Identification of Mollusc Remains (Bivalve and Gastropod) from Archaeological Sites in Semporna, Sabah

Authors:
Deejay Daxter A. Albert, Velat Bujeng and Stephen Chia*

*Correspondence: stephen@usm.my

DOI: https://doi.org/10.21315/tlsr2022.33.2.10

Highlights

- Mollusc remains acquired through excavation of three archaeological sites in Semporna, Sabah namely Bukit Tengkorak, Melanta Tutup and Bukit Kamiri were identified.
- 90 taxa of molluscan species had been identified, where 30 are bivalves and 60 are gastropods.
- Species richness, indicated by NTAXA value, between the three sites preliminarily indicates different level of selectivity in gathering molluscs among ancient communities in different sites, possibly due to different proximity of sites to the coastline.
Identification of Mollusc Remains (Bivalve and Gastropod) from Archaeological Sites in Semporna, Sabah

Deejay Daxter A. Albert, Velat Bujeng and Stephen Chia*

Centre for Global Archaeological Research, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia

Publication date: 30 June 2022
To cite this article: Deejay Daxter A. Albert, Velat Bujeng and Stephen Chia. (2022). Identification of mollusc remains (bivalve and gastropod) from archaeological sites in Semporna, Sabah. Tropical Life Sciences Research 33(2): 197–237. https://doi.org/10.21315/tlsr2022.33.2.10
To link to this article: https://doi.org/10.21315/tlsr2022.33.2.10

Abstract: This paper discusses the identification of mollusc (bivalve and gastropod) remains from three archaeological sites in Semporna, Sabah, namely Bukit Tengkorak, Melanta Tutup and Bukit Kamiri, dated to the prehistoric period, from 3,000 to 800 years ago. Samples of mollusc remains used in this study were obtained from a series of archaeological excavations conducted at these three sites by the Centre for Global Archaeological Research, Universiti Sains Malaysia (CGAR, USM), Penang in collaboration with the Sabah Museum Department (SMD) from 1994 to 2007. In total, 90 taxa of molluscan species, of which 30 are bivalves and 60 are gastropods, had been identified. Out of 90, there were 55 taxa identified to the species level, of which 18 are bivalves and 37 are gastropods. They consisted mainly of marine species with small numbers of freshwater, brackish and terrestrial species. This study had provided new data and insights into the distribution and exploitation of molluscs by ancient human societies in different environments in Semporna, which will be useful not only for malacological research in the tropics but also for future biological and environmental studies in Sabah, Malaysia as well as for the Southeast Asian and Pacific regions.

Keywords: Mollusc Remains, Archaeomalacology, Archaeological Sites, Semporna, Prehistory

Abstrak: Artikel ini membincangkan tentang identifikasi tinggalan moluska (dwicangkerang dan gastropod) dari tiga tapak arkeologi di Semporna Sabah, iaitu Bukit Tengkorak, Melanta Tutup dan Bukit Kamiri, daripada zaman prasejarah 3,000 ke 800 tahun yang lalu. Sampel tinggalan moluska yang digunakan dalam kajian ini diambil daripada beberapa siri ekskavasi arkeologi yang dijalankan di tiga tapak oleh Pusat Penyelidikan Arkeologi Global, Universiti Sains Malaysia, Pulau Pinang, dengan kerjasama Jabatan Muzium Sabah daripada tahun 1994 sehingga 2007. Sebanyak 90 taxa spesies moluska telah dikenalpasti iaitu 30 daripadanya adalah dwicangkerang dan 60 adalah gastropod. Daripada 90 taxa tersebut, 55 taxa dikenalpasti pada tahap spesies, manakala 18 adalah dwicangkerang dan 37 adalah gastropod. Kebanyakan taxa tersebut terdiri daripada spesies marin termasuk

*Corresponding author: stephen@usm.my

© Penerbit Universiti Sains Malaysia, 2022. This work is licensed under the terms of the Creative Commons Attribution (CC BY) (http://creativecommons.org/licenses/by/4.0/).
INTRODUCTION

One of the most common biological materials recovered from archaeological sites during excavations is the remains of bivalve and gastropod from the phylum Mollusca. Animals from the phylum Mollusca usually have a calcium carbonate exoskeleton called the ‘shell’ that is hard and durable in nature that could survive well when buried in the soil (Claassen 1998; Thomas 2015a). Hence, more often than not, only molluscs with shells are found during archaeological excavations, particular from the classes Bivalvia and Gastropoda, while the other classes, especially the shell-less ones like Aplacophora and Monoplacophora are seldom found in the archaeological context (Claassen 1998; Bar-Yosef Mayer 2005; 2007; Reitz & Wing 2008; Thomas 2015a). Mollusc remains are defined as the pieces or parts of the shells of molluscs that are buried underground and uncovered during archaeological excavations. In other words, mollusc remains are dead specimens consisting of only the empty shells of the molluscs. Hence, identification of mollusc remains depends solely on the morphology of the shell. Some archaeologists used the term ‘shell remains’, but the term ‘mollusc remains’ is used because certain animals not from the phylum Mollusca also have shells, such as tortoises, turtles and Crustacean (such as crabs, prawn or mantis shrimp).

In archaeology, the study of mollusc remains in the archaeological contexts is defined as archaeomalacology, which is the sub-field of archaeozoology. The most common contribution in archaeomalacological studies is the interpretation of ancient human diet and subsistence by identifying and quantifying the taxa of mollusc remains found in an archaeological site (Zulkifli et al. 1992; Szabo 2009; Gani et al. 2013; Bujeng 2018). In most cases, a large number of molluscs remains found in an archaeological site that does not occur naturally there would indicate that they were actually gathered and brought into the sites by humans for their sustenance (Thomas, 2015b). Identifying these mollusc remains can help in determining their species and original habitats, which could provide useful data on past environments, movement of humans and their strategies in searching and gathering, as well as the adaptive change of past humans in exploiting molluscs over time (Shackleton & van Andel 1986; Ono et al. 2009; Habu et al. 2011). In addition, archaeomalacological study can help determine the exploitation and use of molluscs by ancient human in the production of artefacts such as ornaments and tools (Szabo 2010; Pawlik et al. 2015; Langley & O’Connor 2016; Insoll 2021).
In biological science, the study of archaeomalacology could be beneficial in determining the distribution of molluscan species over time. Many biological science studies, especially in malacology, had employed archaeological data and records on mollusc species to determine and map the origin, presence or extinction of certain species in a particular region over time (Tebano & Paulay 2000; Giokas et al. 2010; Argente 2016; Mayor & Ancog 2016; Neo et al. 2017; Thaman et al. 2017). The study of modern-day molluscan species, on the other hand, had also benefited and assisted archaeology in identifying ancient mollusc remains from archaeological sites (Meehan 1982; Rouse & Evans 1994; Welter-Schultes 2008). The same can also be said vice versa especially in terms of shell morphometric (Faulkner 2010; Ash et al. 2013; Fiori et al. 2019). In addition, Thaman et al. (2017) had shown how time-depth perspectives on molluscan species with the incorporation of archaeological data could provide a wealth of information on the ecology, evolution and structure of past marine ecosystems as well as the history of human impacts on the environments. In short, archaeomalacology is a significant field of study that is beneficial not only in the study of the past but also for the present.

Bukit Tengkorak was briefly excavated in 1987 by Peter Bellwood with the assistance of SMD (Bellwood 1989). Following this, several archaeological excavations were conducted from 1994–2007 by a research team headed by Stephen Chia from CGAR, USM in collaboration with the SMD team at Bukit Tengkorak, Melanta Tutup and Bukit Kamiri (Chia 2003; 2008; 2009). These detailed excavations by CGAR, USM at the three sites had uncovered a significant amount of archaeological data and materials which had been radiocarbon dated to the Late Prehistoric period from about 3,000 to 800 years ago (Chia 2003; 2008; 2014; 2016). The archaeological materials excavated from these sites consisted of human burials, ornaments, earthenware sherds, lithic artefacts, bone artefacts, animal and fish bones as well as a considerable amount of mollusc remains.

In terms of mollusc remains excavated from the three archaeological sites in Semporna, those from Bukit Tengkorak had been analysed earlier by Bellwood (1989) and Chia (2003; 2014). However, their analyses which included identifications of the taxa of mollusc samples and the quantification of these specimens were done based on weight and number of identified specimens. This method of analysis is often considered to be outdated now in comparison with the recent archaeomalacological method of analysis. Moreover, some of the mollusc species previously identified by these researchers could have been misidentified since the identifications were not done using the latest taxonomic data from the MolluscaBase (2020) database.

Elsewhere in Semporna, mollusc remains excavated from Melanta Tutup and Bukit Kamiri had been preliminarily analysed by Albert et al. (2017; 2018), Bujeng and Albert (2016; 2017) and Chia (2008). The mollusc identification from Melanta Tutup and Bukit Kamiri had so far been reported to class level only by Chia (2008), while Albert et al. (2017) and Bujeng and Albert (2016; 2017) had published mollusc species identified from mollusc remains excavated only from the upper layers (0 cm–30 cm depth) of these two sites. In addition, the
mollusc assemblage from Melanta Tutup identified by Albert et al. (2018) had some outdated nomenclature based on the MolluscaBase (2020) database. For example, the giant clams that were previously listed as a family (Tridacnidae) had now been updated to the subfamily Tridacniniae under the family Cardiidae.

Given the various issues and problems in the previous analyses of mollusc remains from the sites in Semporna, this present study intends to conduct a more detailed and comprehensive study of all the mollusc remains excavated from Bukit Tengkorak, Bukit Kamiri dan Melanta Tutup in Semporna, Sabah. This is in order to have a larger sample representation and a more holistic picture and understanding of mollusc species, its distributions and relationships with ancient human societies in Semporna, Sabah. This study will provide the latest data of the identification of mollusc remains from these research sites based on current and updated data from the global, reputable database of MolluscaBase (2020).

MATERIAL AND METHODS

Sampling of Mollusc Remains

The mollusc remains were sampled from excavated specimens at the archaeological sites of Bukit Tengkorak (4°27'20.08"N, 118°37'04.3"E), Melanta Tutup (4°21'56.58"N, 118°32'2.04"E) and Bukit Kamiri (4°27'59.70"N, 118°34'8.52"E) in Semporna, Sabah (Fig. 1). Only samples excavated from the projects led by Stephen Chia were used in this study. Samples from Bukit Tengkorak excavated in 1994 to 1995 were stored in the artefact storage of the Archaeology Division of SMD, Kota Kinabalu, and were brought to the archaeology laboratory of SMD to be analysed. Meanwhile, samples from Bukit Tengkorak (excavated in 2002, 2007 and 2008), Melanta Tutup (excavated in 2002, 2003 and 2006) and Bukit Kamiri (excavated in 2007), which were all stored in the artefact storage of CGAR, were brought to the archaeozoology lab of CGAR to be analysed. All samples, both in SMD and CGAR, were stored in container boxes labelled based on site and year of excavation. Hence, analysis was conducted by transferring box by box from storage to laboratory. This would mean that analysis was done based on site and year of excavation. Samples would then be rearranged based on trench, depth, and then species upon identification.
For example, a box of samples from Bukit Tengkorak excavated in 1994 was transferred to the laboratory. The samples were previously stored in plastic bags labelled according to trench and depth, often disregarding species. As an example, a plastic bag labelled Trench A Spit 1 contained about 30 g of shells. In archaeology, a trench is an excavation grid, while spit is an arbitrarily assigned measurement of depth used as a unit of excavation, such as 10 cm per spit. The plastic bags were then arranged based on trench and spit, and then analysed accordingly. Using the previous example, a plastic bag labelled Trench A Spit 1 would be opened and the samples in it were identified, for example to *Anadara antiquata*, *Gafrarium pectinatum* and *Vasticardium orbita*. Pieces identified to the respective species were then weighed, reference-coded, quantified, photographed and placed separately in different plastic bags. The process was repeated to the next plastic bag (e.g., Trench A Spit 2, Trench B Spit 1 and so on). Once the whole samples in the box were completely analysed, the samples were stored back in the same box, transferred back to the storage and the next box was taken to the laboratory to be analysed.
For Bukit Tengkorak, 8,550 pieces of mollusc remains (83,774.4 g) were analysed, while the samples from Melanta Tutup and Bukit Kamiri consisted of 16,446 pieces (52,290.9 g) and 2,266 pieces (5320.0 g), respectively. All the samples were dry-cleaned using only soft paint brushes, toothbrushes and wooden skewers to remove dirt carefully from the specimens. Wet cleaning was avoided because it may alter or damage the physical structure or colour of the fragile specimens, which could affect the results of our analysis.

**Identification of Species**

The methods used in the identification of mollusc species consisted of shell anatomic analysis and taxonomic analysis. Identification of the mollusc specimens was done based on the morphology of the mollusc remains. The identification process of each species was done using the following steps:

1. Each sample was identified to its lowest taxonomic levels by referring to the identification keys provided by Dance (1992), Ridzwan (1993), Poutiers (1998a; 1998b) Abbott and Dance (2000), Abbott (2002), Fiene-Severns et al. (2004), Panha and Burch (2004), and Hook (2008).

2. Each sample was also identified as far as possible by comparing the mollusc remains with reference specimens of bivalves and gastropods available at the archaeozoology lab in CGAR, USM.

3. Each species was cross-checked with the database in MolluscaBase (2020) so that all taxa used in this study were the latest and to ensure the consistency as well as accuracy in the identification of the mollusc species (see Albert 2019 for further details).

However, further identification of the samples to the species level required examination of the shell colours, which in this study was very difficult or impossible to do because almost all the samples had lost their original colours after being buried in the soil for thousands of years. In addition, further identification to the species level required examination of the soft flesh and embryonic shells of the mollusc samples which was not possible because all the samples used in this study were dead specimens. Consequently, most of the mollusc samples analysed in this study could only be identified to the lowest taxonomic ranking, which in many cases included the genus, subfamily or family.

**Species Richness**

Species richness is an important unit to measure the species diversity for animals in an ecology. Meanwhile, in archaeology, species richness can be used to examine differences in the taxonomic composition of mollusc assemblage from different sites to provide more interpretation on the selectivity or strategies in gathering
Identification of Mollusc Remains from Semporna

activities (Nagaoka 2001; Harris et al. 2015; 2016). For example, a high value of diversity would indicate low selectivity in the gathering process (Szabo 2009). In this study, species richness was calculated using the NTAXA (number of taxa) method, which is also referred to as taxonomic richness (Lyman 2008; 2015). In an archaeomalacological analysis, NTAXA is best defined as a count of the number of distinct taxa at the highest common taxonomic level so that species richness will not be artificially inflated by taxa that are more easily identified to lower taxonomic levels (Harris et al. 2015). As an example, if an assemblage consisted of species identified to Saccostrea cucullata and Ostreidae sp., then the NTAXA value would be one (1) rather than two (2), as fragments identified to Ostreidae sp. could also possibly be unidentifiable fragments of other species under that family.

RESULTS AND DISCUSSION

This research revealed a total of 90 taxa comprising 30 bivalve taxa and 60 gastropod taxa, of which 18 and 37 were identified to species level for each of the two classes, respectively. Tables 1 and 2 listed the identified bivalve and gastropod taxa, their habitat and morphological characteristics, respectively. Meanwhile, Figs. 2 to 9 illustrated all the identified bivalve and gastropod taxa respectively, along with the reference codes for the specimens depicted.

While it is easier for samples in complete state to be identified to species level, similar yet fragmented samples lacked the full characteristics for them to be identified to species level. Hence, these fragmented samples could only be identified to genus level. For example, fragmented samples similar to Anadara antiquata would only be identified as Anadara sp. instead (see Fig. 2 (A–B) and Table 1). Besides that, certain samples, despite being in complete state, were identified to genus level as it lacked diagnostic anatomic features for identification to species level, such as Barbatia sp. which could only be identified further to species by looking at the original colour of its outer surface (Poutiers 1998a). This was inevitable as our samples were dead specimens buried for thousands of years. Another example would be the gastropod specimen of Sulcospira spp., which could not be identified to the species level as it required observation on their embryonic shell and reproductive organs (Kohler & Glaubrecht 2006; Kohler & Dames 2009), which again was impossible for dead specimens. Hence, such specimens could only be identified as Sulcospira spp., with the possibility of it being Sulcospira pageli, Sulcospira agrestis or Sulcospira infracostata based on its shape and locality (Kohler & Dames 2009; Ng et al. 2017).
Table 1: The identified bivalves, NTAXA, and their habitats as well as morphological characteristics from the archaeological sites in Semporna, Sabah.

| No. | Family   | Genus/Species | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                                                                                                                                                                 |
|-----|----------|---------------|------------------|-------|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | Arcidae  | *Anadara antiquata* | +     +     +     | 1     1     | Intertidal, seagrass bed with sandy or muddy substrate (Afiati 1999; Siahainenia et al. 2018) | Obliquely ovate and elongated to the posterior in outline, about 40 smooth radial ribs with a narrow median groove on top, inflated and forward umbo, numerous teeth on hinge plate |
| 2.  | Arcidae  | *Anadara sp.* | –     +     –     | 1     2     | Sandy or muddy intertidal to shallow subtidal sands (Poutiers 1998a) | Fragmented specimens elongated to the posterior in outline with smooth radial ribs and numerous teeth on hinge plate |
| 3.  | Arcidae  | *Barbatia sp.* | –     +     –     | 1     2     | Intertidal and shallow subtidal rocks or coral rubbles (Garcia & Oliver 2008) | Numerous teeth on hinge plate, exterior sculpted with smooth yet scaled-like radial ribs, narrow ligamental area that slants to the commissural plane of valves. Most specimens lack the exterior colour to be identified to species level |
| 4.  | Arcidae  | *Tegillarca granosa* | +     +     +     | 1     3     | Soft muddy bottoms of tidal flats in estuaries or bays (Joni et al. 2019; Yurimoto et al. 2014) | Ovate, commonly 6 cm in length, about 18 radial ribs bearing rectangular nodules that look like scales and numerous teeth on hinge plate |
| 5.  | Cardiidae| *Fragum unedo* | –     +     –     | 1     4     | Clean sand in shallow water (intertidal to subtidal up to 50 m deep) (Poutiers 1998a) | Radial ribs on the exterior, stout hinge with anterior and posterior lateral and cardinal teeth on both valves, subquadrate in outline, bent posteriorly by a rounded radial angulation |

(Continued on next page)
Table 1 (Continued)

| No. | Family | Subfamily/Genus/Species | Presence at site (+): Present, (−): Absent | NTAXA | Habitat | Characteristics |
|-----|--------|-------------------------|---------------------------------------------|-------|---------|-----------------|
|     |        |                         | BT MT BK f F |       |         |                 |
| 6.  | Cardiidae | Vasticardium pectiniforme | + + − 1 5 |       | Coral or muddy sand flats in intertidal to shallow subtidal up to 20 m deep (Poutiers 1998a) | About 30 prominent, rounded and rugose radial ribs with transverse scales on sides and top on the anterior half of valve, stout hinge with anterior and posterior lateral and cardinal teeth on both valves, oblong-ovate in outline |
| 7.  | Cardiidae | Tridacninae sp. | + + − |       | Intertidal to shallow subtidal, usually around coral reefs (Poutiers 1998a) | Thick and heavy, presence of folds on the exterior. Mostly fragmented specimens |
| 8.  | Cardiidae | Hippopus hippocus | − + − |       | Sandy bottoms of coral reef, intertidal to shallow subtidal up to 6 m deep (Poutiers 1998a) | Thick and heavy, posteroventral margin bordered by interlocking crenulations, prominent ribbed radial folds with the shape of the dorsal free margin is triangulate |
| 9.  | Cardiidae | Hippopus sp. | + + + 1 6 |       | Sandy bottoms of coral reef, intertidal to shallow subtidal (Poutiers 1998a) | Thick and heavy, posteroventral margin bordered by interlocking crenulations, rib-like folds. Mostly fragmented specimens |
| 10. | Cardiidae | Tridacna squamosa | − + − |       | Attached to surfaces of coral reefs in intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Thick and heavy, presence of byssal gape at the posteroventral margin, prominent concentric lines and blade-like projections on its exterior |
| 11. | Cardiidae | Tridacna sp. | + + − |       | Intertidal to shallow subtidal, usually around coral reefs (Poutiers 1998a) | Thick and heavy, presence of byssal gape at the posteroventral margin, prominent concentric lines. Mostly fragmented specimens |

(Continued on next page)
| No. | Family          | Genus/Species | Presence at site (+): Present, (–): Absent | NTAXA | Habitat                                                                 | Characteristics                                                                 |
|-----|----------------|---------------|--------------------------------------------|-------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 12  | Cyrenidae      | Batissa violacea | – + – 1 7 | Sandy or muddy beds of freshwater and brackish-water rivers and mangrove swamps (Mayor & Ancog 2016) | Round to ovate in outline, umbo points anteriorly and situates near midline of valves, presence of three diverging cardinal teeth and transversally striated lateral teeth on the hinge, concentrically striated |
| 13  | Cyrenidae      | Geloina expansa | + + –               | 1 8   | Muddy and brackish, sometimes in almost freshwater areas of mangrove swamps (Yahya et al. 2018) | Trigonal-ovate in outline, prominent umbo points anteriorly and situates near midline of valves, presence of three diverging cardinal teeth and lateral teeth on posterior and anterior (1 each in left valve, 2 each in right valve), concentrically striated |
| 14  | Cyrenidae      | Geloina sp.    | – + + | Generally mangrove areas (Hamli et al. 2015) | Prominent umbo points anteriorly and situates near midline of valves, presence of three diverging cardinal teeth and lateral teeth on posterior and anterior, concentrically striated. Mostly fragmented specimens |
| 15  | Hemidonacidae  | Hemidonax donaciformis | – + – 1 9 | Clean coarse coral sand from low tide of intertidal to shallow subtidal (Poutiers 1998a) | Subtrigonal to wedge-shaped, transversely elongated in outline with anterior side equal or longer than the posterior side, smooth radial ribs, two unequal cardinal teeth and an elongated lateral tooth in each valve |

(Continued on next page)
Table 1 (Continued)

| No. | Family     | Genus/Species | Presence at site | NTAXA | Habitat                                                                                   | Characteristics                                                                                   |
|-----|------------|---------------|------------------|-------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|     |            |               | (+): Present, (-): Absent |       |                                                                                           |                                                                                                  |
|     |            |               | BT MT BK f F_i   |       |                                                                                           |                                                                                                  |
| 16. | Lucinidae  | Austriella corrugata | + + –             |       | Deep burrower in mud of intertidal water of mangrove area (Glover et al. 2008) | Subcircular to quadrate in outline, rounded ventral margin, moderately inflated and sculpted with numerous prominent concentric growth lines, thin hinges with no teeth |
| 17. | Lucinidae  | Austriella sp.   | – – +             |       | Mangrove (Glover et al. 2008)                                                                | Mostly fragmented specimens that showed at least one characteristic of the *Austriella corrugata* above |
| 18. | Mesodesmatidae | Atactodea striata | + + –             | 1 11 | Sedentary filter-feeder found in sandy substrates of the intertidal zone (Ash et al. 2013) | Small, commonly 2.5 cm in length, poorly-defined umbo that curves toward posterior, relatively pronounced lateral teeth and outer surface sculpted with concentric ridges |
| 19. | Ostreidae  | Saccostrea cucullata | + + –             |       | Attached to hard substrates in marine, estuarine and mangrove areas, intertidal and shallow subtidal up to a depth of 5 m (Poutiers 1998a) | Solid, irregularly shaped, inequivalve where left valve is usually larger while the right valve is usually flat, presence of chomata (tiny folds, ridgelets-like in right valve with corresponding pits in left valve) all around the internal shell margin, with single adductor muscle scar and toothless hinge |
| 20. | Ostreidae  | Ostreidae sp.   | – + +             |       | Attached to substrates mainly in intertidal and shallow subtidal areas (Poutiers 1998a)   | Fragmented specimens with irregular shapes, ligamental area with a shallow median groove and two lateral thickening and the presence of single adductor muscle scar |

(Continued on next page)
| No. | Family      | Subfamily/ Genus/ Species | Presence at site (+): Present, (-): Absent | NTAXA | Habitat                                                                 | Characteristics                                                                 |
|-----|-------------|---------------------------|---------------------------------------------|-------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|     |             |                           | BT  | MT  | BK | f | F |                                                      |                                                                              |
| 21. | Pectinidae  | Decatopecten sp.          | +   | +   | –  | 1  | 13 | Sandy bottoms in intertidal and subtidal zones to a depth of 20 m (Poutiers 1998a) | Straight dorsal margin forming wing-like ears at both ends, single adductor muscle scar, radial sculpture on exterior with radial threads on ribs |
| 22. | Spondylidae | Spondylus sp.            | –   | +   | –  | 1  | 14 | Mainly in relatively shallow waters cemented to hard substrate in coraline areas (Poutiers 1998a) | Stout shell with straight hinge line that has 2 strong teeth and 2 deep sockets, small ear on either side, single adductor muscle scar, exterior with irregular spinose radial ribs |
| 23. | Pteriidae   | Isognomon isognomum      | –   | +   | –  | 1  | 15 | Live in dense colonies attached to hard substrates in intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Presence of numerous transverse grooves on ligament area, strong posteroventral elongation and relatively long dorsal margin that expanded posteriorly, lustrous interior |
| 24. | Pteriidae   | Isognomon sp.            | +   | +   | –  | 1  | 15 |                                                      | Presence of numerous transverse grooves on ligament area, lustrous interior, Mostly fragmented specimens |
| 25. | Psammobiidae| Asaphis violascens       | –   | +   | –  | 1  | 16 | Sandy or gravel bottoms in intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Elongate-ovate in outline, shell inflated, slightly gaping posteriorly, exterior sculpted with strong, rounded and often forked radial ribs developed throughout the valves, 2 cardinal teeth in each valve |
| 26. | Veneridae   | Anomalodiscus squamosus  | –   | +   | –  | 1  | 17 | Fine sandy to muddy bottoms of intertidal and shallow subtidal, often near mangroves (Poutiers 1998a) | Subtrigonal in outline, commonly 3 cm in length, thick and prominent umbo, exterior sculpted with strong, dense radial riblets and low concentric cords, forming repeating squares-like sculpture |

(Continued on next page)
Table 1 (Continued)

| No. | Family       | Genus/Species | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                                 |
|-----|--------------|---------------|------------------|-------|-------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|     |              |               | (+): Present, (-): Absent |       |                                                                          |                                                                                 |
| 27. | Veneridae    | *Gafrarium*   | + + – 1 18       |       | Sandy bottoms of intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Thick, relatively compressed, exterior sculpted with strong nodulous radial ribs that diverge obliquely towards the anterior and posterior, strong hinge plate with 3 cardinal teeth and well developed anterior lateral teeth (1 in left valve, 2 in right valve) |
| 28. | Veneridae    | *Gafrarium*   | – + – 1 19       |       | Clean, muddy sand or sandy gravel of intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Similar to *Gafrarium pectinatum*, but exterior is sculpted with fine concentric ridges, and fine radial ridges that diverge in the middle of the shell surface to form chevron lines |
| 29. | Veneridae    | *Periglypta*  | + + – 1 20       |       | Sandy or muddy bottom of intertidal and shallow subtidal up to 20 m deep (Poutiers 1998a) | Rounded-quadrate in outline with finely crenulated internal margin, exterior is sculpted with relatively fine concentric and radial ridges, strong hinge plate with three cardinal teeth in each valve, and a small, tubercle-shaped anterior lateral tooth in left valve |
| 30. | Veneridae    | *Pelecyora* sp.| – + – 1 21       |       | Marine, sandy or muddy intertidal coast or mangrove (Moazzam & Moazzam 2020; Yahya et al. 2020; Al-Asif et al. 2021) | Ovate to bluntly trigonal in outline, sub-central umbo, large and superficial lunule, strong anterior lateral tooth on left valve opposite deep distant pit on right valve (Jukes-Browne, 1908) |

Note: BT = Bukit Tengkorak; MT = Melanta Tutup; BK = Bukit Kamiri; f1 = absolute frequency; F1 = cumulative frequency
Table 2: The identified gastropods, NTAXA, and their habitats as well as morphological characteristics from the archaeological sites in Semporna, Sabah.

| No. | Family    | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                                 |
|-----|-----------|---------------------------|------------------|-------|-------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|     |           |                           | (+): Present, (–): Absent |       |                                                                          |                                                                                   |
|     |           |                           |                  |       |                                                                          |                                                                                   |
| 1   | Cerithiidae | Clypeomorus batillariaeformis | + + –              | 1 1   | Sandy bottoms of reef flats and estuaries in the intertidal zone (Poutiers 1998b) | Small shell up to 3 cm in length, slightly inflated spire worlds, body whorl with 6 to 8 main spiral beaded cords and a strong, slightly oblique, axial varix on the left part of the dorsal side |
| 2   | Cerithiidae | Rhinodavis vertagus       | – + –              | 1 2   | Sandy bottom in the intertidal and subtidal zones to a depth of about 13 m (Poutiers 1998b) | Only fragmented specimens were found. Distinguishable based on relatively low sculpture with fine spiral grooves and strong short axial folds under suture, becoming obsolete anteriorly and on body whorl |
| 3   | Conidae    | Conus sp.                 | + + +              | 1 3   | Clean or muddy-sand bottoms under rocks or corals in intertidal and shallow subtidal (Poutiers 1998b) | Cone-shaped, mostly fragmented specimens with a moderately low or flat spire and/or a well-developed body whorl tapering towards the narrow anterior end |
| 4   | Costellariidae | Vexillum rugosum | – + –              | 1 4   | Sandy bottoms of the shallow subtidal waters, from low tide to a depth of about 10 m (Poutiers 1998b) | Strong axial ribs that formed prominent shoulder nodules on body whorls, elongated aperture that is anteriorly notched by a short siphonal canal, strong spiral folds on columella |
| 5   | Cyclophoridae | Cyclophorus sp. | – + –              | 1 5   | Terrestrial (Egorov & Greke 2007)                                        | Medium to large, smooth shell with fine spiral striation on body whorl, rather wide umbilicus |

(Continued on next page)
Table 2 (Continued)

| No. | Family       | Subfamily/ Genus/ Species | Presence at site (+): Present, (−): Absent | NTAXA | Habitat                                      | Characteristics                                                                 |
|-----|--------------|----------------------------|-------------------------------------------|-------|---------------------------------------------|--------------------------------------------------------------------------------|
|     |              |                            |                                           |       |                                             |                                                                                |
| 6   | Cyclophoridae| Opisthopus sp.             | −                                         | +     | +                                          | 1 6 Terrestrial (Sang et al. 2020)                                             |
|     |              |                            |                                           |       |                                             | Shell discoidal in shape, moderately high spire, wide umbilicus, adorned with irregular axial brownish stripes |
|     |              |                            |                                           |       |                                             |                                                                                |
| 7   | Cymatidae    | Monoplex sp.              | −                                         | +     | −                                          | 1 7 Intertidal and subtidal sandy, rocky and reef environments (Poutiers 1998b) |
|     |              |                            |                                           |       |                                             | Fragmented specimen, distinguished based on presence of axial varix, thickened and toothed outer lip, and moderately short siphonal canal that bent dorsalward |
|     |              |                            |                                           |       |                                             |                                                                                |
| 8   | Cypraeidae   | Cypraea sp.               | +                                         | +     | −                                          | 1 8 Generally associated with coral reefs, but can be collected when empty shell washed ashore (Poutiers 1998b) |
|     |              |                            |                                           |       |                                             | Ovate or oblong in shape, long and narrow aperture with raised transverse ridges or teeth on both lips. Most specimens found with fragmented dorsum |
|     |              |                            |                                           |       |                                             |                                                                                |
| 9   | Ellobiidae   | Ellobium sp.              | +                                         | +     | −                                          | 1 9 Live amphibiously in nipa palm and mangrove swamps (Poutiers 1998b)         |
|     |              |                            |                                           |       |                                             | Fragmented specimens distinguished based on the ovate to cylindrical in shape with a rather short conical spire |
|     |              |                            |                                           |       |                                             |                                                                                |
| 10  | Fasciolaridae| Pleuroloca sp.            | +                                         | +     | −                                          | 1 10 Shallow water near rocky areas or inner reef flats to a depth of about 20 m (Snyder et al. 2012) |
|     |              |                            |                                           |       |                                             | Fragmented specimens distinguished by its large shell, fusiform in shape with shoulder nodules, moderately long siphonal canal, roughly quadrato apertures that is finely pirate inside |

(Continued on next page)
| No. | Family     | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                       |
|-----|------------|---------------------------|-----------------|-------|------------------------------------------------------------------------|----------------------------------------------------------------------|
|     |            |                           | (+): Present, (–): Absent |       |                                                                                      |                                                                      |
|     |            |                           | BT   | MT   | BK  | f | fi |                                                                                      |                                                                      |
| 11  | Melongenidae | Volema myristica           | –    | +    | –   | 1  | 11 | Sandy mud flats of intertidal zone as well as brackish water and mangroves (Vermeij & Raven 2009) | Relatively small shell, biconical and quiet short in shape, spinose at the suture, short siphonal canal, sculpted with axial folds and rather thick spiral cords |
| 12  | Mitridae    | Nebularia eremitarum       | –    | +    | –   | 1  | 12 | Abundant in the intertidal zone on coral reef environments (Poutiers 1998b)             | Fusiform-ovate with a high tapering spire, rather narrow and elongated aperture that is anteriorly notched by a short siphonal canal, strong columellar folds |
| 13  | Muricidae   | Chicoreus brunneus         | –    | +    | –   | 1  | 13 | Rocky, muddy and coral reef areas in the intertidal and subtidal zones (Poutiers 1998b) | High and acute spire, broad yet narrowly open anterior canal, crenulated outer lips without tooth-like process, three strong spinose axial varices with a single node between the varices |
| 14  | Muricidae   | Chicoreus capucinus        | +    | +    | –   | 1  | 13 | Intertidal species common in mangroves (Tan & Oh 2002)                               | Similar to Chicoreus brunneus, but has three bluntly foliated axial varices on the body whorls with two nodes between the varices |
| 15  | Muricidae   | Chicoreus sp.              | +    | +    | +   | 1  | 13 | Intertidal shore, estuary or mangrove (Poutiers 1998b)                              | Mostly fragmented specimens exhibiting spinose axial varices and narrowly open anterior canal |

(Continued on next page)
| No. | Family    | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat                                                                                           | Characteristics                                                                                                                                                                                                 |
|-----|-----------|----------------------------|------------------|-------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |           |                            | (+): Present, (-): Absent |       |                                                                                                  |                                                                                                                                                                                                                        |
|     |           |                            | BT       | MT   | BK | fi | Fi |                                                                                                  |                                                                                                                                                                                                                        |
| 16  | Muricidae | *Hexaplex cichoreum*       | –        | +    | –  | 1  | 14 | Rocky to muddy areas in the intertidal and subtidal zones (Poutiers 1998b)                        | Globose-ovate with a broad conical spire, wide body whorl, subcircular aperture, strongly spinose axial varices ranges from six to eight around its body whorl, moderately developed siphonal canal with spines |
| 17  | Muricidae | *Drupella margaritica*     | –        | +    | –  | 1  | 15 | Coral reef environment (Houart 2008; Claremont *et al.* 2011)                                      | About 3 cm long, outer surface sculpted with axial nodose ribs with strong varices, high spire, ovate aperture with short siphonal canal                                                                               |
| 18  | Muricidae | *Reishia bitubercularis*   | –        | +    | –  | 1  | 16 | Rocky intertidal areas (Tengku Hanidza *et al.* 2017)                                              | Spirally ridged with axial stripes, spines on shoulder, short siphonal canal                                                                                                                                              |
| No. | Family     | Genus/ Species | Presence at site | NTAXA | Habitat | Characteristics |
|-----|------------|----------------|-----------------|-------|---------|-----------------|
|     |            |                | (+): Present, (–): Absent |       |         |                 |
|     |            |                | BT  | MT  | BK  | f  | F  |         |
| 19  | Nassariidae| *Nassarius* arcularia | –   | +   | –   |     |     |         |
|     |            |                |     |     |     |     |     |         |
| 20  | Nassariidae| *Nassarius* coronatus | –   | +   | –   |     |     |         |
|     |            |                |     |     |     |     |     |         |
| 21  | Nassariidae| *Nassarius* dorsatus | +   | +   | –   |     |     |         |
|     |            |                |     |     |     |     |     |         |
| 22  | Nassariidae| *Nassarius* sp. | –   | +   | –   |     |     |         |
|     |            |                |     |     |     |     |     |         |
| 23  | Naticidae  | *Polinices* sp. | –   | +   | –   | 1   | 18  |         |

Sand bottoms in coral reef areas in intertidal and subtidal zones (Poutiers 1998b)

Squat and thick shell with a fairly high spire, large columellar callus that forms a smooth flat shield over the ventral side of shell, spire whorls with shoulder nodules

Intertidal and subtidal sand (Poutiers 1998b)

Intertidal scavengers, common at the mid-tide level on sheltered mud-flats (McKillup & McKillup 1997)

Intertidal and subtidal sands or reef areas (Poutiers 1998b)

On sandy bottoms, often associated with coral reefs in the intertidal and subtidal zones (Poutiers 1998b)

Small yet stout shell, large columellar callus that forms a smooth flat shield over the ventral side of shell, spire whorls with thick axial ribs, aperture lirate inside

Specimens found with broken apices, smooth and glossy body whorl with only spiral grooves at the anterior end, outer lip has varixed backside, narrow columellar callus, aperture lirate inside

Fragmented specimens exhibiting aperture that is lirate inside, bear calloused columellar, fairly high conical spire

Pear-shaped shell, umbilicus filled by callus, short spire, smooth and glossy exterior, large semicircular aperture
| No. | Family | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat | Characteristics |
|-----|--------|---------------------------|-----------------|-------|---------|----------------|
|     |        |                           | (+): Present, (−): Absent |       |         |                 |
|     |        |                           | BT   | MT   | BK   | f   | F_i |
| 24  | Neritidae | *Nerita albicilla*     | −    | +    | −    |     |     |
|     |        |                           | Rocky shores, in the upper mid-tidal pools on damp and submerged rocks (Poutiers 1998b) |       |         | Thick, globose shell with flat spire, wide and flat columellar shield, numerous small denticles at inner margin of outer lip, numerous distinct pustules over the surface of columellar shield. |
| 25  | Neritidae | *Nerita histrio*       | −    | +    | −    |     |     |
|     |        |                           | Tree trunks and stilt roots in mangrove or breakwater rocks in muddy sand flats (Tan & Clements 2008) |       |         | Globose shell sculpted with rough and unevenly raised spiral cords with prominent axial sculpturing, few obsolete teeth at center of columellar edge, low to nearly flat spire. |
| 26  | Neritidae | *Nerita plicata*       | −    | +    | −    | 1   | 19  |
|     |        |                           | Holes and crevices in rocks of supralittoral zone (Tan & Clements 2008) |       |         | Thick, turbinate shell with moderately high conical spire, numerous coarse rounded spiral ribs on the body whorl, a calloused and convex columellar shield with elongated and square teeth on inner margin. |
| 27  | Neritidae | *Nerita undata*        | +    | +    | −    |     |     |
|     |        |                           | In between rocks in the upper intertidal shores, but usually only appear at dusk (Tan & Clements 2008) |       |         | Spirally sculptured exterior with a moderately high spire, inner margin of columellar shield contains 3 to 5 teeth with the uppermost tooth shaped like a square, dentate outer lip with a distinctly larger tooth at the upper end. |
| 28  | Neritidae | *Nerita sp.*           | +    | +    | +    |     |     |
|     |        |                           | Generally rocky intertidal areas (Poutiers 1998b) |       |         | Any fragmented specimens that resemble the spire, columellar shield and outer lip of nerites. |
| No. | Family   | Subfamily/ Genus/ Species | Presence at site (+): Present, (−): Absent | NTAXA | Habitat | Characteristics |
|-----|----------|---------------------------|------------------------------------------|-------|---------|-----------------|
|     |          |                           |                                         |       | BT      | MT  | BK  | f  | fi | F  |       |
| 29  | Neritidae| Neritina cf. pulligera    | −                                        | +     | −       | 1   | 20  |     |     |     |        |
|     |          |                           | Fast-flowing freshwater streams and rivers or brackish waters in close proximity to ocean (Gerlach et al. 2016) | Flat spire lower than the outer lip, flat parietal wall that is larger than the aperture, axial growth lines on exterior |
|     |          |                           |                                         | Thin yet solid shell that is elongated-ovate in outline due to having an elevated and conical spire that is often eroded at the apex, smooth outer surface, columellar shield and outer lip. Most specimens still retain their colour: black with white axial stripes |
| 30  | Neritidae| Vittina turrita           | +                                        | +     | +       | 1   | 21  |     |     |     |        |
|     |          |                           | Common in brackish water of mangrove and estuaries, occasionally in freshwater streams (Poutiers 1998b) | Thck, porcelaneous shell that is elongate-ovate, short spire, elongated aperture with a wide and short siphonal canal, inner lip calloused with columella obliquely grooved |
|     |          |                           |                                         | Easily distinguished by the globular egg-shape of shell that is smooth and porcelaneous, short yet stout anterior and posterior extremities, long and narrow aperture with thickened outer lip that is irregularly dentate |
| 31  | Olividae | Oliva sp.                 | −                                        | +     | −       | 1   | 22  |     |     |     |        |
|     |          |                           | In sand flats of intertidal and shallow subtidal zones (Poutiers 1998b) |     |        |     |     |     |     |     |        |
| 32  | Ovulidae | Ovula ovum               | +                                        | +     | −       | 1   | 23  |     |     |     |        |
|     |          |                           | Common on the coral Sarcophyton to a depth of 20 m (Poutiers 1998b) |     |        |     |     |     |     |     |        |
| No. | Family     | Genus/Species | Presence at site | NTAXA | Habitat | Characteristics                                                                 |
|-----|------------|---------------|------------------|-------|---------|--------------------------------------------------------------------------------|
|     |            |               | (+): Present, (-): Absent |       |         |                                                                                |
|     |            |               | BT   | MT   | BK | f | F |                                                                            |
| 33  | Pachychilidae | Sulcospira spp. | +    | +    | +  | 1 | 24                            | In relatively fast running freshwater such as rivers, streams or creeks (Marwoto & Isnaningsh 2012) |
| 34  | Paludomidae | Paludomus everetti | +    | +    | +  | 1 | 25                             | Forest streams and in the vicinity of limestone caves (Ng et al. 2017) |
|     |            |               |       |       |    |    |                                | Ovate to ovate-lanceolate shape, distinctive spiral impressed lines on the succeeding whorls below the suture, aperture is ovate or less acuminate or tapering to a point, thick inner lip, spire shorter than aperture |
| 35  | Paludomidae | Paludomus sp. | –    | +    | –  |    |                                | Freshwater rivers or streams, especially rocky-bottomed, narrow, shallow, shady and slow-moving (Amarasinghe & Krishnarajah 2009) |
| 36  | Planaxidae | Planaxis sulcatus | –    | +    | –  | 1 | 26                             | In intertidal rocky shores, around the mid to low tidal zones during low tide (Tan & Low 2014) |

(Continued on next page)
| No. | Family       | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                                                                                                 |
|-----|--------------|----------------------------|------------------|-------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| 37  | Potamididae  | Cerithidea cf. quoyii      | – + –            | 1 27  | On mangrove trees in marine intertidal water and occasionally brackish area (Reid 2014) | Small shell with axial and spiral sculpture, periphery of the last whorl is angular. All specimens are fragmented, with no aperture and outer lip, hence could be compared to other species |
| 38  | Potamididae  | Telescopium telescopium    | + + –            | 1 28  | Soft mangrove muds (Zaman & Jahan 2013)                                   | High-conical shell with many spire whorls sculpted with three large and one narrow spiral cords alternately with deep grooves, relatively small and obliquely quadrangular aperture, twisted columella with a central spiral ridge with a short siphonal canal. Mostly fragmented specimens |
| 39  | Potamididae  | Terebralia sulcata         | + + –            | 1 29  | In mangrove areas, and occasionally brackish estuaries (Poutiers 1998b; Putri & Patria 2018) | Elongated shell sculpted with deeply incised suture that has four or five spiral cords alternate in each suture along with numerous axial ridges resembling a pattern of square nodules, thick outer lip that is widely flared and expanded anteriorly that connects to the base of columella forming a short tube-like bottom that looks like an umbilicus |
| 40  | Potamididae  | Terebralia sp.             | + + +            |       | Mangrove                                                                 | Any fragmented specimens that exhibited at least one characteristic of Terebralia sulcata above                                                                 |

(Continued on next page)
| No. | Family | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat | Characteristics |
|-----|--------|---------------------------|-----------------|--------|---------|-----------------|
|     |        |                           | (+): Present, (–): Absent |        |         |                 |
|     |        |                           | BT  | MT  | BK  | f | F |         |         |         |         |
| 41  | Strombidae | Canarium urceus | +  | +  | –  | 1  | 30 | Sandy mud bottoms in intertidal and subtidal up to 40 m deep (Poutiers 1998b) | Elongated-ovate in shape, high spire, a more drawn out siphonal canal, a smooth central portion of columella that is pirate (having fine thread-like lines) at both ends, body whorl sculpted with fine spiral grooves near anterior end and outer lip margin only |
| 42  | Strombidae | Canarium sp. | +  | +  | +  |     |     | Intertidal | Any fragmented specimens that exhibited at least one characteristic of Canarium urceus above |
| 43  | Strombidae | Conomurex luhuanus | +  | +  | –  | 1  | 31 | Sandy bottoms of coral reefs, lagoons, seagrass and coral rubbles in intertidal and shallow subtidal up to 20 m deep (Poutiers 1998b) | Small, short spire with a long and narrow aperture, somewhat similar to cone shells but has a well-developed stromboid notch of the outer lip, black or chocolate brown inner lip on the aperture |
| 44  | Strombidae | Laevistrombus canarium | +  | +  | –  | 1  | 32 | Muddy sand and algae bottoms in intertidal and subtidal up to 55 m deep (Poutiers 1998b) | Solid, heavy, globose and smooth shell, with moderately high conical spire, long aperture and a greatly expanded-thickened-rounded outer lip with its upper end projecting slightly upward with a stromboid notch |
| 45  | Strombidae | Lambis sp. | +  | +  | –  | 1  | 33 | Usually associated with coral reefs and lagoons, either in intertidal or subtidal (Poutiers 1998b) | Mostly fragmented specimens distinguished based on the features of the flaring outer lips with marginal digitations |

(Continued on next page)
| No. | Family     | Species                  | Presence at site | NTAXA | Habitat                                                                 | Characteristics                                                                 |
|-----|------------|--------------------------|------------------|-------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|     |            |                          | (+): Present, (−): Absent |       |                                                                          |                                                                                  |
|     |            |                          | BT   | MT  | BK | f  | F  | |
| 46  | Tegulidae  | *Tectus fenestratus*     | +    | +   | −  | 1  | 34 | Common on rocky shores in the muddy areas of intertidal zone (Naung 2018; Poutiers 1998b) |
| 47  | Tegulidae  | *Tectus* sp.             | −    | +   | −  | 1  | 35 | Rocky shores                                                                 |
| 48  | Tegulidae  | *Rochia nilotica*        | −    | +   | −  | 1  | 35 | Common in coral reefs, especially shallow, high-energy portions of barrier and fringing reefs (Poutiers 1998b) |
| 49  | Terebridae | *Terebra* sp.            | −    | +   | −  | 1  | 36 | Sandy intertidal and subtidal (Poutiers 1998b)                                |
| 50  | Thiaridae  | *Stenomelania* spp.      | +    | +   | +  | 1  | 37 | Freshwater, or near brackish water of estuaries (Apiraksena et al. 2020)      |
| 51  | Tonnidae   | *Tonna* sp.              | −    | +   | −  | 1  | 38 | Mainly living on sandy bottoms where seagrasses abounded in the subtidal zone (Poutiers 1998b) |

(Continued on next page)
| No. | Family     | Subfamily/ Genus/ Species | Presence at site | NTAXA | Habitat | Characteristics |
|-----|------------|----------------------------|-----------------|-------|---------|-----------------|
|     |            |                            | (+): Present, (-): Absent |       |         |                 |
|     |            |                            | BT  | MT  | BK  | f | f, |
| 52  | Trochidae  | Monodonta labio            | –   | +   | –   | 1 | 39 |
| 53  | Turbinellidae | Vasum turbinellus | +   | –   | –   | 1 | 40 |
| 54  | Turbinidae | Lunella cinerea            | –   | +   | –   | 1 | 41 |
| 55  | Turbinidae | Turbo bruneus              | –   | +   | –   | 1 | 42 |
| 56  | Turbinidae | Turbo sp.                  | +   | +   | –   |     |     |

Common on rocky shores in intertidal zone, grazing on microalgae (Takada 2001; Poutiers 1998b)

Small yet thick shell, with an asymmetrical cone with spirals of rounded bumps, a convex base and a single large tooth-shaped structure on the columella at the aperture

Common in rocky bottoms on reef flats in the intertidal and subtidal zones (Poutiers 1998b)

Only fragmented specimens found, but could easily be distinguished based on biconical shape, the blunt spines on body, and strong unequal columellar folds

Common among rocks or gravel in rocky intertidal shore (Poutiers 1998b)

Shell looks more like a dome than turbinated, commonly 3 cm in length, body whorl sculpted with fine nodulose spiral cords, low spire, wide open umbilicus

Turbinated in shape, sculpted with strong spiral cords and very fine axial ridges, large and oval aperture that extends to half of the total length of shell and flares a little at the anterior end of the smooth columella

Mainly living in intertidal and shallow subtidal zones on rocky and coral reef habitats (Poutiers 1998b)

Any fragmented specimen that has at least one of the characteristics of Turbo bruneus above

(Continued on next page)
| No. | Family   | Subfamily/ Genus/ Species | Presence at site (+): Present, (−): Absent | NTAXA | Habitat                                                                 | Characteristics                                                                                                                                 |
|-----|----------|---------------------------|-------------------------------------------|-------|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
|     |          |                           |                                           |       | BT | MT | BK | f | F_i |                                      |                                                                                                                                             |
| 57  | Turridae | *Unedogemmula indica*    | −                                         | +    | −  | 1 | 43 |     |     | Common on muddy bottoms in shallow subtidal to a depth of about 50 m (Poutiers 1998b) | Fusiform shell strongly keeled at the shoulder, angulated sides of the whorls, bear posterior notch of outer lip, outer surface with spiral cords |
| 58  | Turritellidae | *Turritella sp.*          | −                                         | +    | +  | 1 | 44 |     |     | Shallow subtidal up to 30 m deep (Poutiers 1998b) | Mostly fragmented specimens, distinguished based on the numerous whorls sculpted with spiral cords |
| 59  | Viviparidae | *Filopaludina cf. javanica* | −                                         | +    | −  | 1 | 45 |     |     | Freshwater: rivers, lakes, ponds, swamps (Marwoto & Nurinsiyah 2009) | Globose shell, fine axial growth lines, round aperture, pointed yet blunt spire |
| 60  | Volutidae | *Cymbiola vespertilio*    | +                                         | +    | −  | 1 | 46 |     |     | On muddy sand or mud bottom in intertidal and subtidal zone to a depth of 20 m (Poutiers 1998b) | Elongate-ovate in shape, short and conical spire, spiny tubercles on shoulder of body whorl, bear oblique columella folds, wide and long aperture about 80% the total length of shell |

Note: BT = Bukit Tengkorak; MT = Melanta Tutup; BK = Bukit Kamiri; f = absolute frequency; F_i = cumulative frequency
Identification of Mollusc Remains from Semporna

Figure 2: Bivalve specimens identified from archaeological sites in Semporna: (A) *Anadara antiquata* (MT/C/160), (B) *Anadara* sp. (MT/C/104), (C) *Barbatia* sp. (MT/D/Q1/154), (D) *Tegillarca granosa* (MT/C/165), (E) *Fragum unedo* (MT/D/Q1/137), (F) *Vasticardium pectiniforme* (MT/A/141), (G) *Tridacninae* sp. (BT02/P/Q2/29) and (H) *Hippopus hippopus* (MT/D/Q1/209).

Figure 3: Bivalve specimens identified from archaeological sites in Semporna: (I) *Hippopus* sp. (MT/C/144), (J) *Tridacna squamosa* (MT/D/Q3/81), (K) *Tridacna* sp. (BT/G17/229), (L) *Batissa violacea* (BK/56), (M) *Geloina expansa* (MT/D/Q2/122) and (N) *Geloina* sp. (BK/40).
Figure 4: Bivalve specimens identified from archaeological sites in Semporna: (O) *Hemidonax donaciformis* (MT/A/33), (P) *Austriella corrugata* (BT02/P/Q2/23), *Atactodea striata* (MT/B/195), (R) *Saccostrea cucullata* (MT/D/Q1/24), (S) *Decatopecten* sp. (MT/C/280), (T) *Spondylus* sp. (MT/C/98), (U) *Isognomon isognomum* (MT/C/94) and (V) *Isognomon* sp. (MT/C/148).

Figure 5: Bivalve specimens identified from archaeological sites in Semporna: (W) *Asaphis violascens* (BT/B/188), (X) *Anomalodiscus squamosus*, (Y) *Gafriarium pectinatum* (MT/C/157), (Z) *Gafriarium divaricatum* (MT/C/93), (AA) *Periglypta puerpera* (MT/D/Q1/184) and (AB) *Pelecyora* sp. (MT/B/194).
Identification of Mollusc Remains from Semporna

Figure 6: Gastropod specimens identified from archaeological sites in Semporna: (A) Clypeomorus batillariaeformis (MT/A/122), (B) Rhinoclavis vertagus (MT/C/121), (C) Opisthoporpus sp. (MT/A/22) (D) Conus sp. (MT/D/Q3/115), (E) Vexillum rugosum (MT/D/Q2/44), (F) Cyclophorus sp. (MT/D/Q3/158), (G) Monoplex sp. (MT/D/Q2/161), (H) Cypraes sp. (MT/D/Q1/9), (I) Ellobium sp. (MT/D/Q4/135), (J) Pleuroloca sp. (BT/G17/177), (K) Volema myristica (MT/C/127), (L) Nebularia eremitarum (MT/D/Q4/71), (M) Chicoreus capucinus (MT/C/72), (N) Chicoreus brunneus (MT/C/71) and (O) Chicoreus sp. (MT/C/73).

Figure 7: Gastropod specimens identified from archaeological sites in Semporna: (P) Hexaplex cichoreum (MT/C/74), (Q) Drupella margaritcola (MT/D/Q1/124), (R) Reishia bitubercularis (MT/D/Q1/126), (S) Nassarius arcularia (MT/B/202), (T) Nassarius coronatus (MT/D/Q2/137), (U) Nassarius dorsatus (MT/A/119), (V) Polinices sp. (MT/D/Q2/62), (W) Nerita albicilla (MT/C/24), (X) Nerita histrio (MT/C/84), (Y) Nerita plicata (MT/C/133), (Z) Nerita undata (MT/C/139), (AA) Neritina cf. pulligera (MT/C/23), (AB) Vittina turrita (MT/C/81), (AC) Oliva sp. (MT/D/Q2/42), (AD) Ovula ovum (BT07/A/3), (AE) Sulcospira spp. (MT/D/Q2/65), (AF) Paludomus everetti (BK/44), (AG) Planaxis sulcatus (MT/B/166) and (AH) Cerithidea cf. quoyii (MT/B/168).
Figure 8: Gastropod specimens identified from archaeological sites in Semporna: (AI) *Telescopium telescopium* (MT/C/118), (AJ) *Terebralia sulcata* (MT/D/Q2/52), (AK) *Terebralia* sp. (BT02/P/Q2/15), (AL) *Canarium urceus* (BT08/C/11), (AM) *Canarium* sp. (BT08/C/10), (AN) *Conomurex luhuanus* (BT02/P/Q2/8), (AO) *Laevistrombus canarium* (MT/C/122), (AP) *Lambis* sp. (MT/D/Q1/204 & MT/D/Q2/170), (AQ) *Tectus fenestratus* (MT/D/Q2/49), (AR) *Rochia nilotica* (MT/D/Q1/94) and (AS) *Terebra* sp. (MT/D/Q2/99).

Figure 9: Gastropod specimens identified from archaeological sites in Semporna: (AT) *Stenomelania* spp. (BK/45), (AU) *Tonna* sp. (MT/C/114), (AV) *Monodonta labio* (MT/C/79), (AW) *Vasum turbinellus* (BT02/P/Q2/2), (AX) *Lunella cinerea* (MT/D/Q2/71), (AY) *Turbo bruneus* (MT/D/Q3/99), (AZ) *Unedogemmula indica* (MT/D/Q1/118), (BA) *Turritella* sp. (BK/46), (BB) *Filopaludina cf. javanica* (MT/C/77) and (BC) *Cymbiola vespertilio* (MT/D/Q1/128).
In archaeology, whenever a large number of mollusc remains is discovered, the basic assumption is that it is part of the food refuse (Waselkov 1987; Thomas 2015b). This assumption is often confirmed when the mollusc remains identified are edible species. In this study, most of the species of molluscs identified from the research sites were edible species, which made it clear that almost all of them had been exploited as food resources (Poutiers 1998a; 1998b). In fact, some of the species are still collected and consumed by the local Bajau Laut in Semporna today (Ridzwan 1993; Albert 2019). The Bajau Laut people live a semi-nomadic life, usually in boat-houses covered with thatches, although most had started to settle in houses on stilts along the coastline of Semporna but maintain a dominantly marine-oriented lifestyle working as fishermen and collecting marine products (Sather 1985; 2001; Halina 2007). Some of the Bajau Laut’s nomenclature of species identified in this study were ‘kohang’ (which includes various species of clams such as Anadara antiquata, Tegillarca granosa and Gafrarium pectinatum), ‘tehem’ (oysters under the family Ostreidae), ‘kima’ (giant clams under the subfamily Tridacninae), ‘mestuli’ (murex snails such as Hexaplex chicoreum), ‘sesoh’ (nerites under the genus Nerita), ‘binga-binga’ (turban snails such as Turbo bruneus), ‘baggungan’ (Telescopium telescopium), ‘limbi-limbi’ (Terebralia sulcata), and ‘buku-buku’ (Pleurolopa trapezium).

In addition, artificial man-made cuts found on certain species of the mollusc remains also indicated that they had been processed specifically for consumption. For instance, the long-spiralled gastropods such as Sulcospira spp., Terebralia sulcata and Telescopium telescopium had their apices removed. Such condition was a clear sign of food processing as it is well-known that apices of long-spiralled gastropods need to be cut so that their flesh can be easily sucked out from their apertures (Meehan 1982; Zuraina et al. 1994; Bujeng 2009; Nilus et al. 2010). On the other hand, small-sized gastropods such as Nerita undata, Lunella cinerea, Paludomus everetti and Canarium urceus were mostly found in their complete state because their meat could be easily extracted from their apertures using a sharp-pointed tool (Meehan 1982). Additionally, bivalves such as Anadara antiquata, Tegillarca granosa, and Gafrarium pectinatum were also found mostly in complete state because their meat could be easily extracted as their valves will open automatically when heated by boiling or roasting (Meehan 1982; Suniarti et al. 2019). These observations on the condition of specimens strengthen further the interpretation that the samples were food refuse.

The different habitats from which the identifiable molluscs originated from, as listed in Tables 1 and 2, suggested that subsistence activities took place in different environments, which required different gathering or foraging strategies and techniques. For instance, mollusc remains found on rocks in the intertidal zone such as Nerita undata, Monodonta labio and Lunella cinerea could be easily gathered during mid-tide (Poutiers 1998b). In addition, species living in seagrass beds such as Anadara antiquata, Gafrarium pectinatum and Canarium urceus could also be easily gathered during low tide by walking on the knee-deep shallow water. During high tide, certain tools might be needed such as a long pole with a net, locally known as ‘tangguk bergalah’ used by present day Malay fishermen to
gather cockles from the sea bed while on a boat (Hamid 1989). Other species such as the giant clams (*Tridacninae* sp.) are often found attached on coral reefs and could be collected by diving into the ocean (Poutiers 1998a; Neo 2020). *Geloina expansa*, which is usually found at upper mangroves that are more freshwater than saltwater, is best collected during low tide because it burrows into the muddy bottoms (Meehan 1982; Albert & Bujeng 2021). In contrast, the mangrove or estuarine species *Terebralia sulcata* is usually collected during high tide because it will climb on stems and roots of mangrove trees (Poutiers 1998b).

Determining specific types of environment that the mollusc species originated from could only be done by identifying the specimens to their lowest taxonomic ranking as far as possible. In most cases, archaeological research often provided a general description of the original habitat of the mollusc remains, for instance by simply stating it as marine shells (see Datan 1993; Lertcharnrit 2005; Fajari & Kusmartono 2013; Sarjeant 2014). This study shows how important it is to do a detailed and comprehensive identification of the mollusc samples in order to be able to determine the types of environments the molluscs originated from. Some marine species of the same family can originate from different marine habitats, for example, *Hexaplex cichoreum* and *Chicoreus capucinus* are both from the Muricidae family but the former is found in rocky shores, while the latter is a coastal mangrove species (Poutiers 1998b; Tan & Oh 2002). Furthermore, the original habitat of the mollusc remains can provide useful insights into the past environment of the research sites. To date, most of the mollusc species identified in this study can still be found in Semporna today (Ridzwan 1993; Ridzwan & Kaswandi 1995). Therefore, it is highly likely that the past environments around the research sites from 3,000 to 800 years ago are closely similar to what it is today in Semporna, Sabah.

Next, for the species richness, despite the total number of taxa identified is 90 (30 for bivalves and 60 for gastropods), the unit of species richness, which is NTAXA, only calculates the number of taxa identified at the highest common taxonomic level. This is as seen in Tables 1 and 2, where the absolute frequency of NTAXA is denoted by $f_i$, while the cumulative frequency of NTAXA is denoted by $F_i$. Hence, the NTAXA value of bivalves is 21, while for gastropod is 46, which brought a total of NTAXA value for the whole assemblage from archaeological sites in Semporna to 67. Table 3 then compared the NTAXA values of bivalves and gastropods identified in the three archaeological sites, which showed that Melanta Tutup had the most species richness, followed by Bukit Tengkorak and Bukit Kamiri. This would give a possibility of a lower level of selectivity by the ancient community of Melanta Tutup when gathering molluscs compared with those from the other sites. This lower selectivity would mean that molluscs were gathered regardless of species without targeting any specific species. Perhaps the closer proximity of Melanta Tutup to the coastline (see Fig. 1) allowed the ancient community of the site to gather a wider array of molluscan species, hence not being selective, compared to the other sites. This is because marine species are generally considered more diverse compared to other environments (Rosenberg 2014).
Table 3: NTAXA values of the three archaeological sites from Semporna, Sabah.

| Site/Class | Bukit Tengkorak | Melanta Tutup | Bukit Kamiri |
|------------|----------------|---------------|--------------|
| Bivalves   | 12             | 21            | 6            |
| Gastropods | 23             | 45            | 11           |
| Total      | 36             | 66            | 17           |

However, it has also been widely documented that species richness is dependent on sample size. Smaller assemblages tend to have fewer taxa, and larger assemblages tend to have more taxa. In addition, a straightforward comparison of NTAXA between assemblages will inform more about differences in sampling rather than revealing the meaningful differences in richness ecologically, unless the sample sizes being compared are identical (Faith & Lyman 2019). Several statistical analyses can be used to evaluate species richness while taking sample size and sampling issues in consideration. The first one is sampling-to-redundancy, which aims to examine the adequacy of one’s sample by plotting the incremental addition of material in order to assess at what point a sample become representative of an assemblage’s population (Mitchell et al. 2016; Faulkner et al. 2018; Faith & Lyman 2019). The second one is rarefaction, which aims to estimate the expected NTAXA that would have been recovered had fewer specimens been collected (Woo et al. 2016; Faith & Lyman 2019). Next, regression analysis that uses one or more regression lines between sample size and NTAXA of multiple assemblages (Grayson & Delpech 1998; Faith & Lyman 2019). These statistical analyses would strengthen or correct interpretation made solely by comparison of NTAXA values, which is worth exploring further in future studies.

SUMMARY AND CONCLUSION

This study had identified a total of 90 taxa of molluscs, with 55 identified to the species level, from the three archaeological sites in Semporna, Sabah. Some specimens could only be identified to genus, family or subfamily levels due to the lack of distinguishable elements because of their fragmented and discoloured state for being buried for thousands of years. The identified mollusc remains originated from a wide range of habitats, but marine species dominated, which suggested that the ancient community of Semporna during that time had a predominantly maritime-oriented economy, yet also exploited resources from freshwater and mangrove environments as well. Most of the mollusc remains were determined to be food leftovers because they were edible species based on data from malacological literature, evidence of food preparation found on specimens as well as local knowledge from the local Bajau Laut villagers in Semporna. By calculating the number of taxa at the highest common taxonomic level, the total NTAXA value from all three sites is 67, of which Melanta Tutup has the highest NTAXA value of 66, followed by Bukit Tengkorak (36) and Bukit Kamiri (17). This suggested a lower selectivity in gathering activities among ancient communities in
Melanta Tutup, while those from Bukit Tengkorak and Bukit Kamiri probably had specific species targeted. However, such interpretation could be strengthened or altered by conducting statistical analyses that look into the relationship between NTAXA and sample size. Nevertheless, this study illustrated the importance of identification of mollusc remains uncovered from archaeological sites not only to interpret the behaviour of past humans, but also past environment and distribution of mollusc species in Semporna, Sabah.

ACKNOWLEDGEMENTS

The authors would like to thank the Director of Sabah Museum Department (SMD) and staff of the Archaeology section in Kota Kinabalu, Sabah for their support in this research. We also wish to thank the staff of CGAR, USM for all the technical and logistical support. The authors wish to acknowledge Universiti Sains Malaysia, Penang for funding the research through the Universiti Sains Malaysia Research University Grants, (1001/PARKEO/870010), and (1001/PARKEO/870012).

REFERENCES

Abbott R T and Dance S P. (2000). *Compendium of seashells*. California: Odyssey Publishing.
Abbott R T. (2002). *Seashells of the world*. New York: St. Martin’s Press.
Afiati N. (1999). The chromosomes of *Anadara antiquata* (L.) (Bivalvia: Arcidae) from central Java, Indonesia. *Majalah Ilmu Kelautan* 15 (IV): 136–144.
Al-Asif A, Hamli H, Kamal A H M, Idris M H, Gerusu G J, Ismail J and Abualreesh M H. (2021). Bivalves (Mollusca: Bivalvia) in Malaysian Borneo: Status and threats. *Journal of Threatened Taxa* 13(11): 19553–19565. https://doi.org/10.11609/jott.7287.13.11.19553-19565
Albert D D A and Bujeng V. (2021). Strategi memungut spesies moluska paya bakau di Sabah dari perspektif etnoarkeologi. *Jurnal Arkeologi Malaysia* 34(1): 29–41.
Albert D D A, Bujeng V and Chia S. (2017). Analisis awalan sisa-sisa cangkerang moluska prasejarah akhir di Melanta Tutup dan Bukit Kamiri, Semporna, Sabah. *Jurnal Arkeologi Malaysia* 30(1): 1–12.
________. (2018). Analisis cangkerang moluska dari Melanta Tutup, Semporna, Sabah. In Zuliskandar R, Narayanen S, Ruzairy A, Nasha R K and Farizah I. (Eds.). *Prosiding Seminar Arkeologi Kebangsaan Ke-4 2018*. Kuala Lumpur: Jabatan Warisan Negara, 81–97.
Albert D D A. (2019). *A study on the mollusc remains from archaeological sites in Semporna, Sabah, Malaysia*. Unpublished MA thesis. Universiti Sains Malaysia, Pulau Pinang.
Amarasinghe A A T and Krishnarajah S R. (2009). Distribution patterns of the genus *Paludomus* (Gastropoda: Thiaridae: Paludominae) in Mahaweli, Kelani, Kalu, Gin and Maha-oya River Basins of Sri Lanka. *TAPROBANICA* 1(2): 130–134. https://doi.org/10.47605/tapro.v1i2.21
Apiraksena K, Namchote S, Komsuwan J, Dechraksa W, Tharapoom K, Veeravechesukij N, Glaubrecht M and Krailas D. (2020). Survey of *Stenomelania* Fischer 1885 (Cerithioidea, Thiaridae): The potential of trematode infections in a newly-recorded snail genus at the coast of Andaman Sea, South Thailand. *Zoosystematics and Evolution* 96(2): 807–819. https://doi.org/10.3897/zse.96.59448

Argente F A T. (2016). Bivalve superpower: The global invasion of corbiculid clams. *Annual Research & Review in Biology* 10(3): 1–10. https://doi.org/10.9734/ARRB/2016/26448

Ash J, Faulkner P, Brady L M and Rowe C. (2013). Morphometric reconstructions and size variability analysis of the surf clam, *Atactodea (=Paphies)* striata from Muralag 8, Southwestern Torres Strait, Northern Australia. *Australian Archaeology* 77(1): 82–93. https://doi.org/10.1080/03122417.2013.11681981

Bar-Yosef Mayer D E. (2005). An introduction to archaeomalacology. In Bar-Yosef Mayer D E (Ed.), *Archaeomalacology: Molluscs in former environments of human behaviour*. Oxford: Oxbow Books, 1–4.

———. (2007). Archaeomalacological research in Israel: The current state of research. *Israel Journal of Earth Sciences* 56: 191–206. https://doi.org/10.1560/IJES.56.2-4.191

Bellwood P. (1989). Archaeological investigations at Bukit Tengkorak and Segarong, South Eastern Sabah. *Bulletin of the Indo-Pacific Prehistory Association* 9: 122–161. https://doi.org/10.7152/bippa.v9i0.11286

Bujeng V and Albert D D A. (2016). Preliminary analysis on the Metal Age shell mollusc remains from Melanta Tutup, Semporna, Sabah. *Asia Pacific Journal of Advanced Business and Social Studies* 2(1): 288–301.

———. (2017). Exploitation of aquatic fauna during the Metal Age in Bukit Kamiri, Semporna, Sabah, Malaysia. *Archives of Business Research* 5(5): 24–36. https://doi.org/10.14738/abr.55.3081

Bujeng V. (2009). Zooarchaeological evidence from the Late Prehistoric-Late Holocene at Lenggong Valley, Perak. *Warisan Arkeologi Malaysia* 2: 82–109.

———. (2018). Moluska: Sumber diet masyarakat prasejarah Bukit Sarang, Ulu Kakus, Sarawak. *Melayu: Jurnal Antarabangsa Dunia Melayu* 11(2): 169–182.

Chia S. (2003). *The prehistory of Bukit Tengkorak as a major pottery making site in Southeast Asia*. Sabah Museum Monograph 8. Kota Kinabalu, Sabah: Department of Sabah Museum.

———. (2008). Prehistoric sites and research in Semporna, Sabah, Malaysia. *Bulletin of the Society for East Asian Archaeology* (BSEAA) 2: 1–7.

———. (2009). Recent archaeological discoveries in Semporna, Sabah, Malaysia. In Mokhtar S and Kamarudin A R. (Eds.), *Proceedings of the International Seminar on Sharing our Archaeological Heritage*. Johor Bahru: Yayasan Warisan Johor, 203–212

———. (2014). Kajian arkeologi di Bukit Tengkorak (2007), Semporna, Sabah. *Monograf Muzium Sabah* 12: 126–154.

———. (2016). *Arkeologi Bukit Tengkorak*, Sabah. Pulau Pinang: Penerbit Universiti Sains Malaysia.

Claassen C. (1998). *Shells*. Cambridge: Cambridge University Press.

Claremont M, Reid D G and Williams S T. (2011). Evolution of corallivory in the gastropod genus *Drupella*. *Coral Reefs* 30: 977–990. https://doi.org/10.1007/s00338-011-0788-5

Dance S P. (1992). *Shells*. London: Dorling Kindersley.
Deejay Daxter A. Albert et al.

Datan I. (1993). Archaeological excavations at Gua Sireh (Serian) and Lubang Angin (Gunung Mulu National Park), Sarawak, Malaysia. Sarawak Museum Journal Special Monograph 45(66). Kuching: Sarawak Museum Department.

Egorov R and Greke K. (2007). The Genus Cyclophorus Montfort, 1810: Systematics and Nomenclature. Club Conchylia Informationen 38(3/4): 57–64.

Faith J T and Lyman R L. (2019). Paleozoology and palaeoenvironments: Fundamentals, assumptions, techniques. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108648608

Fajari N M E and Kusmartono V P R. (2013). The excavation of Gua Payung, South Kalimantan, Indonesia. Journal of Indo-Pacific Archaeology 33: 20–23. https://doi.org/10.7152/jipa.v33i0.14511

Faulkner P, Harris M, Ali A K, Haji O, Crowther A, Horton M C and Boivin N L. (2018). Characterising marine mollusc exploitation in the eastern African Iron Age: Archaeomalacological evidence from Unguja Ukuu and Fukuchani, Zanzibar. Quaternary International 471: 66–80. https://doi.org/10.1016/j.quaint.2017.08.051

Faulkner P. (2010). Morphometric and taphonomic analysis of granular ark (Anadara granosa) dominated shell deposits of Blue Mud Bay, northern Australia. Journal of Archaeological Science 37(8): 1942–1952. https://doi.org/10.1016/j.jas.2010.02.021

Fiene-Severns P, Severns M and Dyerly R. (2004). Tropical seashells. Singapore: Periplus Editions (HK) Ltd.

Fiori S, Frontini R and Bayón C. (2019). Morphometric analysis of the yellow clam (Amarilladesma mactroides) to interpret fragmentary archaeological specimens. The Journal of Island and Coastal Archaeology 14(2): 291–300. https://doi.org/10.1080/15564894.2018.1521482

Gani N, Chia S and Bujeng V. (2013). Faunal remains from Gua Tupak, Bau, Sarawak. Sarawak Museum Journal XXI(92): 123–168.

Garcia A A and Oliver G. (2008). Species discrimination in seven species of Barbatia (Bivalvia: Arcoidea) from Thailand with a redescription of B. grayana (Dunker, 1858). The Raffles Bulletin of Zoology Supplement No. 18: 7–23.

Gerlach J, Madhyastha A, Köhler F and Van Damme D. (2016). Neritina pulligera. The IUCN Red List of Threatened Species 2016: e.T165773A91284470. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T165773A91284470.en (Accessed on 12 November 2021).

Giokas S, Thomaz D, Douris V, Iecanidou R and Rodakis G C. (2010). 5000 years of molecular evolution in a population of the land snail Albinaria caerulea transported by humans. Journal of Molluscan Studies 76(1): 49–56. https://doi.org/10.1093/mollus/eyp041

Glover E A, Taylor J D and Williams S T. (2008). Mangrove-associated lucinid bivalves of the Central Indo-West Pacific: review of the "Austriella" group with a new genus and species (Mollusca: Bivalvia: Lucinidae). The Raffles Bulletin of Zoology Supplement No. 18: 25–40.

Grayson D K and Delpech F. (1998). Changing diet breadth in the early upper palaeolithic of Southwestern France. Journal of Archaeological Science 25: 1119–1129. https://doi.org/10.1006/jasc.1998.0339

Habu J, Matsui A, Yamamoto N and Kanno T. (2011). Shell midden archaeology in Japan: Aquatic food acquisition and long-term change in the Jomon culture. Quaternary International 239(1–2): 19–27. https://doi.org/10.1016/j.quaint.2011.03.014

Halina S M Y. (2007). Identiti budaya etnik Palau’ di Semporna, Sabah: Konservasi, adaptasi dan transformasi budaya. Kota Kinabalu: Penerbit Universiti Malaysia Sabah.
Identification of Mollusc Remains from Semporna

Hamid R. (1989). *Peralatan mengutip siput-siput laut dan kerang*. Kuala Lumpur: Jabatan Perikanan, Kementerian Pertanian Malaysia.

Hamli H, Rahim A A, Idris M H, Kamal A H M and Wong S K. (2015). Morphometric variation among three local mangrove clam species of Corbiculidae. *Songklanakarin Journal of Science & Technology* 37(1): 15–20.

Harris M, Lambrides A B J and Weisler M I. (2016). Windward vs. leeward: Inter-site variation in marine resource exploitation on Ebon Atoll, Republic of the Marshall Islands. *Journal of Archaeological Science Reports* 6: 221–229.

Harris M, Weisler M and Faulkner P. (2015). A refined protocol for calculating MNI in archaeological molluscan shell assemblages: A Marshall Islands case study. *Journal of Archaeological Science* 57: 168–179. https://doi.org/10.1016/j.jas.2015.01.017

Ho N and Kassem K. (2009). *Reef status of Semporna Priority Conservation Area*. Kota Kinabalu, Sabah, Malaysia: WWF Malaysia. http://repository.wwf.org.my/technical_reports/R/ReefStatusOfSempornaReport.pdf

Hook P. (2008). *Seashells and the seashore*. Bath: Parragon Books Ltd.

Houart R. (2008). Rehabilitation of *Ergalatax martensi* (Schepman, 1892) (Gastropoda: Muricidae), senior synonym of *Ergalatax obscura* Houart, 1996, and description of *Ergalatax junionae*, new name for *Morula martensi* Dall, 1923. *The Nautilus* 122(2): 99–106.

Insoll T. (2021). Marine shell working at Harlaa, Ethiopia, and the implications for Red Sea Trade. *Journal of African Archaeology* 19: 1–24. https://doi.org/10.1163/21915784-20210001

Joni A A M, Yusuff F M, Mohamed K N, Kusin F M and Zulkifli S Z. (2019). Growth performance of blood cockle (*Tegillarca granosa*) within Kongkong Laut Estuaries, Masai, Johor. *Pertanika Journal of Science & Technology* 27(4): 1917–1927.

Jukes-Browne A J. (1908). On the genera of Veneridae represented in the Cretaceous and older Tertiary deposits. *Proceedings of the Malacological Society of London* 8(3): 148–177. https://www.biodiversitylibrary.org/page/32058345 (Accessed 11 November 2021)

Kirk H J C. (1962). *The geology and mineral resources of the Semporna Peninsula, North Borneo*. Kuching: Sarawak Government Press.

Kohler F and Dames C. (2009). Phylogeny and systematics of the Pachychilidae of mainland South-East Asia – novel insights from morphology and mitochondrial DNA (Mollusca, Caenogastropoda, Cerithioidea). *Zoological Journal of the Linnean Society* 157: 679–699. https://doi.org/10.1111/j.1096-3642.2009.00541.x

Kohler F and Glaubrecht M. (2006). A systematic revision of the Southeast Asian freshwater gastropod *Brotia* (Cerithioidea: Pachychilidae). *MALACOLOGIA* 48(1–2): 159–251.

Langley M C and O’Connor S. (2016). An enduring shell artefact tradition from Timor-Leste: Oliva bead production from the Pleistocene to late Holocene at Jerimalai, Lene Hara and Matja Kuru 1 and 2. *PLoS ONE* 11(8): e0161071. https://doi.org/10.1371/journal.pone.0161071

Lertcharnrit T. (2005). Late prehistoric and early historic archaeology in Thailand: recent evidence from the Central Highland. *Silpakorn University Journal of Social Sciences, Humanities, and Arts* 5: 55–72.

Lyman R L. (2008). *Quantitative paleozoology*. Cambridge: Cambridge University Press.

Lyman R L. (2015). On the variable relationship between NISP and NTAXA in bird remains and in mammal remains. *Journal of Archaeological Science* 53: 291–296.
Marwoto R M and Isnaningsih N R. (2012). The freshwater snail genus *Sulcospira troschel*, 1857 from Java, with description of a new species from Tasikmalaya, West Java, Indonesia (Mollusca: Gastropoda: Pachychilidae). *The Raffles Bulletin of Zoology* 60(1): 1–10.

Marwoto R M and Nurinsiyah A S. (2009). Keanekaragaman keong air tawar marga Filopaludina di Indonesia dan status taksonominnya (Gastropoda: Viviparidae). In Yulianda F, Pratiwi N T M, Mayalanda Y and Cordova M R. (Eds.), *Prosiding Seminar Nasional Moluska 2 “Moluska: Peluang Bisnis dan Konservasi”*. Bogor: Institut Pertanian Bogor, 202–213.

Mayor A D and Ancog R. (2016). Fishery status of freshwater clam (Batissa violacea, Corbiculidae) (Bivalvia) (Lamarck, 1818) in Cagayan River, Northern Philippines. *International Journal of Fisheries and Aquatic Studies* 4(3): 500–506.

McKillup S C and McKillup R V. (1997). Effect of food supplementation on the growth of an intertidal scavenger. *Marine Ecology Progress Series* 148: 109–114. https://doi.org/10.3354/meps148109

Meehan B. (1982). *Shell bed to shell midden*. Canberra: Australian Institute of Aboriginal Studies.

Mitchell J, Peacock E and Myatt S. (2016). Sampling to redundancy in an applied zooarchaeology: a case study from a freshwater shell ring in the Mississippi Delta, southeastern USA. *Journal of Archaeological Science: Reports* 5: 499–508. https://doi.org/10.1016/j.jasrep.2015.12.020

Moazzam M and Moazzam N. (2020). Rediscovery of venerid bivalves belonging to genus Pelecyora Dall, 1902 from Pakistan. *International Journal of Biology and Biotechnology* 17(3): 491–495.

MolluscaBase (eds.). (2020). *MolluscaBase*. http://www.molluscabase.org/ (Accessed 16 December 2020).

Nagaoka L. (2001). Using diversity indices to measure changes in prey choice at the Shag River Mouth Site, Southern New Zealand. *International Journal of Osteoarchaeology* 11: 101–111.

Naung N O. (2018). Top shells of Andrew Bay in Rakhine coastal region of Myanmar with notes on habitat, local distribution and utilization. *Journal of Aquaculture & Marine Biology* 7(3): 127–133. https://doi.org/10.15406/jamb.2018.07.00198

Neo M L, Wabnitz C C C, Braley R D, Heslinga G A., Fauvelot C, Van Wynsberge S, Andrefouet S, Waters C, Tan A S-H, Gomez E D, et al. (2017). Giant clams (Bivalvia: Cardiidae: Tridacninae): A comprehensive update of species and their distribution, current threats and conservation status. In Hawkins S J, Evans A J, Dale A C, Firth L B, Hughes D J and Smith I P (Eds.), *Oceanography and marine biology: An annual review* Vol. 55. Boca Raton: CRC Press, 87–388. https://doi.org/10.1201/b21944

Neo M L. (2020). Conservation of giant clams (Bivalvia: Cardiidae). In Goldstein M I and Dellasala D A. (Eds.), *Encyclopedia of the World's Biomes*, Vol. 1. Amsterdam: Elsevier, 527–538. https://doi.org/10.1016/B978-0-12-409548-9.11780-4

Ng T H, Dulipat J, Foon J K, Lopes-Lima M, Zieritz A and Liew T-S. (2017). A preliminary checklist of the freshwater snails of Sabah (Malaysian Borneo) deposited in the BORNEENSIS collection, Universiti Malaysia Sabah. *ZooKeys* 673: 105–123. https://doi.org/10.3897/zookeys.673.12544

Nilus R, Chung A Y C, Pereira J T, Sugau J B, Tangah J, Sabran S and Chong R F Y. (2010). *Mangroves of Sabah: An introduction to the flora and fauna*. Sandakan: Sabah Forestry Department.
Ono R, Soegondho S and Yoneda M. (2009). Changing marine exploitation during late pleistocene in Northern Wallacea: Shell remains from Leang Sarru Rockshelter in Talaud Islands. Asian Perspectives 48(2): 318–341. https://doi.org/10.1353.asi.2009.0002

Panha S and Burch J B. (2004). Mollusca. In Yule C M and Yong H S (Eds.), Freshwater invertebrates of the Malaysian region (pp.207–224). Kuala Lumpur: Academy Sciences Malaysia, 207–224.

Pawlik A F, Piper P J, Wood R A, Lim K A, Faylona M G P G, Mijares A S B and Porr M. (2015). Shell tool technology in Island Southeast Asia: An early Middle Holocene Tridacna adze from Ilin Island, Mindoro, Philippines. Antiquity 89: 292–308. https://doi.org/10.15184/aqy.2015.3

Poutiers J M. (1998a). Bivalves (Acephala, Lamellibranchia, Pelecypoda). In Carpenter K E and Niem V H. (Eds). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. Rome: FAO, 123–352.

_______. (1998b). Gastropods. In Carpenter K E and Niem V H. (Eds). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. Rome: FAO, 263–648.

Putri S A and Patria M P. (2018). Peran siput Terebralia (Gastropoda: Potamididae) dalam mengurai daun mangrove Rhizophora di Pulau Panjang, Serang-Banten. Jurnal Kelautan dan Perikanan Terapan 1(2): 87–94. https://doi.org/10.15578/jkpt.v1i2.7380

Reid D G. (2014). The genus Cerithidea swainson, 1840 (Gastropoda: Potamididae) in the Indo-West Pacific region. Zootaxa 3775(1): 1–65.

Reitz E J and Wing E S. (2008). Zooarchaeology, 2nd ed. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511841354

Ridzwan B H and Kaswandi M A. (1995). Hidupan marin intertidal: Sumber makanan penduduk daerah Semporna, Sabah. Malaysian Journal of Nutrition 1: 105–114.

Ridzwan H. (1993). Sumber makanan persisiran Laut Sabah. Kuala Lumpur: Dewan Bahasa dan Pustaka.

Rosenberg G. (2014). A new critical estimate of named species: Level diversity of the recent mollusca. American Malacological Society 32(2): 308–322. https://doi.org/10.4003/006.032.0204

Rouse A J and Evans J G. (1994). Modern land mollusca from Maiden Castle, Dorset, and their relevance to the interpretation of subfossil archaeological assemblages. Journal of Molluscan Studies 60(3): 315–329. https://doi.org/10.1093/mollus/60.3.315

Sang D D, Chinh B T and Nhuong D V. (2020). The land snail genus Opisthodorop Benson in L. Pfeiffer, 1851 (Gastropoda: Caenogastropoda: Cyclophoridae) from Vietnam, with description of a new species. Raffles Bulletin of Zoology 68: 103–111. https://doi.org/10.26107/RBZ-2020-0011

Sarjeant C. (2014). Contextualising the neolithic occupation of Southern Vietnam: The role of ceramics and potters at An Son. Canberra: Australian National University Press.

Sather C. (1985). Boat crews and fishing fleets: The social organization of maritime labour among the Bajau Laut of Southeastern Sabah. Contributions to Southeast Asian Ethnography 4: 165–214.

_______. (2001). Bajau Laut boat-building in Semporna. Techniques & Culture 35–36: 117–198. https://doi.org/10.4000/tc.288
Shackleton J C and van Andel T H. (1986). Prehistoric shore environments, shellfish availability, and shellfish gathering at Franchthi, Greece. *Geoarchaeology* 1(2): 127–143. https://doi.org/10.1002/gea.3340010202

Siahainenia L, Tuhumury S F, Uneputty P A and Tuhumury N C. (2018). Pattern of relative growth in cockle Anadara antiquata in Ihamahu coastal waters, Central Maluku. *IOP Conference Series: Earth Environmental Sciences* 139: 012015. https://doi.org/10.1088/1755-1315/139/1/012015

Snyder M A, Vermeij G J and Lyons W G. (2012). The genera and biogeography of Fasciolariinae (Gastropoda, Neogastropoda, Fasciolariidae). *Basteria* 76(1–3): 31–70.

Sunarti Y, Mahirta, O’Connor S and Nayati W. (2019). Perilaku konsumsi kerang oleh masyarakat pesir Desa Halaeman, Alor Barat Daya, Nusa Tenggara Timur. *Forum Arkeologi* 32(2): 133–144. https://doi.org/10.24832/fa.v32i2.556

Szabo K. (2009). Molluscan remains from Fiji. In Clark G and Anderson A. (Eds.). *The early prehistory of Fiji (Terra Australis 31).* Canberra: ANU ePress, 183–211. https://doi.org/10.22459/TA31.12.2009.08

________. (2010). Shell artefacts and shell-working within the Lapita Cultural Complex. *Journal of Pacific Archaeology* 1(2): 115–127.

Takada Y. (2001). Activity patterns of the herbivorous gastropod *Monodonta labio* on a boulder shore at Amakusa, Japan. *VENUS* 60(1–2): 15–25.

Tan K-S and Oh T M. (2002). Feeding habits of *Chicoreus capucinus* (Neogastropoda: Muricidae) in a Singapore mangrove. *Bollettino Malacologico* 38 (Supplemento 4): 43–50.

Tan S K and Clements R. (2008). Taxonomy and distribution of the Neritidae (Mollusca: Gastropoda) in Singapore. *Zoological Studies* 47(4): 481–494.

Tan S K and Low M E Y. (2014). Singapore mollusca: 5. The subfamily Plaxaninae (Gastropoda: Caenogastropoda: Cerithioidea: Planaxidae). *Nature in Singapore* 7: 15–23.

Tebano T and Paulay G. (2000). Variable recruitment and changing environments create a fluctuating resource: The biology of *Anadara uropigimelana* (Bivalvia: Arcidae) on Tarawa Atoll. *Atoll Research Bulletin* 488: 1–15. https://doi.org/10.5479/si.00775630.488.1

Tengku Hanidza T I, Nur Azyan F A and Mohd Armi A S. (2017). Study on accumulation of Fe, Pb, Zn, Ni and Cd in *Nerita lineata* and *Thais bitubercularis* from Tanjung Harapan and Teluk Kemang, Malaysia. *Journal CleanWAS* 1(1): 6–16. https://doi.org/10.26480/jcleanwas.01.2017.06.16

Thaman B, Thaman R R, Balawa A and Veitayaki J. (2017). The recovery of a tropical marine mollusk fishery: A transdisciplinary community-based approach in Navakavu, Fiji. *Journal of Ethnobiology* 37(3): 494–513. https://doi.org/10.2993/0278-0771-37.3.494

Thomas K D. (2015a). Molluscs emergent, Part I: Themes and trends in the scientific investigation of mollusc shells as resources for archaeological research. *Journal of Archaeological Science* 56: 133–140. https://doi.org/10.1016/j.jas.2015.01.024

________. (2015b). Molluscs emergent, Part II: Themes and trends in the scientific investigation of mollusc shells as resources for archaeological research. *Journal of Archaeological Science* 56: 159–167. https://doi.org/10.1016/j.jas.2015.01.015

Vermeij G J and Raven H. (2009). Southeast Asia as the birthplace of unusual traits: The Melongenidae (Gastropoda) of northwest Borneo. *Contributions to Zoology* 78(3): 113–127. https://doi.org/10.1163/18759866-07803003
Waselkov G. A. (1987). Shellfish gathering and shell midden archaeology. *Advances in Archaeological Method and Theory* 10: 93–210. https://doi.org/10.1016/B978-0-12-003110-8.50006-2

Welter-Schultes F. W. (2008). Bronze Age shipwreck snails from Turkey: First direct evidence for oversea carriage of land snails in antiquity. *Journal of Molluscan Studies* 74(1): 79–87. https://doi.org/10.1093/mollus/eym047

Woo K, Faulkner P and Ross A. (2016). The effects of sampling on the analysis of archeological molluscan remains: A quantitative approach. *Journal of Archaeological Science: Reports* 7: 730–740. https://doi.org/10.1016/j.jasrep.2015.08.001

Yahya N, Idris I, Rosli N S and Bachok Z. (2018). Population dynamics of mangrove clam, *Geloina expansa* (Mousson, 1849) (Mollusca, Bivalvia) in a Malaysian mangrove system of South China Sea. *Journal of Sustainability Science and Management* 5(Special issue): 203–216.

Yurimoto T, Kassim F M, Fuseya R and Man A. (2014). Mass mortality event of the blood cockle, *Anadara granosa*, in aquaculture ground along Selangor coast, Peninsular Malaysia. *International Aquatic Research* 6: 177–186.

Zaman M B and Jahan M S. (2013). Food and feeding habits of mangrove shellfish, *Telescopium telescopium* (Linnaeus, 1758) in Bangladesh. *Bangladesh Journal of Zoology* 41(2): 233–239. https://doi.org/10.3329/bjz.v41i2.23326

Zulkifli M.S., Zubaid A.M.A. & Davison, G.W.H. (1992). Satu Kajian Terhadap Mollusk Purba di Tapak Arkeologi Kuala Selinsing, Pulau Kelumpang, Perak. *Jurnal Arkeologi Malaysia* 5, 55–96.

Zuraina M, Mokhtar S, Chia S and Zolkurnian H. (1994). Artifacts from the Gua Gunung Runtuh excavation. In Zuraina M. (Ed.), *The excavation of Gua Gunung Runtuh and the discovery of the Perak Man in Malaysia*. Kuala Lumpur: Department of Museums and Antiquity Malaysia, 149–171.