonged to the same indeterminable species.

FAMILY LATERNULIDAE HEDLEY, 1918

**Genus *Laternula* Röding, 1798**

**Definition.**- Shells medium sized. Thin shelled. Gaping posteriorly. Often subrostrate. Umbos low with a low transverse slit. No teeth. Ligament in spoon shaped chondrophore supported by an oblique buttress. Pallial sinus broad.

**Material examined.**- ZRC1992.8636-8637, ZRC1991.1373 (Singapore River), ZRC1991.18511-18523, ZRC1993.1249-1250, ZRC1993.2376, ZRC1993.2404, ZRC1993.2412-2413, ZRC1993.2448-2449, ZRC1992.7449, ZRC1992.7475-7480, ZRC1991.13443-13444, ZRC1991.13664 (Sungei Buloh).

**Remarks.**- All samples belonged to the same indeterminable species.

FAMILY LUCINIDAE FLEMING, 1828

**Genus *Anodontia* Link, 1807**

**Definition.**- Outline is circular or globose. Shells medium to large in size. Equivalve. Sculpture of fine irregular concentric lines with faint radial striae. Hinge lacking teeth in adult. Ligament deeply sunken. Anterior adductor muscle scar divergent from pallial line. The inner margin smooth.

**Material examined.**- ZRC1990.3739-3755, ZRC1991.11855-11883, ZRC1990.3662-3663, ZRC1990.3682, ZRC1991.12823, ZRC1991.12245-12247, ZRC1991.11373, ZRC1991.12095, ZRC1991.11585-11592, ZRC1992.7657, ZRC1992.7628-7629, ZRC1993.2411, ZRC1993.2390-2391, ZRC1993.2536, ZRC1993.2573, ZRC1993.2563, ZRC1992.7562-7565, ZRC1993.2525, ZRC1991.17930, ZRC1993.2374, ZRC1993.2468, ZRC1993.2488, ZRC1993.2433, ZRC1993.2502-2504 (Sungei Buloh), ZRC1991.1330 (Singapore River), ZRC1993.1064-1065 (Pulau Semakau).

**Remarks.**- *A. edentula* (Linnaeus, 1758) and one indeterminable species were noted from this sample.

**Genus *Lucina* Bruguiere, 1797**

**Definition.**- Outline ranges from subcircular to lenticular. Size small to medium. Equivalve. Sculpture of concentric lamellae. Two cardinals in each valve. Anterior and posterior laterals present in both valves.

**Material examined.**- ZRC1993.2462, ZRC1993.2395, ZRC1992.7474 (Sungei Buloh), ZRC1990.2134 (West Johore Straits).

**Remarks.**- One indeterminable species was observed in this collection.

FAMILY MACTRIDAE LAMARCK, 1809

**Genus *Mactra* Linnaeus, 1767**

**Definition.**- Outline oval to trigonal. Shells medium to small in size. Equivalve. Right

valve with inverted V-shaped cardinals and single laterals. Left valve with two unfused cardinals and double laterals. Pallial sinus oval.

**Material examined.**- ZRC1993.2372, ZRC1991.17967-17972, ZRC1993.2445-2446, ZRC1993.2454-2456, ZRC1993.2388-2389, ZRC1993.2538, ZRC1993.2568, ZRC1993.2586, ZRC1990.2158-2162, ZRC1990.2163, ZRC1990.2171-2199, ZRC1990.3653-3655, ZRC1990.3703-3712, ZRC1991.13458, ZRC1991.12821-12822, ZRC1991.12198, ZRC1991.12147, ZRC1991.13435 (Sungei Buloh), ZRC1991.1379-1385, ZRC1991.1329, ZRC1990.7917, ZRC1990.7911-7915 (Singapore River), ZRC1990.8502-8503, ZRC1990.8518, ZRC1990.8523, ZRC1990.8254-8258, ZRC1990.8076-8077, ZRC1990.8061-8064, ZRC1990.8151, ZRC1990.8058-8059, ZRC1990.8207, ZRC1990.8113-8114 (Kallang Basin).

**Remarks.**- One indeterminable species was recorded from the sample.

#### FAMILY MALLEIDAE LAMARCK, 1819

##### Genus *Vulsella* Röding, 1798

**Definition.**- Outline elongate dorsoventrally. Shell medium in size. Subequivalve and compressed. Sculpture varies. Ligament is in spoon shaped depression.

**Material examined.**- ZRC1991.6286-6287 (Pulau Semakau).

**Remarks.**- All specimens were *Vulsella vulsella* (Linnaeus, 1758).

#### FAMILY MYIDAE LAMARCK, 1809

##### Genus *Mya* Linnaeus, 1758

**Definition.**- Medium in size. Chondrophore present in left valve. Sculpture of concentric lines.

**Material examined.**- ZRC1990.8102, ZRC1990.8060, ZRC1990.8054, ZRC1990.8176-8177, ZRC1991.6108-6110, ZRC1990.8103, ZRC1990.8519-8521, ZRC1990.7718-7736, ZRC1990.7717, ZRC1990.7788-7791, ZRC1990.8504-8505, ZRC1990.8251-8252 (Kallang Basin), ZRC1993.2513-2514 (Sungei Buloh).

**Remarks.**- One indeterminable species was recorded from this sample.

#### FAMILY MYTILIDAE RAFINESQUE, 1815

##### Genus *Arcuatula* Jousseume MS in Lamy, 1919

**Definition.**- Outline modioliform. Elongated and slightly arcuate. Equivalve. Sculpture of radial riblets on the anterior and posterior region of the shell. Dysodont teeth present.

**Material examined.**- ZRC1991.13481-13652, ZRC1992.7626-7627, ZRC1992.7632-7645, ZRC1992.7671-7678, ZRC1990.2200-2206, ZRC1991.13653-13654, ZRC1992.7120-7448, ZRC1991.17700-17707, ZRC1991.12782, ZRC1992.7566, ZRC1992.8616-8617, ZRC1991.17835-17913, ZRC1993.2153-2177, ZRC1993.2319-2334, ZRC1993.2180-2316, ZRC1993.1251-12152,

ZRC1991.12832-1331, ZRC1992.8624-8634, ZRC8618, ZRC1992.7508-7549, ZRC1992.7500, ZRC1991.12267-2766, ZRC1992.7451, ZRC1992.7453-7473, ZRC1992.7503-7506, ZRC1991.12824 (Sungei Buloh), ZRC1990.8259-8261, ZRC1990.8218-8241 (Kallang Basin), ZRC1991.1331, ZRC1991.1370-1371, ZRC1994.4311 (Singapore River).

**Remarks.**- One indeterminable species was recorded from this sample.

### **Genus *Botula* Mörch, 1853**

**Definition.**- Outline subcylindrical. Shell medium in size. Equivalve. Beaks terminal. Dorsal margin is finely serrated beneath ligament.

**Material examined.**- ZRC1991.15266-15271 (Pulau Tekong).

**Remarks.**- *B. cinnamomea* (Gmelin, 1791) was noted from this sample.

### **Genus *Lithophaga* Röding, 1798**

**Definition.**- Outline elongate and cylindrical. Shells small to medium in size. Equivalve. Beaks subterminal. Hinge teeth lacking. Inner margins without crenulations.

**Material examined.**- ZRC1992.5590, ZRC1993.886-888, ZRC1993.1227 (Pulau Semakau).

**Remarks.**- *L. malaccana* (Reeve, 1857) was noted from this sample.

### **Genus *Modiolus* Lamarck, 1799**

**Definition.**- Outline modioliform. Shell medium to large. Equivalve. Beaks subterminal. Sculpture smooth with growth lines. Periostracum present, sometimes with long hairs. Inner margins not crenulate.

**Material examined.**- ZRC1990.4156-4160, ZRC1990.16337-16338 (Pulau Tekong), ZRC1991.13480, ZRC1992.7646-7647 (Sungei Buloh), ZRC1994.4312-4314 (Singapore River). ZRC1990.7800-7803 (Kallang Basin).

**Remarks.**- *M. metcalfei* Hanley, 1844 and *M. aratus* Reeve, 1857 were identified from the collection..

### **Genus *Musculus* Röding, 1798**

**Definition.**- Outline modioliform. Shell small. Equivalve. Beaks subterminal. Sculpture of radiating riblets except on median area which is smooth or concentrically striate. Dysodont teeth present. Inner margins crenulate throughout except at median area of margin.

**Material examined.**- ZRC1991.6130, ZRC1991.6121 (Pulau Semakau).

**Remarks.**- One indeterminable species was recorded from the sample.

**Genus *Perna* Retzius, 1788**

**Definition.**- Outline mytiliform; wedge shaped. Equivalve with terminal beaks. Shell with concentric growth lines. Inner margins smooth. Anterior adductor muscle scar absent. Posterior retractor scars widely separated.

**Material examined.**- ZRC1991.17708-17710, ZRC1991.17829- 7834, ZRC1991.17821 -7828, ZRC1991.18036, ZRC1993.2543-2545, ZRC1993.2529, ZRC1990.3519-3529, ZRC1990.3660-3674, ZRC1990.3811-3815, ZRC1990.2213, ZRC1991.13439, ZRC1991.12827, ZRC1991.12250, ZRC1994.4303-4310 (Sungei Buloh), ZRC1990.620-621, ZRC1991.9737, ZRC1991.1372 (Singapore River).

**Remarks.**- *P. viridis* (Linnaeus, 1758) was identified from the collection.

FAMILY NUCULANIDAE ADAMS & ADAMS, 1858

**Genus *Nuculana* Link, 1807**

**Definition.**- Outline subovate. Posteriorly subrostrate. Equivalve. Hinge with numerous small teeth. Ligament internal. Rostrum demarcated by a strong posterior sulcus. Sculpture partly oblique.

**Material examined.**- ZRC1991.16417-16426, ZRC1991.16404, ZRC1990.4215-4219 (Pulau Tekong).

**Remarks.**- One indeterminable species was identified from this sample.

**Genus *Yoldia* Möller, 1842**

**Definition.**- Outline elongate-ovate. Thin shelled. Shell gaping in most. Pallial sinus deep and wide. Resilium pit large.

**Material examined.**- ZRC1991.16427 (Pulau Tekong).

**Remarks.**- One indeterminable species was identified from the collection.

FAMILY NUCULIDAE GRAY, 1824

**Genus *Nucula* Lamarck, 1799**

**Definition.**- Outline ovate to ovate-trigonal. Shells small in size. Equivalve. Taxodont dentition. Ligament internal. Periostracum smooth and maybe shiny. Inner margin denticulate.

**Material examined.**- ZRC1991.7620, ZRC1991.8328, ZRC1991.7622, ZRC1991.8329-8330, ZRC1991.7374, ZRC1991.8865, ZRC1991.7618, ZRC1991.6298, ZRC1991.6349, ZRC1991.6295, ZRC1992.5588-5589, ZRC1993.963, ZRC1993.1194 (Pulau Semakau), ZRC1990.2126-2130 (West Johore Straits), ZRC1991.16327-16328, ZRC 1991.16327-16328, ZRC1991.16455, ZRC1991.16446, ZRC1991.16360-16403, ZRC1991.16414-6415, ZRC1991.16460 (Pulau Tekong).

**Remarks.**- Two indeterminable species were observed from the collection.

FAMILY OSTREIDAE RAFINESQUE, 1815

**Genus *Ostrea* Linnaeus, 1758**

**Definition.**- Outline subcircular. Size small to large. Lower valve cemented. Upper valve flat to weakly concave. Adductor muscle scar kidney shaped. Colour white and often with shades of purple.

**Material examined.**- ZRC1991.15282-15286, ZRC1990.7336-7340 (Pulau Tekong), ZRC1990.6560 (Singapore River).

**Remarks.**- Two indeterminable species were noted from this sample.

**Genus *Saccostrea* Dolfuss & Dautzenberg, 1920**

**Definition.**- Outline irregular; usually subcircular. Shells medium sized. Lower valve cemented to substrate. Ligament elongated. Upper valve flat. Attachment muscle scar kidney shaped. Nodular chomata usually present around margins. Colouration white internally with a purple-black border. Muscle scar may be darker than surrounding shell area. Outside coloured shades of purple-black.

**Material examined.**- ZRC1990.7335 (Pulau Tekong).

**Remarks.**- One indeterminate species was identified from this sample.

FAMILY PECTINIDAE RAFINESQUE, 1815

**Genus *Chlamys* Roding, 1798**

**Definition.**- Shells small to medium in size. Upper and lower valves convex. Anterior auricles large. Sculpture of many radial riblets or ribs with scales.

**Material examined.**- ZRC1990.4190-4195 (Pulau Tekong), ZRC1992.5597, ZRC1992.5595, ZRC1992.5565 (Pulau Semakau).

**Remarks.**- Two indeterminable species were recorded in the collection.

**Genus *Decatopecten* Rüppell in Sowerby, 1839**

**Definition.**- Shell medium in size. Left valve slightly flatter than right valve. Compressed. Outline subcircular-elongate. Auricles small. Strong cardinal crura present. Sculpture of broad ribs. Radial threads present. Byssal notch absent or small. Ctenolium absent.

**Material examined.**- ZRC1991.6296 (Pulau Semakau).

*Remarks.*- One indeterminable species was noted in the collection.

FAMILY PSAMMOBIIDAE FLEMING, 1828

**Genus *Gari* Schumacher, 1817**

*Definition.*- Outline subtrapezoidal. Shell small to medium in size. Equivalve. Gape present. Posterior area with carina. Sculpture present in lines all over with the exception of the posterior area. Hinge has 1-3 cardinals. Laterals weak or absent. Pallial sinus deep.

*Material examined.*- ZRC1990.8110 (Kallang Basin).

*Remarks.*- Only one specimen was observed as an indeterminable species.

FAMILY SOLECURTIDAE D'ORBIGNY, 1846

**Genus *Tagelus* Gray, 1847**

*Definition.*- Outline elongated. Narrow. Surface smooth. Periostracum present. Two teeth per valve. Pallial sinus deep, reaching to or beyond the midline and partly confluent with the pallial line.

*Material examined.*- ZRC1993.1239, ZRC1993.1236-1235, ZRC1993.1230-1235, ZRC1993.2347-2348, ZRC1991.17799-17800, ZRC1991.18498 (Sungei Buloh).

*Remarks.*- Specimens were identified as one distinct indeterminable species.

FAMILY SOLENIDAE LAMARCK, 1809

**Genus *Solen* Linnaeus, 1758**

*Definition.*- Outline cylindrical; flattened. Shell small to medium in size. Equivalve. Beaks are terminal. One cardinal tooth in each valve. Anterior adductor muscle scar elongate.

*Material examined.*- ZRC1990.6262-6266, ZRC1990.6448-6548, ZRC1990.6250-6260, ZRC1990.6247, ZRC1990.7918-7956, ZRC1990.7957, ZRC1990.7958-7960, ZRC1991.1333-1346, ZRC1991.1347, ZRC1991.1374-1378, ZRC1991.1390, ZRC1991.10036-10049, ZRC1991.10033, ZRC1991.9714-9732, ZRC1992.8598-8599, ZRC1992.8602-8604, ZRC1992.8605-8606, ZRC1992.8612, ZRC1992.8614, ZRC1992.8619, ZRC1992.8638-8737 (Singapore River), ZRC1990.2222, ZRC1990.2209-2210, ZRC1990.3603, ZRC1990.3369-3517, ZRC1990.3757-3764, ZRC1990.3683, ZRC1991.13440-13441, ZRC1991.12803-12820, ZRC1991.12778, ZRC1991.12772, ZRC1991.12774-12775, ZRC1991.12767-12770, ZRC1991.13660-13661, ZRC1991.12166-12196, ZRC1991.13433-13434, ZRC1991.13430-13431, ZRC1991.13429, ZRC1991.17693, ZRC1991.17699, ZRC1992.7663-7666, ZRC1992.7631, ZRC1991.7653-7655, ZRC1991.12149-12165, ZRC1991.17931, ZRC1991.17979-18035, ZRC1991.18441-18487, ZRC1993.2349-2353, ZRC1993.2357-2361, ZRC1993.2339, ZRC1993.2464-2467, ZRC1993.2435-2444, ZRC1993.2378-2379, ZRC1992.7452, ZRC1992.7567, ZRC1992.7619, ZRC1992.7679, ZRC1993.2405-2416, ZRC1993.2377, ZRC1993.2379, ZRC1993.2519, ZRC1993.2515-2518, ZRC1993.2505-2508, ZRC1993.2521-2524, ZRC1993.2531-2535, ZRC1993.2537, ZRC1993.2526-2528, ZRC1993.2541-2542, ZRC1993.2546-2549, ZRC1993.2553-2555, ZRC1993.2583, ZRC1993.2559-2562,

ZRC1993.2558, ZRC1993.2587-2589, ZRC1993.2596-2598, ZRC1993.2575, ZRC1993.2572, ZRC1993.2392-3394 (Sungei Buloh), ZRC1991.7423, ZRC1991.7520, ZRC1993.1216, ZRC1991.6119 (Pulau Semakau), ZRC1990.7272-7277, ZRC1990.7284-7285, ZRC1990.7280-7283, ZRC7825-7829, ZRC1990.7830, ZRC1990.7841-7843, ZRC1990.7831-7838, ZRC1990.7840, ZRC1990.7844, ZRC1990.7715, ZRC1990.8507-8515, ZRC1990.8516, ZRC1990.8524-8531, ZRC1990.7754-7776, ZRC1990.7787, ZRC1990.8253, ZRC1990.8055-8056, ZRC1990.8250, ZRC1990.8080-8102, ZRC1990.8158-8160, ZRC1990.8153-8154 (Kallang Basin), ZRC1990.4220-4221, ZRC1990.4203-4205, ZRC1990.4170-4172 (Pulau Tekong).

**Remarks.**- The entire collection of this genus belonged to one indeterminable species.

#### FAMILY TELLINIDAE DE BLAINVILLE, 1814

##### Genus *Tellina* Linnaeus, 1758

**Definition.**- Shell somewhat elongate; ligament external. Valves more or less unequal. Most forms with posterior flexure, especially in right valve. Lateral teeth present in at least one valve. Two cardinals present. Sculpture varies.

**Material examined.**- ZRC1990.2125, ZRC1990.2131-2133 (West Johore Straits), ZRC1990.4175-4178, ZRC1991.11336, ZRC1991.16456, ZRC1991.16408-16413, ZRC1991.16335, ZRC1990.4179-4181, ZRC1991.15281, ZRC1990.4201-4202 (Pulau Tekong), ZRC1990.8111, ZRC1990.7268, ZRC1990.7279, ZRC1990.8203-8204, ZRC1990.8147, ZRC1990.7753, ZRC1990.8067, ZRC1990.8111, ZRC1990.8186, ZRC1991.6103, ZRC1990.7269, ZRC1990.7278, ZRC1990.8053, ZRC1990.8501 (Kallang Basin), ZRC1991.18502, ZRC1990.2214-2216, ZRC1990.3765, ZRC1993.2367-2371, ZRC1992.7598, ZRC1991.12771, ZRC1992.7573-7575, ZRC1990.3765, ZRC1993.2576-2580, ZRC1993.2340, ZRC1993.2590-2592, ZRC1992.7550-7555, ZRC1993.2569, ZRC1992.7580-7581, ZRC1992.7569-7570, ZRC1991.12199-12209, ZRC1993.2354-2356, ZRC1990.3756, ZRC1991.12795-12802, ZRC1992.7650-7651, ZRC1993.2582, ZRC1993.2423-2429, ZRC1993.2383-2387, ZRC1990.3716-3738, ZRC1993.2539-2546, ZRC1993.2400-2403, ZRC1993.2530, ZRC1991.13436-13438, ZRC1993.2418-2422, ZRC1993.2496-2501, ZRC1992.7585, ZRC1993.2472-2474, ZRC1993.2463, ZRC1991.12785-12789, ZRC1991.18499, ZRC1991.17920-17921, ZRC1991.18431, ZRC1991.18601, ZRC1991.17929, ZRC1990.3625, ZRC1991.18435-18438, ZRC1990.2211-2212, ZRC1991.17932-17933, ZRC1990.2217-2218, ZRC1991.18432, ZRC1990.2219, ZRC1991.18491-18495, ZRC1991.12783, ZRC1990.2223, ZRC1990.2208, ZRC1990.3531-3572, ZRC1991.12776-12777, ZRC1991.12779-12781, ZRC1992.8600, ZRC1992.7613-7614, ZRC1991.18439-18440, ZRC1992.7591, ZRC1993.2556, ZRC1992.7576, ZRC1992.7668, ZRC1993.2557, ZRC1993.2600, ZRC1992.7656, ZRC1993.2471, ZRC1991.17922-17928, ZRC1991.17798, ZRC1991.18496-18497, ZRC1992.7618, ZRC1990.3684-3902, ZRC1992.7487-7488, ZRC1992.7624, ZRC1991.17934-17950, ZRC1993.2509, ZRC1992.7501, ZRC1992.7660-7662, ZRC1992.7667 (Sungei Buloh), ZRC1990.7854-7910, ZRC1990.7962-7963, ZRC1991.1325-1328, ZRC1991.10053-10056 (Singapore River),

**Remarks.**- Only one species, *T. (Pistris) serricostata* Tokunaga, 1906 was identified with five other indeterminable species in the material examined.

#### FAMILY TRAPEZIIDAE LAMY, 1920

##### Genus *Coralliophaga* Blainville, 1824

**Definition.**- Outline oblong-elongate. Shell medium sized. Thin. Equivalve. Beaks close to the anterior. Hinge has two cardinals and one posterior lateral tooth in each valve. Sculpture of radiating lines and elevated concentric lamellae posteriorly. Pallial sinus shallow.

**Material examined.**- ZRC1993.2520, ZRC1993.1248, ZRC1993.2362-2366, ZRC1993.2318 (Sungei Buloh).

**Remarks.**- Specimens were identified as *C. coralliophaga* (Gmelin, 1791).

FAMILY UNGULINIDAE ADAMS & ADAMS, 1857

**Genus *Diplodonta* Bronn, 1831**

**Definition.**- Outline suborbicular to subovate. Shell small to medium in size. Equivalve. Sculpture of concentric lines only; more or less smooth. Two cardinal teeth in each valve. Median tooth bifid. Ligament visible externally. Anterior adductor scar confluent with pallial line. Inner margin without crenulations.

**Material examined.**- ZRC1992.7583-7584, ZRC1991.17918, ZRC1992.7489-7499, ZRC1992.7658-7659, ZRC1992.7622-7623, ZRC1991.18507, ZRC1991.18508-18510, ZRC1993.2343, ZRC1992.7502, ZRC1992.7625 (Sungei Buloh), ZRC1991.6310, ZRC1991.6131 (Pulau Semakau).

**Remarks.**- Two indeterminable species were noted in the material examined.

FAMILY VENERIDAE RAFINESQUE, 1815

**Genus *Anomalocardia* Schumacher, 1817**

**Definition.**- Outline ovate-trigonal. Thick shell. Shell with undulating concentric folds crossed by radial riblets. Lunule large. Pallial sinus short and ascending.

**Material examined.**- ZRC1993.2581, ZRC1991.17951-17952, ZRC1992.7630 (Sungei Buloh), ZRC1990.7916 (Singapore River), ZRC1990.7747-7748, ZRC1990.8201, ZRC1990.8182 (Kallang Basin).

**Remarks.**- *A. squamosa* (Linnaeus, 1758) was observed from the sample.

**Genus *Dosinia* Scopoli, 1777**

**Definition.**- Outline lenticular. Shell size small to medium. Equivalve. Sculpture of concentric lines and low lamellae. Three cardinals per valve. Anterior laterals short. Ligament sunken. Pallial sinus deep; ascending. Inner margins smooth.

**Material examined.**- ZRC1991.18505-18506, ZRC1993.2567, ZRC1993.2574, ZRC1993.2585, ZRC1991.17695, ZRC1991.17794-17796, ZRC1993.2593-2595, ZRC1991.13449-13450, ZRC1990.2167, ZRC1992.7507, ZRC1992.7450, ZRC1992.7556-7561, ZRC1993.2458-2461, ZRC1992.7586-7588, ZRC1993.2396, ZRC1992.7568, ZRC1992.7601-7612, ZRC1992.7669-7670, ZRC1993.7238, ZRC1993.1229, ZRC1993.2341-2346, ZRC1993.2381-2382, ZRC1993.2338, ZRC1993.2510-2512, ZRC1992.7481-7486, ZRC1993.2492-2495, ZRC1992.7582, ZRC1993.2417, ZRC1992.7615, ZRC1992.7620-7621, ZRC1991.17919, ZRC1992.7617, ZRC1991.18490, ZRC1992.7680, ZRC1993.2335-2337, ZRC1993.2450-2453, ZRC1993.2480-2485, ZRC1993.2550-2552 (Sungei Buloh), ZRC1990.2117-2119 (West Johore Straits), ZRC1990.4173, ZRC1991.16332-16334 (Pulau Tekong), ZRC1991.6105-6107, ZRC1990.7737-7738 (Kallang Basin).

**Remarks.**- *D. cf diana* was observed from the sample together with two indeterminate species.

### Genus *Gafrarium* Röding, 1798

**Definition.**- Outline quadrate to subovate. Shells medium in size. Equivalve. Sculpture of radial riblets, that may be dichotomous. Three cardinals in each valve. Anterior laterals well developed. Pallial sinus shallow.

**Material examined.**- ZRC1990.4168 (Pulau Tekong).

**Remarks.**- *Gafrarium divaricatum* (Gmelin, 1791) was identified from the sample.

### Genus *Irus* Schmidt, 1818

**Definition.**- Outline is oblong and anteriorly narrowed. Shells medium sized. Equivalve. Sculpture of fine radial grooves and thin concentric lamellae. Three cardinals in each valve. Pallial sinus deep.

**Material examined.**- ZRC1991. 1324 (Singapore River).

**Remarks.**- One indeterminate species was observed from the sample.

### Genus *Marcia* H. & A. Adams, 1857

**Definition.**- Outline ovate-cordate. Shells medium sized. Inflated. Equivalve. Lunule large but not sunken. Sculpture ribbed or smooth. Three cardinals in each valve. Lateral teeth absent. Pallial sinus quite deep and rounded. Inner margin smooth.

**Material examined.**- ZRC1993.2397-2398, ZRC1991.17789-17793, ZRC1992.7592, ZRC1990.3773-3781, ZRC1990.3805-3806, ZRC1991.12248-12249, ZRC1990.3573-3602, ZRC1990.3810, ZRC1990.3767-3772, ZRC1990.3807-3808, ZRC1990.3675-3681, ZRC1990.3656-3659, ZRC1990.3626, ZRC1991.13451-13457, ZRC1991.12829-12831, ZRC1991.12238-12243, ZRC1991.17966, ZRC1992.7577-7578, ZRC1991.17711-17719, ZRC1993.7589, ZRC1992.7589, ZRC1991.17801-17802, ZRC1993.2496-2487(Sungei Buloh), ZRC1990.6437, ZRC1992.8613, ZRC1992.8635, ZRC1990.8031-8032, ZRC1990.8030, ZRC1991.1350, ZRC1991.10035 (Singapore River), ZRC1991.4167 (Pulau Tekong).

**Remarks.**- *M. japonica* (Gmelin, 1791) and *M. hiantina* (Lamarck, 1818) were identified from the sample.

### Genus *Paphia* Röding, 1798

**Definition.**- Outline elongate, narrowed posteriorly. Shells medium sized; compressed. Lateral teeth absent. Shell sculpture concentric or smooth and glossy. Pallial sinus ascending.

**Material examined.**- ZRC1993.2317, ZRC1993.2347-2348, ZRC1993.2430-2432, ZRC1990.3652, ZRC1991.13432, ZRC1993.1128, ZRC1991.1239, ZRC1993.1236-1237, ZRC1993.1230-1235,

ZRC1993.1247, ZRC1993.2178-2179, ZRC1993.1240-1246 ZRC1993.2425-2479, ZRC1993.1240-1246, ZRC1991.17694, ZRC1991.17696-17698, ZRC1991.17692, ZRC1991. 17803-17830, ZRC1992.7571-7572, ZRC1991.13459-13479, ZRC1991.17953-17954, ZRC1992.7593-7597, ZRC1991.12828, ZRC1991.17957-17962, ZRC1992.7579, ZRC1991. 12210-12237, ZRC1991.18503-18504, ZRC1990.3702-3804, ZRC1990.3624, ZRC1991. 13445-13448, ZRC1991.17720-17788 (Sungei Buloh), ZRC1990. 4432-4438, ZRC1990.4169, ZRC1991.15272-15273, ZRC1991.15279, ZRC1991.15280, ZRC1991.16458-16459 ZRC1991. 16330-16331 (Pulau Tekong).ZRC1990.2121-2122, ZRC1990.2108-2113, ZRC1990.2104-2106, ZRC1990.2120, ZRC1990.2114, ZRC1990.2107 (West Johore Straits), ZRC1990.8517, ZRC1990.7739-7946, ZRC1990.8104-8105, ZRC1990. 8213-8217, ZRC1990.8178, ZRC1990. 7845, ZRC1990.7846, ZRC1990.7777-7783, ZRC1990.8211, ZRC1990.8106-8108, ZRC1990. 7266 ZRC1990.8202 (Kallang Basin),ZRC1991.1323, ZRC1991.9747, ZRC1991.10052 ZRC1991. 9735-9736, ZRC1992.8620 (Singapore River).

**Remarks.-** *P. undulata* (Born,1778) and *P. semirugata* (Philippi, 1847) were observed from the sample..

### Genus *Pitar* Römer, 1857

**Definition.-** Outline subovate to subtrigonal. Shells small to medium in size. Equivalve. Umbo positioned slightly to the anterior. Lunule and escutcheon absent or poorly defined. Sculpture usually smooth, sometimes weakly lamellate. Three cardinals in each valve. Median cardinal in left valve triangular in shape. Anterior laterals prominent. Pallial sinus deep and pointed. Inner margins smooth.

**Material examined.-** ZRC1990.4421-4431, ZRC1990.4174, ZRC1990.4200 (Pulau Tekong), ZRC1992.7652 ZRC1993.2457, ZRC1991.12244, ZRC1990.2207, ZRC1991.11277-11278, ZRC1993.2380, ZRC1993.2375 (Sungei Buloh). ZRC1990.8048-8052 (KallangBasin)ZRC1991. 6104, ZRC 1990.7785.

**Remarks.-** Three indeterminate species were observed from the sample.

### Genus *Placamen* Iredale, 1925

**Definition.-** Shell quite small. Thick shelled. Outline subcircular to subtrigonal. Equivalve. Outer surface with regularly spaced concentric lamellae. Pallial sinus shallow, trigonal and pointed. Anterior adductor muscle scar larger than the posterior scar. Inner margin finely crenulated.

**Material examined.-** ZRC1990.4165-4166, ZRC1990.4188-4189, ZRC1990.4182-4183, ZRC1991.15274-15277, ZRC1991.16329, ZRC1990.4206-4208, ZRC1990.4209-4213 (Pulau Tekong), ZRC1990.9120, ZRC1990.8243 (Kallang Basin), ZRC1991.10050 (Singapore River).

**Remarks.-** *P. chloroticum* (Philippi, 1849) and *P. calophyllum* (Philippi, 1836) were observed from the collection.

### Genus *Tapes* Mergerle von Muhlfeldt, 1811

**Definition.-** Outline ranging from rhomboidal to oblong. Narrowed anteriorly. Shell size ranges from medium to large. Equivalve. Slightly compressed. Sculpture of concentric lines and ridges. Three cardinal teeth per valve. Laterals absent. Pallial sinus prominent.

**Material examined.**- ZRC1993.1247, ZRC1993.2373 (Sungei Buloh).

**Remarks.**- One indeterminate species was recorded from the sample.

## RESULTS

A total of 10,829 specimens were examined and identified. The most common genus was *Mytilopsis* with 5,500 individuals (50.8%) making up half the total number collected. These were mainly collected from Singapore River. The next most common genus was *Arcuatula* with 2,819 individuals (26%), collected mainly from Sungei Buloh. The genus *Bucardium* is recorded for the first time from Singapore. Table 1. Shows the distribution of the bivalve genera in Singapore.

**Sungei Buloh.** - This location was sampled over a period of six years from 1988 to 1993. Fifteen families and 23 genera were recorded. Genera such as *Anomia* Linnaeus, 1758, *Tagelus* Gray, 1847, *Tellina (Moerella) Fischer*, 1887, *Anodontia* Link, 1807, *Coralliophaga* Blainville 1824, *Tellina (Pistris)* Thiele, 1934 and *Geloina* Gray 1842 occur here and nowhere else. Over the period of six years, the highest number of specimens collected was in 1990 with 1,392 followed by 1993 with 1,362 specimens. The year with the lowest number of specimens was 1989.

**Singapore River.** - This location was sampled over a six year period from 1987 to 1992. A total of 10 families and 16 genera were recorded here. Total number of individuals collected was 5,932. The family Dressenidae consisted of 5,489 individuals of *Mytilopsis*. Singapore River is the only location where the venerid genus *Irus* Schmidt, 1818 occurred and was represented by one specimen. The family Tellinidae was missing from this station. Over the five year sampling period, sampling done in 1987 yielded the highest number of specimens with 5,235 and in 1990 the lowest with 30 specimens.

**Kallang Basin.** - This location was sampled over a four year period from 1987 to 1990. A total of 10 families and 15 genera were recorded here, making up a total of 280 individuals. The only individual of the genus *Gari* Schumacher, 1817 occurred here. The most common species was *Solen* which was also the most abundantly occurring species in all the years of sampling. A total of 106 specimens were collected. The surveyed year that yielded the most number of individuals was 1989 with 136 specimens.

**West Johore Straits.** - This location was sampled in 1987. Total number of individuals collected was 29. The most abundant genus was *Paphia* Röding, 1778 with 14 specimens. All species found here were also found elsewhere at other locations.

**Pulau Tekong.** - This location was only sampled in 1987. It yielded a total of 13 families and 21 genera with 241 individuals. Pulau Tekong is the only location where *Bucardium* Gray, 1853, *Botula* Mörch, 1853, *Nuculana* Link, 1807, *Yoldia* Möller, 1842, *Saccostrea* Dolfuss and Dautzenberg, 1920 and *Gafrarium* Röding, 1798 occurred. The most commonly occurring genus at this location is *Crassatella* Lamarck, 1799.

**Pulau Semakau.** - Surveys were carried out over a period of five years from 1989 to 1993. A total of 14 families and 18 genera were recorded from here, yielding 82 individuals.

*Pododesmus*, *Corbula* and *Chama* occur here. The only specimen in this study from the family Malleidae, *Vulsella* sp Röding, 1798 is recorded from this location. Also the only recorded specimens of *Chlamys* and *Decatopecten* occur here. The families Veneridae and Tellinidae were conspicuously missing from this location. Both were commonly found at every other sampling location (except Singapore River). Over the five year sampling period, the first survey in the year 1989 yielded the most number of individuals (25). In the following year, numbers dropped from 25 to 14 and in 1993, only 13 specimens were obtained.

## DISCUSSION

The sample represented 26 families and 46 genera. Of the identified genera all are previously known from Singapore. Only the genus *Bucardium* Gray, 1853 has not been previously reported from Singapore.

The greatest generic richness recorded from all samples was at Sungei Buloh (25 genera) and the lowest at West Johore Straits (six genera). This is probably due to the fact that Sungei Buloh was sampled for six consecutive years while West Johore Straits was sampled for only one year. Sungei Buloh also had five collecting stations compared to West Johore Straits' four stations.

The most common bivalve encountered during the surveys was *Mytilopsis sallei* Recluz, 1852 from the family Dressenidae. It was found in large numbers at Singapore River. The abundance of these bivalves could help provide living habitats for other invertebrates such as polychaetes, which use broken pieces of shells and dead leaves to build tubes to live in. The large numbers of *Diopatra* (Polychaetae) in Sungei Buloh could be linked to the large numbers of *Arcuatula* occurring there (Tan,1992).

The next most frequently occurring family was Mytilidae. It was well represented at all locations with the exception of the West Johore Straits. The family was represented by six genera namely *Perna* Retzius,1788, *Musculus* Röding,1798, *Arcuatula* Jousseume MS in Lamy,1919, *Modiolus* Lamarck,1799, *Botula* Mörch,1853 and *Lithophaga* Röding,1798. The latter two are usually found boring into coral heads and also found off islands. The others were found at the more riverine areas (Sungei Buloh, Kallang Basin and Singapore River). The most abundant bivalve of the family was *Arcuatula* that numbered 2,819 individuals in total, mostly concentrated in Sungei Buloh (2,787 individuals).

The three riverine sites were sampled more frequently and had more sampling stations. Large numbers of specimens were present because of the dominance of certain species. Among the riverine locations, Singapore River (16 genera) and Kallang Basin (15 genera) had fewer genera as compared to Sungei Buloh (25 genera). Both Singapore River and Kallang Basin have undergone a massive clean-up operation project involving extensive and constant dredging. Sungei Buloh on the other hand had not been dredged to such a great extent. Polluting activities such as pig farming activities have been stopped. This could account for the high generic richness present at Sungei Buloh as compared to the other two riverine sites.

Pulau Tekong had a higher generic richness compared to Pulau Semakau although Pulau Tekong was sampled only once and Pulau Semakau four times. This could be due to a difference in substrata.

The practice of mariculture is prevalent in Southeast Asia. Oysters, mussels and clams have been cultivated for centuries using ancient methods. In many places in Thailand, Malaysia, Singapore and the Philippines, the green mussel, *Perna viridis* is extensively cultivated and annual production of this mussel in Thailand is in excess of 4,500 metric tons. *Anadara granosa* is also cultivated in this region. In places such as Papua New Guinea and the Palau islands, *Tridacna squamosa* is being successfully raised for meat and shell (Abbott,1991).

Bivalves are regularly consumed in this part of the world. They have enormous potential in being cultivated and being eaten. Species such as *Anadara granosa* (blood cockle) and others of the genus, *Perna viridis*, *Glaucanome* sp, *Paphia undulata* and can be commonly found for sale in local markets. Oysters and the adductor muscles of *Tridacna* are eaten as well. Chai (1966) reported the eating of various mussel species by local fishermen. He gave a list of bivalves that have been used for consumption at one time or other.

Purchon & Purchon 1981 also gave a list of commonly eaten bivalves that included those consumed in Malaysia as well as Singapore. Many of these species are found growing on soft muddy bottoms. Mangroves are ideal places for these and Morton (1983) gave an account of the more commonly occurring families in mangroves and their distribution in the Indo-Pacific region. He equates the great variety and number of bivalves that occur in the mangroves to the rich food supply that the mangroves provide. The rivers and streams that drain through the mangrove (i.e. Sungei Buloh) bring down with them fallen mangrove leaves that degrade and add to the productivity of the system.

The importance of our soft-bottom habitats cannot be emphasised sufficiently. Among the sites sampled, three are in danger. Pulau Semakau is to be used as a landfill site together with nearby Pulau Sakeng. The project will involve the building of a 7-km long bund to connect Pulau Semakau to Pulau Sakeng and the dumping area will cover 350 hectares and have a capacity of 63 million cubic metres (Nathan,1993).

Dredging and reclamation works have already begun in the West Johore Straits to build a new Singapore Customs and Immigration checkpoint and a second link bridge to Johore, Malaysia (Tan,1994). Singapore River is to be deepened to allow for more traffic and activities. Starting in the year 1997, jet grouting will be used to strengthen the soft marine clay (Anon,1994).

Organisms that inhabit soft-bottoms live closely with or within the top one metre of the seabed and few are found deeper than this. Dredging work causes the seabed to be rapidly removed and sedimentation levels to increase due to perturbation of the substrate. Attached and slow moving organisms such as bivalves tend to get dredged along with the sediment. In Singapore, dredging is carried out constantly along the harbour, waterways and shipping lanes to facilitate maritime activities. The removal of these bivalves could affect dependant organisms at higher trophic levels.

Sedimentation caused by reclamation and dumping is a great threat to sessile and slow moving organisms. High levels of suspended sediments can clog the gills of bivalves and also cause abrasion. Dumping of waste and earth spoils from dredging activities in vast quantities also literally smothers bottom dwellers. Untreated industrial waste and sewage discharged into the water can be accumulated by bivalves that are filter-feeders. This can give rise to Hepatitis viruses and heavy metal poisoning in humans and other animals that

are consumers of these infected bivalves (Hodgson, 1994).

Benthic organisms perform important roles in nutrient cycling, by feeding on microscopic life and in return providing materials through their wastes to maintain microscopic life. The economic and ecological importance of benthic communities such as those of the bivalves studied is very often not realised. Chou (1994) attributes this to the fact that these benthic habitats are submerged and hence seldom seen.

Activities such as reclamation, dredging, discharge of toxic pollutants and wastes should be assessed and proper management of these areas must take place. Proper management will enable benthic habitats to carry out their vital functions and maintain their usefulness to man.

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### LITERATURE CITED

- Abbott, R.T., 1991. *Seashells of South East Asia*. Tynron press, Scotland. 145 pp.
- Abbott, R.T. & S.P. Dance, 1982. *Compendium of seashells*. Dutton, E.P., INC, New York 411 pp.
- Anonymous, 1994. S'pore River to be deepened to allow for more activities. *The Straits Times*, 24 August, 1994.
- Chai, H.L., 1966. A note on the mussels (Mytilidae, Bivalvia) and their distribution in Singapore and Malayan waters. *Journal of University of Singapore Science Society*: 40-51.
- Chai, H.L., 1966. Food from the sea- mollusca. A list of edible molluscs from Malaya and Singapore. *Journal of University of Singapore Science Society*: 95-99.
- Chou, L.M., 1994. Marine soft bottom benthic habitats - An invaluable but unappreciated resource. In: C.R. Wilkinson (ed.), *Proceedings Third ASEAN-Australia Symposium on Living Coastal Resources: Management Forum*. Australian Institute of Marine Science, Australia. 133 pp.
- Chou, L.M. & H.W. Khoo, 1990. The influence of treated sewage outfall on the distribution of nearshore benthic organisms. In: H.T. Yap, M. Bohle-Carbonell and E.D. Gomez (eds.), *Oceanography and Marine Pollution: An ASEAN-EC Perspective*. Philippines: Marine Science Institute, University of the Philippines, 1990: 225-237.
- Chuang, S.H., 1972. Sea Shells. In: S.H. Chuang (ed.), *Animal life and nature in Singapore*. Singapore University Press. 302 pp.
- Chuang, S.H., 1961. *On Malayan Shores*. Muwu Shosa Publication, Singapore. 225 pp.

- Chuang, C.T.N., B.P.L Goh & L.M. Chou, 1992. Distribution of soft-bottom benthic molluscs in Singapore. In: L.M.Chou and C.R. Wilkinson (eds.), *Third ASEAN Science and Technology Week Conference Proceedings, Vol 6, Marine Science: Living Coastal Resources*, 21-23 Sept 1992. Department of Zoology, National University of Singapore & National Science and Technology Board. 471 pp.
- English, S., C. Wilkinson & V. Baker, 1994. *Survey Manual For Tropical Marine resources. ASEAN-Australia Marine Science Project: Living Coastal Resources*. Australian Institute of Marine Science. Townsville. 368 pp.
- Hodgson, G., 1994. *The environmental impact of marine dredging in Hong Kong*. Coastal Management in Tropical Asia. March 1994.
- Lee, D., 1972. *A preliminary survey of the macrobenthos of the East Johore Straits*. Unpublished BSc (Hons) thesis. Department of Zoology. University of Singapore. 87 pp.
- Lim, C.F., 1963a. *Guide to the families of Malaysian Marine Bivalves*. Unpublished report, Department of Zoology, University of Singapore. 28 pp.
- Lim, C.F., 1963b. A preliminary illustrated account of mangrove molluscs from Singapore and South-West Malaya. *Malayan Nature Journal*, **17**: 235-240.
- Morton, B., 1983. Mangrove bivalves. In: Wilber, K.M. (ed.), *The Mollusca*. Vol 6. Ecology. Academic Press - New York. 360 pp.
- Nathan, D., 1993. Measures in place to prevent pollution at landfill site. *The Straits Times*, November 1, 1993.
- Oliver, R.G., 1992. *Bivalved seashells of the Red Sea*. Verlag Christa Hemmen F.R.G and National Museum of Wales. 330 pp.
- Purchon, R.D. & S. Morris, 1981. The marine shelled molluscs of West Malaysia and Singapore. Part 3. Bivalvia. *Journal of Molluscan Studies*, **47**: 322-327.
- Tan, L.C., 1994. Dredging work starts on S'pore end of 'second link' bridge. *The Straits Times*, October 12, 1994.
- Tan, L.T., 1992. *Taxonomy and distribution of soft bottom benthic polychaetes in Singapore*. Unpublished BSc (Hons) thesis. Department of Zoology. National University of Singapore. 168 pp.

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