



**UNIVERSITI PUTRA MALAYSIA**

***GONAD DEVELOPMENT, GONAD INDEX AND CONDITION INDEX OF  
MARSH CLAM *Polymesoda epansa* Mousson FROM MIRI, MALAYSIA***

**AZIMAH ABDUL RAHIM**

**FSPM 2014 8**



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CONDITION INDEX OF MARSH CLAM *Polymesoda  
expansa* Mousson FROM MIRI, MALAYSIA**

**By**

**AZIMAH BINTI ABDUL RAHIM**

**Thesis Submitted to the School of Graduate Studies,  
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Requirements for the Degree of Master of Science**

**October 2014**

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Abstract of thesis presented to the Senate of Universiti Putra  
Malaysia in fulfilment of the requirement for the degree of Master of Science

**GONAD DEVELOPMENT, GONAD INDEX, AND CONDITION INDEX OF  
MARSH CLAM *Polymesoda expansa* Mousson FROM MIRI, MALAYSIA**

By

**AZIMAH BINTI ABDUL RAHIM**

**October 2014**

**Chairman: Mohd Hanafi Idris, PhD**

**Faculty: Agriculture and Food Sciences (Bintulu)**

The research study was conducted at Kelulut mangrove, Sibuti, Miri from October 2010 until November 2011. Monthly sampling has been done by recording and collecting data and samples from the study area. Further analysis for histological studies and condition index were brought to the laboratory at UPM Bintulu Campus.

The IUCN Red list has stated *Polymesoda expansa* as a least concern. Thus, little information is available on *P. expansa* found in Sarawak especially on the reproductive cycle. The aim of this research study was to conduct histological investigations that lead to explain the dynamics of gonad development, gonad index, and condition index of *P. expansa* at Miri, Sarawak.

Study on the gametogenesis of *P. expansa* from Miri, Sarawak was performed using histological sections. Several steps involved in the processes including dissection, fixation, dehydration, clearing, infiltration with paraffin wax, embedding in paraffin wax, sectioning, staining and mounting. Microscopic observations of gonad sections determine that *P. expansa* was dioecious species. Five (5) stages of gonad development has been carried out and clearly identified for both male and female which includes rest, development, mature, spawn and spent. The rest phase in *P. expansa* in this study was observed only in the months of January, May June and October. On the other hand, development, mature spawning and spent phases were observed throughout the study period. Thus, active and continuous gametogenesis was recorded throughout the study period since the tropical conditions are fairly stable throughout the year.

In the determination of gonad index (GI), the same sample population was used. Sixty nine (69) individuals were prepared for histological analysis. GI was figured by

following a numerical grading system in order to obtain a quantitative value that represents the reproductive activity. The GI calculation was (the numbers in each stage) x (numerical ranking of that stage) / (number of animals in the samples). The values for pooled of *P. expansa* were higher in November 2010 and November 2011 with the value of 2.3 and 2.8, and were lower in December 2010, June and September 2011 with the value of 1.5 and 1.0. The GI values indicated that the reproduction was inactive in December, June and September while gametogenesis started in January and continued until July. GI has shown a seasonal trend along the year with high values related with mature individuals while the fall of GI values due to spawning activity. Spawning between sexes was fairly synchronized except in January, and September. Between March and July, spawning activities was occurred mainly in males but it shown less in September. However, no significant differences ( $p>0.05$ ) of GI was found between males and females since spawning activities were all year around.

Condition index (CI) of *P. expansa* was concurrently studied with the histological observations. Fifty five (55) specimens were processed in the size range of 65-75 mm due to the average of collected samples. CI that was generally used to characterize the physiological activity of organisms was calculated by [dry tissue weight (g) / (dry shell weight (g) x 100)]. The values varied from 1.8% in December 2010 to 3.4% in October 2011, which could be categorized as thin to moderate. In present study, the CI showed a clear relationship with the reproductive cycle (gametogenesis). The close correlation between condition index and gonad development indicated that condition index is a good indicator for identifying the gonad maturity of *P. expansa*.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

**PERKEMBANGAN GONAD, INDEKS GONAD, DAN INDEKS KEADAAN  
PADA LOKAN SELAM *Polymesoda expansa* Mousson DARI MIRI,  
MALAYSIA**

Oleh

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Kajian penyelidikan telah dijalankan di kawasan bakau Kelulit, Sibuti, Miri dari Oktober 2010 sehingga November 2011. Persampelan bulanan telah dilakukan dengan merekod dan mengumpul data dan sampel dari kawasan kajian. Analisis lanjutan untuk kajian histologi dan indeks keadaan telah dibawa ke makmal di UPM Kampus Bintulu.

Senarai Merah IUCN menyatakan *Polymesoda expansa* sebagai kurang perhatian. Oleh itu, hanya sedikit maklumat boleh didapati mengenai *P. expansa* yang terdapat di Sarawak terutamanya pada kitaran pembiakan. Tujuan kajian penyelidikan ini adalah untuk menjalankan siasatan histologi yang membawa kepada penerangan dinamik berkenaan perkembangan gonad, indeks gonad, dan indeks keadaan *P. expansa* di Miri, Sarawak.

Kajian pada gametogenesis *P. expansa* dari Miri, Sarawak dilakukan melalui pembahagian histologi. Beberapa langkah terlibat dalam proses termasuk pembedahan, penetapan, dehidrasi, pembersihan, penyusupan dengan lilin parafin, penerapan dalam lilin parafin, pembahagian, mewarnakan dan penyediaan. Pemerhatian mikroskop pada pembahagian gonad mendapati *P. expansa* adalah spesies dioecious. Lima (5) peringkat perkembangan gonad dilaksanakan dan dikenalpasti dengan jelas untuk kedua-dua jantan dan betina termasuk rehat, perkembangan, matang, pembenih dan pembebasan. Fasa rehat pada *P. expansa* dalam kajian ini hanya didapati dalam bulan Januari, Mei Jun dan Oktober. Manakala, fasa perkembangan, matang, pembenihan dan pembebasan didapati sepanjang tempoh kajian. Oleh itu, gametogenesis yang aktif dan berterusan dicatatkan sepanjang tempoh kajian memandangkan keadaan tropika adalah stabil sepanjang tah

Dalam penentuan indeks gonad (GI), populasi sampel yang sama digunakan. Enam puluh sembilan (69) individu disediakan untuk analisis histologi. GI diperolehi berdasarkan sistem penggredan bagi mendapatkan nilai kuantitatif yang mewakili aktiviti pembiakan. Pengiraan GI adalah (nombor dalam setiap peringkat) x (kedudukan berangka tahap) / (bilangan haiwan dalam sampel). Nilai terkumpul untuk *P. expansa* adalah lebih tinggi pada bulan November 2010 dan November 2011 dengan nilai 2.3 dan 2.8, dan adalah lebih rendah pada bulan Disember 2010, Jun dan September 2011 dengan nilai 1.5 dan 1.0. Nilai GI menunjukkan bahawa pembiakan kurang aktif pada bulan Disember, Jun dan September manakala gametogenesis bermula pada bulan Januari sehingga bulan Julai. GI telah menunjukkan corak bermusim di sepanjang tahun dengan nilai tinggi berkaitan dengan individu matang manakala kejatuhan nilai GI disebabkan oleh aktiviti pembenihan. Pembenihan antara jantina berlaku serentak kecuali pada bulan Januari dan September. Antara Mac dan Julai, aktiviti pembenihan berlaku terutama pada jantan tetapi kurang pada bulan September. Walau bagaimanapun, tiada perbezaan yang signifikan ( $p > 0.05$ ) didapati pada GI antara jantan dan betina memandangkan aktiviti pembenihan adalah sepanjang tahun.

Indeks Keadaan (CI) *P. expansa* dikaji serentak dengan pemerhatian histologi. Lima puluh lima (55) spesimen diproses dalam pelbagai saiz diantara 65-75 mm mengikut purata sampel. CI amnya digunakan untuk mencirikan aktiviti fisiologi organisma dikira mengikut [berat tisu kering (g) / (berat cengkerang kering (g) x 100)]. Nilai pelbagai dari 1.8% pada bulan Disember 2010 ke 3.4% pada bulan Oktober 2011, boleh dikategorikan sebagai sederhana. Dalam kajian ini, CI menunjukkan hubungan yang jelas dengan kitaran pembiakan (gametogenesis). Hubung kait antara indeks keadaan dan perkembangan gonad menunjukkan bahawa keadaan indeks adalah petunjuk yang baik untuk mengenal pasti kematangan gonad pada *P. expansa*.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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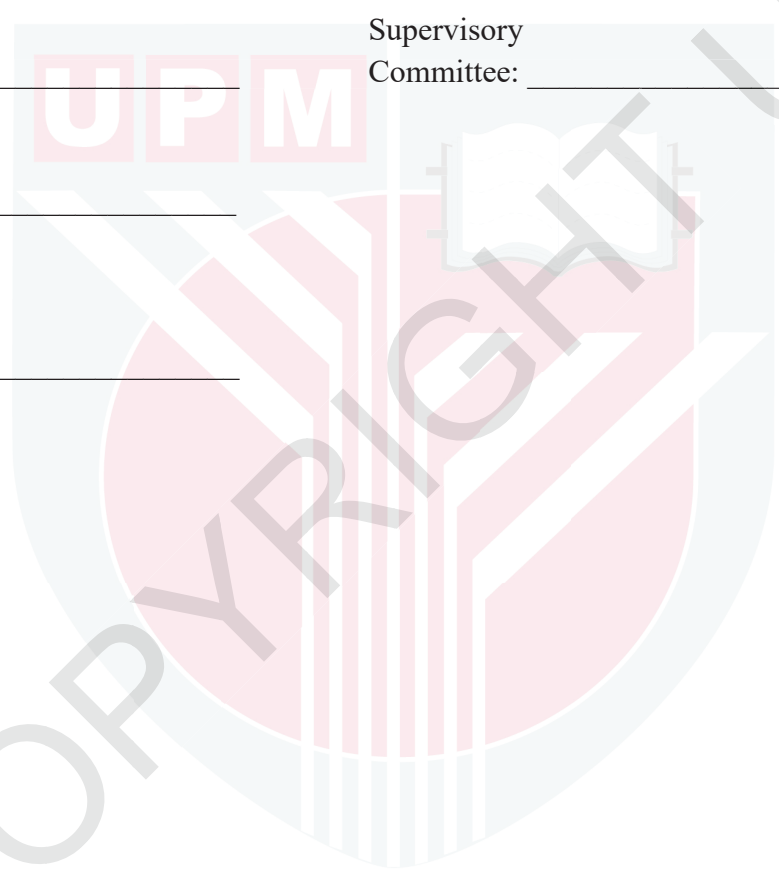
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## LIST OF ABBREVIATIONS

mm	-	millimeter
h	-	hour
L	-	liter
mg/l	-	milligram per liter
min	-	minute
mL	-	milliliter
g	-	gram
pH	-	hydrogen-ion levels
psu	-	practical salinity unit
$\mu\text{m}$	-	micrometer
rpm	-	rotation per minute
ka	-	thousand years ago
DO	-	dissolved oxygen
nm	-	nanometers

## CHAPTER 1

### GENERAL INTRODUCTION

#### Background of the Study

Molluscs evolved about 600 million years ago during the Cambrian period based on the geological time scale. In 1757, the name 'Mollusca' was first used by Linnaeus (Shanmugam and Vairamani, 2009). The number of species identified under Phylum Mollusca vary between 80 000 to 100 000 (Shanmugam and Vairamani, 2009). Molluscs have colonized all possible habitats from deep sea to high mountains. They are also found throughout most mangrove habitats where they live on and in the muds, forage in the canopy or firmly attached to the roots (Shanmugam and Vairamani, 2009; Kathiresan and Bingham, 2001).

The muddy or sandy sediments of the mangrove are the home of variety of epibenthic, infaunal, and meiofaunal of invertebrates. Among this invertebrates, *Polymesoda expansa* known as lokan selam or mangrove clam lives in the mangroves habitats. The diagrammatic profile of a mangrove swamp (Figure 1.1) shows a scheme of the essential features of animal zonation. The height where bivalve can be found is between five to nine feet. This is due to the physical conditions which strongly influenced to the nature of the molluscs community. Jiang and Li (1995) found that density and biomass of the molluscs which including 52 species were consistently highest in the high tide zones and decreased with depth in the mangroves of China.

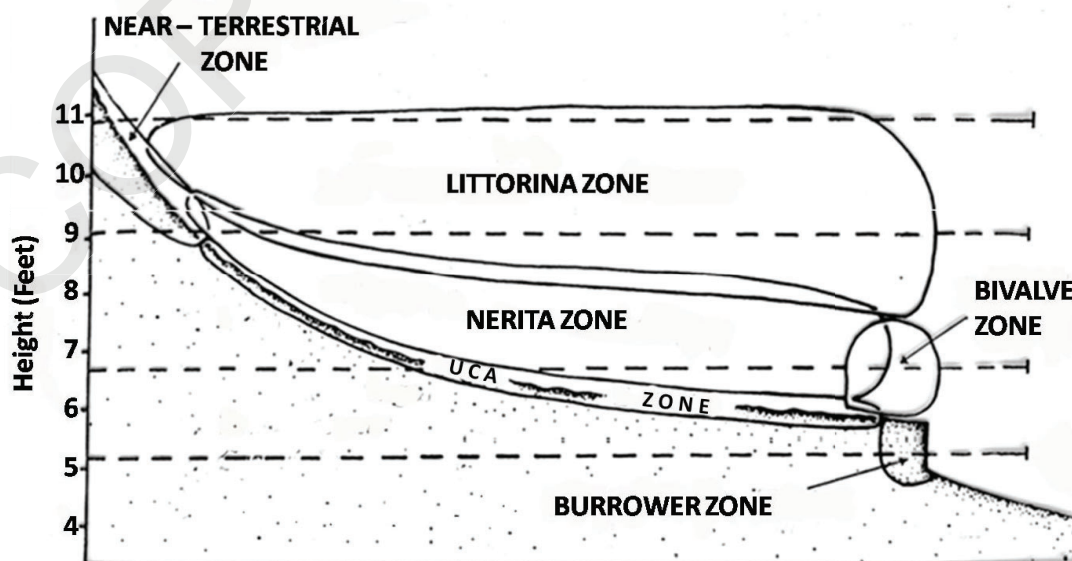


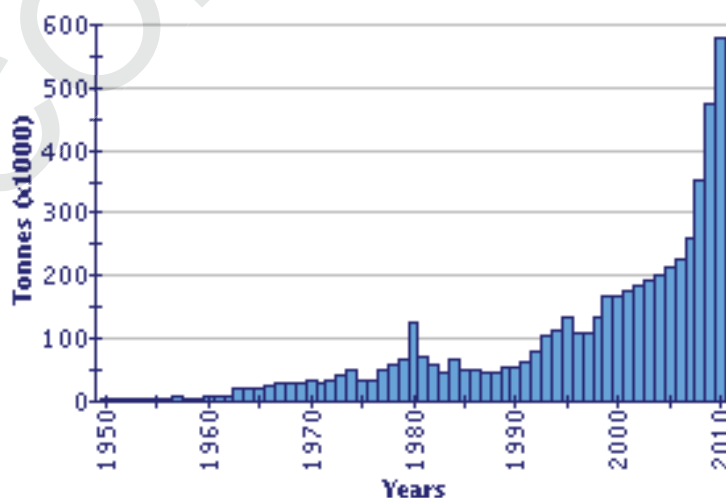
Figure 1.1. Diagrammatic profile of a mangrove swamp showing a scheme of the essential features of animal zonation (Shanmugam and Vairamani, 2009)

Molluscs of the class bivalvia are identified mainly based on the shell morphology. The shell comprises of two valves; equivalve (similar valves) as in clams and mussels and inequivalve (dissimilar valves) for example, scallops. The outer surface may be striated or ribbed and usually covered with a periostracum. An elastic ligament which leaves a scar on the hinge used to hold the two valves together. The hinge may in addition have interlocking ridges called the dentition, which similar to teeth.

Interiorly, the two valves are attracted to the soft body by adductor muscles that produce scar on its surface. Each valves with a single such scar known as monomyarian shell while if there are two scars on each valve, the shell is dimyarian. A projection of the shell called umbo is located at the hinge which always points towards the anterior end of the bivalves. Thus, an anterior adductor scar and a posterior adductor scar in dimyarian shell are distinguishable (Shanmugam and Vairamani, 2009; Poutiers, 1998; Morton, 1984).

Along the Indo-Pacific coast region, edible marine bivalves such as clams, mussels and oysters are widely distributed, commercially important and form a sustainable fishery. They provide cheap source of nutritious food and as an essential part of protein in the diet of the coastal people (Hamli *et al.*, 2012; Rinyod and Rahim, 2011; Yap *et al.*, 2009; Dwiono, 2003; Ingole *et al.*, 2002).

In Malaysia, brackish water species accounted for more than 70 percent of the total aquaculture production in terms of value and quantity (FAO, 2014). Marine and brackish water aquaculture production recorded an increase of more than 20 percent in comparison to production in 2002. The culture of bivalve molluscs is the easiest with few overheads and has proved very successful among the poor households in coastal areas. Figure 1.2 shows total aquaculture production in Malaysia according to FAO statistics.



**Figure 1.2. Reported aquaculture production in Malaysia from 1950 (FAO, 2014)**

The mangrove clam *Polymesoda (Geloina)* Gray 1842 from the family Corbiculidae, is a typical mangrove bivalve, which are abundantly available lives semi-infaunally on the soft sediment (mostly in the tidal flats of Southeast Asia) that accumulates around the roots of the mangrove trees (Rizal, 2010; Gimin *et al.*, 2004; Dwiono, 2003; Ingole *et al.*, 2002; Poutiers, 1998; Kubo and Kurozumi, 1995; Morton 1984, Morton, 1976).

The distribution of *P. bengalensis* (Lamarck, 1818) is restricted to the Bay of Bengal, whereas *P. erosa* (Solander, 1786) and *P. expansa* (Mousson, 1849) are known to have wider, somewhat overlapping distribution in the Indo-Pacific region (Morton, 1984). *P. erosa* is an indigenous communities living in the coastal regions of northern Australia (Gimin *et al.*, 2004) while in Papua province, *Polymesoda* (syn. *Geloina* spp. (Morton, 1984) is an important part in traditional ceremonies and even believed to have properties to increase stamina and accelerate the healing process (Anonymous, 1999 in Dwiono, 2003).

*P. radiata* (Hanley, 1844) commonly known as green clam in mud, is circulated from Mazatlan, Mexico to Ecuador and is found mainly near the mouths of rivers (Morton, 1985). In addition, according to Bachok *et al.* (2003), *Geloina coaxans* is the only bivalve species that coexists successfully in the mangrove forest of Oura, Okinawa together with other invertebrates such as crabs and gastropods.

In Sarawak, Malaysia, three species of mangrove clams are known to occur: *P. bengalensis* (lokan bakau), *P. erosa* (lokan apung) and *P. expansa* (lokan selam) (Hamli *et al.*, 2012; Ingole *et al.*, 1994). *P. expansa* is distinguished from the other two species by few physical features such as colour and shape (Dwiono, 2003; Morton, 1984).

### Statement of the Problems

The status of *P. expansa* is least concern regarding to The IUCN Red List of Threatened Species. Currently, it is unlikely to be impacted by any major threat processes. However, due to a destruction of mangrove habitats by natural disaster and human activity, this species could have serious effects in the future. Since *P. expansa* is endemic to the mangrove habitats, more efforts and strategies are needed to conserve this species. The practice of gleaning activity on shorelines might results uncontrolled exploitation of the natural stocks and put considerable pressure on the sustainability, especially on fishery management and aquaculture (Rinyod and Rahim, 2011; Ingole *et al.*, 2002).

Little information is available on *P. expansa* reproductive cycle in Sarawak. This information will provide important knowledge for restocking of mangrove clam in their habitats. Because of that, it is vital to ascertain the reproductive cycle of *P. expansa* as a first step to its sustainable management and ultimate culture (Adjei -

Boateng and Wilson, 2011; Rinyod and Rahim, 2011). Such data are necessary for assessing sustainable exploitation rates for this species, as well as for estimating its potential capacity for sustainable aquaculture production (Mladineo *et al.*, 2007).

In this research study, the findings will be based on the more in detail research on a) studies on the accurate determination of the gonad development through histology techniques; b) studies on condition index and how it could be linked to environmental factors;

### Objectives

The objectives of this research are:

- a) to describe gonad development of *P. expansa* through histological technique and gonad index (GI);
- b) to determine the gonad stages through condition index (CI) of *P. expansa*.

## REFERENCES

- Adjei-Boateng, D. and Wilson, J.G. 2011. Body condition and gametogenic cycle of *Galatea paradoxa* (Mollusca: Bivalvia) in the Volta River estuary, Ghana, *Estuarine, Coastal and Shelf Science*, doi: 10.1016/j.ecss.2011.06.018.
- Aldrich, J.C. and Crowley, M. 1986. Condition and Variability in *Mytilus edulis* (L.) From Different Habitats in Ireland, *Aquaculture* 52: 273-286.
- Ahn IY, Surh J, Park YG, Kwon H, Choi KS, Kang SH, et al. 2003. Growth and seasonal energetics of the Antarctic bivalve *Laternula elliptica* from King George Island, Antarctica. *Marine Ecology Progress Series* 257: 99-110.
- Aminot, A. and Rey, F. 2000. Standard procedure for the determination of chlorophyll *a* by spectroscopic methods. In *ICES Techniques in Marine Environmental Sciences*. pp. 8-11. Copenhagen: Palaegade.
- APHA, Standard Methods for the Examination of Water and Wastewater, Method #10200H, 19<sup>th</sup> Edition.
- Bachok, Z., Mfilinge, P.L. and Tsuchiya, M. 2003. The diet of the mud clam *Geloina coaxans* (Mollusca, Bivalvia) as indicated by fatty acid markers in a subtropical mangrove forest of Okinawa, Japan. *Journal of Experimental Marine Biology and Ecology* 292: 187-197.
- Bancroft, J.D. and Stevens A. 1996. Theory and Practice of Histological Techniques. Fourth Edition. Shurchil Livingston Inc., New York, USA.
- Bancroft, J.D. and Gamble, M. 2002. Theory and Practical of Histological Techniques. Fifth Edition. Churchill Living-stone, 796.
- Barker, G.M. 2001. Gastropods on Land: Phylogeny, Diversity and Adaptive Morphology. In *The Biology of Terrestrial Molluscs*, ed G.M. Barker, pp. 576. Wallingford, UK: CABI Publishing.
- Bayne, B.L., Thompson, R.J. and Widdows, J. 1976. Physiology: I. In: Bayne, B.L. (Ed.), *Marine Mussels: Their Ecology and Physiology*. Cambridge University Press, London, pp. 121-206.
- Berthelin C, Kellner K, Mathieu M. 2000. Storage metabolism in the Pacific oyster (*Crassostrea gigas*) in relation to summer mortalities and reproductive cycle (west coast of France). *Comparative Biochemistry Physiology Part B*, 125: 359-69.
- Bougrier, S. Hawkins, A.J.S. and Héral, M. 1997. Preingestive selection of different microalgal mixtures in *Crassostrea gigas* and *Mytilus edulis*, analysed by flow cytometry. *Aquaculture* 150: 123-134.



- Brandt, R. 1974. The non-marine aquatic mollusca of Thailand. *Archiv fuer Molluskenkunde* 105: 1-423.
- Buchanan, S. 2001. Measuring Reproductive Condition in the Greenshell Mussel *Perna canaliculus*. *New Zealand Journal of Marine and Freshwater Research*. 35: 859-870.
- Carell, B., Forberg, S., Grundelius, E., Hermikson, L., Johnels, A., Lindh, U., Mutvei, H., Olsson, M., Svardstrom, K. and Torbjorn, W. 1987. Can mussel shells reveal environmental history? *Ambio*, 16: 2-10.
- Çelik, M.Y., S. Karayucel, R. Ozturk and B. Eyuboglu. 2012. Meat yield, condition index and biochemical composition of mussels (*Mytilus galloprovincialis* Lamarck, 1819) in Sinop, South of the Black Sea. *J. Aqua. Food Prod. Technol.*, 21: 198-205.
- Clemente S. and Ingole B. 2009. Gametogenic Development and Spawning of the Mud Clam, *Polymesoda erosa* (Solander, 1876) at Chorao Island, Goa. *Marine Biology Research*. 5: 109-121.
- Crow, T. 1996. Different effects of microhabitat fragmentation on patterns of dispersal of an intertidal gastropod in two habitats. *Journal of Experimental Marine Biology and Ecology* 206: 83-107.
- Cruz, R.A. 1984. Some Aspect of the Reproduction of *Anadara tuberculosa* (Pelecypoda: Arcidae) From Punta Morales, Punterenas, Costa Rica, *Revista de Biologia Tropical* 32: 45-50.
- Cruz, R.A. 1987. The reproductive Cycle of the Mangrove Cockle *Anadara grandis* (Bivalvia: Arcidae) in Costa Rica, *Brenesia* 27: 1-8.
- Dame, R.F. 1996. *Ecology of Marine Bivalves: an Ecosystem Approach*. CRC Press, Florida. pp. 254.
- Darriba, S., Juan, F.S. and Guerra, A. 2004. Reproductive cycle of the razor clam *Ensis arcuatus* (Jeffreys, 1865) in northwest Spain and its relation to environmental conditions. *Journal of Experimental Marine Biology and Ecology* 311: 101-115.
- Davenport, J.X. and Chen. 1987. A comparison of methods for assessment of condition in the mussel (*Mytilus viridis*). *Journal of Molluscan Study* 53: 293-297.
- de Zwaan, A. and Mathieu, M. 1992. Cellular biochemistry and endocrinology. In *The Mussel Mytilus: Ecology, Physiology, Genetics and Culture*. Ed, Gosling, E. Elsevier, Amsterdam, pp. 223-293.
- Delgado, M. and Camacho, A. P. 2005. Histological Study of the Gonadal Development of *Ruditapes decussates* (L.) (Mollusca: Bivalvia) and its Relationship with Available Food. *Science Marine*. 69(1): 87-97.



- Dibacco, D., Robert, G., Grant, J. 1995. Reproductive cycle of the sea scallop, (Gmelin, 1791), on northeastern Georges Bank. *Journal of Shellfish Research* 14: 59-69.
- Dious, S.R.J. and Kasinathan, R. 1994. Tolerance limits of two pulmonate snails *Cassidula nucleus* and *Melampus ceylonicus* from Pitchavaram mangroves. *Environment and Ecology* 12: 845 - 849.
- Department of Fisheries Malaysia. Malaysia Fisheries Directory 2005-06. Asia Medialine (M) Sdn. Bhd.
- Drummond, L., Mulcahy, M. and Culloty, S. 2005. The Reproductive Biology of the Manila clam, *Ruditapes phillipinarum* from the North-West of Ireland. *Aquaculture*. 254: 326-340.
- Dwiono, S.A.P. 2003. Introduction to mangrove clam, *Geloina erosa* and *Geloina expansa*. *Oseana* XXVIII 2: 31-38. In Bahasa Melayu.
- Dzyuba, S.M. and Maslennikova, L.A. 1982. Reproductive cycle of the Bivalve Molluscs *Anadara broughtoni* from the Southern Peter the Great Bay of the Sea Japan. *Journal of Biological Reproduction* 3: 34-40.
- Emmett, B., Thompson, K., Podham, J.D. 1987. The reproductive and energy storage cycles of two populations of *Mytilus edulis* (Linne) from British Coloumbia. *Journal of Shellfish Research* 6: 29-36.
- FAO 2014 FishStat fishery statistical collections: aquaculture production (1950–2010). Rome, Italy: Food and Agriculture Organization of the United Nations. See <http://www.fao.org/fishery/statistics/software/fishstat/en>
- Gabbott PA. 1975. Storage cycles in marine bivalve molluscs: A hypothesis concerning the relationship between glycogen metabolism and gametogenesis. In: Barnes H, editor. Proceedings of Ninth European Marine Biology Symposium. Scotland: Aberdeen University Press, p 191-211.
- Gimin, R., Mohan, R., Think, L.V. and Griffiths, A.D. 2004. The relationship of shell dimensions and shell volume to live weight and soft tissue weight in the mangrove clam, *Polymesoda erosa* (Solander, 1786) from northern Australia. *Articles NAGA, WorldFish Center Quarterly*. Vol. 27 No. 3 & 4 Jul-Dec 2004 32-35.
- Gosling, E.M. 2003. Bivalve Molluscs: Biology, ecology and culture. Fishing News Books. An imprint of Blackwell Science. MPG Books Ltd. Bodmin, Cornwall, Great Britain. pp. 433.
- Gribben PE, Helson J, Jeffs AG .2004. Reproductive cycle of the New Zealand Geoduck, *Panopea zelandica*, in two North Island populations. *Veliger* 47: 53–65.

- Grizel, H. 2003. An Atlas of Histology and Cytology of Marine Bivalve Molluscs. Infermer, France. 201.
- Guillou, J., Bachelet, G., Desprez, M., Ducrotoy, J.P., madani, I., Rybarczyk, H., Sauriau, P.G., Sylvand, B., Elkaim, B., Glemarec, M. 1990. Les modalités de la reproduction de la coque *Cerastoderma edule* sur le littoral français de la Manche et de l'Atlantique. *Journal of Aquatic Living Research* 3: 29-41.
- Gupta, P.K. 1999. Estimation of soil texture. In *Soil, plant, water and fertilizer analysis*. pp. 14-17. Jodhpur, India: Agrobios.
- Hadfield, A.J. and Anderson, D.T. 1988. Reproductive Cycles of Bivalve, Mollusca *Anadara trapezia* (Dashayes) *Venerupis cerenata* (Lamarck) and *Anomia descripta* iredale in the Sydney Region, *Australian Journal of Marine and Freshwater Research* 39: 649-660.
- Hadi, H., Azimah, A.R., Mohd Hanafi, I., Abu Hena, M.K., and Wong, S.K. 2015. Morphometric variation among three local mangrove clam species of Corbiculidae. *Songklanakarinn Journal of Science and Technology*, 37(1): 15-20.
- Hamli, H., Idris, M.H., Abu Hena, M.K. and Wong, S.K. 2012. Taxonomic study of edible bivalve from selected Division of Sarawak, Malaysia. *International Journal of Zoological Research* 8: 52-58.
- Hines, A., W.H. Yeung, J. Craft, M. Brown, J. Kennedy, J. Bignell, G.D. Stentiford, M.R. Viant. 2007. Comparison of Histological, Genetic, Metabolomics, and Lipid-based Methods for Sex Determination in Marine Mussels. *Journal of Analytical Biochemistry*. 369: 175-186.
- Hunt, C.O., Gilbertson, D.D. and Rushworth, G. 2007. Modern humans in Sarawak, Malaysian Borneo, during Oxygen Isotope Stage 3: palaeoenvironmental evidence from the great cave of Niah. *Journal of Archaeological Science* 34: 1953-1969.
- Hyun-Sung, Y., Do-Hyung, K., Heung-Sik, P. and Kwang-Sik, C. 2011. Seasonal Changes in Reproduction and Biochemical Composition of the Cockle, *Fulvia mutica* (Reeve, 1884), in Cheonsu Bay off The West Coast of Korea. *Journal of Shellfish Research*, 30: 95-101.
- Iglesias, J.I.P. and Navarro, E. 1991. Energetic of Growth and Reproduction in Cocles (*Cerastoderma edule*): Seasonal and Age- Dependent Variations, *Marine Biology* 111: 359-368.
- Ingole, B.S., Krishna kumara, L., Ansari, Z.A and Parulekar, A.H. 1994. New record of mangrove clam *Geloina erosa* (Solander 1789) from the west coast of India. *Journal of Bombay National History Society*, 91: 338-339.

- Ingole, B.S., Naik, S., Furtado, R., Ansari, Z.A. and Chatterji, A. 2002. In *Population characteristics of the mangrove clam Polymesoda (Geloina) erosa (Solander, 1786) in the Chorao mangrove, Goa*, Proceedings of the National Conference on Coastal Agriculture, Goa, India, Apr. 6-7.
- Isaji, S. 1993. Formation of organic sheets in the inner shell layer of *Geloina* (Bivalvia:Corbiculidae): An adaptive response to shell dissolution. *Veliger* 36: 166-173.
- Isaji, S. 1995. Defensive strategies against shell dissolution in bivalves inhabiting acidic environments: The case of *Geloina* (Corbiculidae) in mangrove swamps. *Veliger* 38: 235-246.
- Integrated Taxonomic Information System. *Polymesoda* Rafinesque, 1820. ITIS Report. Retrieved 18 May 2013 from [http://www.itis.gov/servlet/SingleRpt/SingleRpt?search\\_topic=TSN&search\\_value=81382](http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=81382)
- International Union for Conservation of Nature and Natural Resources. *Polymesoda expansa*. The IUCN Red List of Threatened Species. Retrieved 18 May 2013 from <http://www.iucnredlist.org/details/189095/0>
- Jaramillo, R., Winter, J., Valencia, J., Rivera, A. 1993. Gametogenic cycle of the Chiloe scallop *Chlamis amandi*. *Journal of Shellfish Research* 12: 59-64.
- Jaramillo, R., Navarro, J. 1995. Reproductive cycle of the Chilean ribbed mussel *Aulacomya ater* (Molina, 1782). *Journal of Shellfish Research* 4: 165-171.
- Jiang, J.X. and Li, R.G. 1995. An ecological study on the Mollusca in mangrove areas in the estuary of the Jiulong River. *Hydrobiologia* 295: 213-220.
- Jintamas, S., Chinnawat, P. and Suppattana, T. 2009. Reproductive Cycle of *Anadara granosa* at Pattani Bay and its Relationship with Metal Concentrations in the Sediments. *Songklanakarin Journal of Science and Technology*. 31: 471-479.
- Joaquim, S., Matias, D., Lopes, B., S. Arnold, W. and B. Gaspar, M. 2008. The Reproductive Cycle of White Clam *Spisula solida* (L.) (Mollusca: Bivalvia): Implications for aquaculture and wild stock management. *Aquaculture*, 281: 43-48.
- Kathiresan, K. and Bingham, B.L. 2001. Biology of mangroves and mangrove ecosystem. *Advances in Marine Biology* 40: 81-251.
- Kautsky, N. 1982. Growth and Size Structure in a Baltic *Mytilus edulis* Population. *Marine Biology*. 68: 117-133.
- Kennedy, V., and Huekelem, L. 1985. Gametogenesis and Larval Production in a Population of the Introduced Asiatic clam, *Corbicula* sp. (Bivalvia: Corbiculidae), in Maryland. *Biology Bulletin*. 168: 50-60.

- King, P.K., Mcgrath, D., and Gosling, E.M. 1989. Reproduction and settlement of *Mytilus edulis* on an exposed rocky shore in Galway Bay, West Coast of Ireland. *Journal of the Marine Biological Association of the United Kingdom*, 69: 355-365.
- Kinne, O. 1964. The effects of temperature and salinity on marine and brackish-water animals. II. *Oceanography and Marine Biology*. An Annual Review, 2:281-339.
- Knox, G.A., 1986. Estuarine Ecosystems: A Systems Approach, Volume. I. CRC Press, p.198.
- Koch, V. and Wolff, M. 1996. The mangrove snail *Thais kioquiformis* Duclos: A case of life history adaptation to an extreme environment. *Journal of Shellfish Research* 15: 421-432.
- Kubo, H. and Kurozumi, T. 1995. Mollusca of Okinawa. Okinawa Shuppan, p.197. In Japanese.
- Kuriakose, P.S. 1980. Mussels (Mytilidae: Genus Perna) of the Indian coast. In Nayar, K.N., Mahadevan, S., Alagarswami, K. and Meenakshisundaram, P. T (Ed.) Coastal aquaculture: Mussel Farming, Progress and prospects. CMFRI bulletin, 29: 47-50.
- Laker, M.C. and Dupreez, C.C. 1982. An investigation into the accuracy of hydrometers for soil particle size determination. *Journal of Agroplanta* 14: 17-22.
- Laruelle, F., Guillou, J. and paulet, Y.M. 1994. Reproductive Pattern of the clams, *Ruditapes decussates* and *R. philippinarum* on Intertidal Flats in Brittany. *Journal of Marine Biology Association of United Kingdom*. 74: 351-366.
- Lee, SY.Y. 1988. The Reproductive Cycle and Sexuality of the Green Mussel *Perna viridis* (L.) (Bivalvia; Mytilacea) in Victoria Harbour, Hong Kong. *Journal of Molluscan Studies*. 54: 317-325.
- Li, Y., J.G. Qin, X. Li and K. Benkendorff. 2009. Monthly variations of condition index, energy reserves and antibacterial activity in pacific oysters, *Crassostrea gigas*, in Stansbury (South Australia). *Aquaculture*, 286: 64-71.
- Li, Q.L., Yang, Q. Ke and L. Kong. 2011. Gametogenic cycle and biochemical composition of the clam *Macra chinensis* (Mollusc: Bivalvia): Implications for aquaculture and wild stock management. *Marine Biol. Res.*, 7: 407-415.
- Mackie, G.L. 1998. Applied Aquatic Ecosystem Concepts. University of Guelph Custom Coursepack. 12 chapters.
- Marshall, R., McKinley, R.S. and Pearce, C.M. 2012. Effect of temperature on gonad development of the Pacific geoduck clam (*Panopea generosa* Gould, 1850). *Journal of Aquaculture* 338-341: 264-273.

- McIvor, A.L. 2004. *Freshwater mussels as biofilters*, PhD Thesis, University of Cambridge.
- Mercado-Silva, N. 2005. Condition Index of the Eastern Oyster, *Crassostrea virginica* (Gmelin, 1791) in Sapelo Island Georgia – Effects of Site, Position on Bed and Pea Crab Parasitism. *Journal of Shellfish Research*, 1: 121-126.
- Mladineo, I., Peharda, M., Orhanović, S., Pavela-Vrančić, M., Bolotin, J. and Treursić, B. 2007. The reproductive cycle, condition index and biochemical composition of the horse-bearded mussel *Modiolus barbatus*. *Helgoland Marine Research* 61: 183-192.
- Moore, M.N. Bubel, A. and Lowe, D.M. 1980. Cytology and cytochemistry of the pericardial gland cells of *Mytilus edulis* and their lysosomal responses to injected horseradish peroxidase and anthracene. *Journal of the Marine Biological Association of the United Kingdom* 60: 135-149.
- Morton, B. 1976. The biology and functional morphology of the Southeast Asian mangrove bivalve, *Polymesoda (Geloina) erosa* (Solander 1786) (Bivalvia: Corbiculidae). *Journal of Zoological* 54: 482-500.
- Morton, B. 1982. Some aspects of the population structure and sexual strategy of *Corbicula cf. fluminalis* (Bivalvia: Corbiculacea) from the Pearl River, Peoples's Republic of China. *Journal of Mollusca Studies* 48: 1 - 23.
- Morton, B. 1984. A review of *Polymesoda (Geloina)* Gray 1842 (Bivalvia: Corbiculidae) from Indo-Pacific mangroves. *Asian Marine Biology* pp. 77-86.
- Morton, B. 1985. The reproductive strategy of the mangrove bivalve *Polymesoda (Geloina) erosa* (Bivalvia: Corbiculidae) in Hong Kong. *Malacological Review* 18: 83-89.
- Morton, B. 1989. The functional morphology of the organs of the mouth cavity of *Batissa violacea* (Lamarck, 1797) (Bivalvia: Corbiculacea). *American Malacostraca Bulletin* 7: 73-79.
- Morton, B. 1990. The Life Cycle and Sexual Strategy of *Gafrarium pectinatum* (Bivalvia: Veneridae) in Hong Kong Mangrove. *Malacological Review* 23:53-62.
- Morton, B. 1992. The evolution and success of the heteromyarian form in the Mytiloidea. In *The Mussel Mytilus: Ecology, Physiology, Genetics and Culture*. Ed, Gosling, E. Elsevier, Amsterdam, pp. 21-48.
- Moscose, E.R., Pazo, J.P., Garcia, A. and Cortes, F.F. 1992. Reproductive Cycle Clam, *Ruditapes philippinarum* (Adams, Reev, 1850) in Ria of Vigo (NW Spain), *Journal of Science Marine* 56: 61-67.



- Narasimhan, K.A. 1988. Biology of the Blood Clam, *Anadara rehombea* (Born) in Kakinada Bay, *Journal of Marine Biological Association* 30: 134-135.
- Nybakken, J. 1992. *Biologi Laut Suatu Pendekatan Ekologis*. PT. Gramedia Pustaka Utama, Jakarta. pp.459.
- Ojea J, Pazos AJ, Marti´nez D, Novoa S, Sa´nchez JL, Abad M. 2004. Seasonal variation in weight and biochemical composition of the tissues of *Ruditapes decussatus* in relation to the gametogenic cycle. *Aquaculture* 238: 451–469.
- Okumuş,i. 1993. *Evaluation Suspended Mussel (Mytilus edulis L.) Culture and Integrated Experimented Mariculture with Salmon in Scottish Sea Loch*. PhD Thesis, University of Stirling.
- Park MS, Kang CK, Lee PY. 2001. Reproductive cycle and biochemical composition for the ark shell *Scapharca broughtonii* (Schrenck) in a southern coastal bay of Korea. *Journal of Shellfish Research* 20: 177-84.
- Park, H.J., W.C. Lee, E.J. Choy, K.S. Choi and C.K. Kang. 2011. Reproductive cycle and gross biochemical composition of the ark shell *Scapharca subcrenata* (Lischke, 1869) reared on subtidal mudflats in a temperate Bay of Korea. *Aquaculture*, 322-323: 149-157.
- Parsons, T. R., Y. Maita and C. M. Lalli.1984. *A Manual of Chemical and Biological Methods for Seawater Analysis*. Pergamon Press, Oxford, pp.173.
- Peharda M, Mladineo I, Bolotin J, Kekez L, Skaramuca B. 2006. The reproductive cycle and potential protandric development of the Noah’s Ark shell, *Arca noae* L.: implications for aquaculture. *Aquaculture* 252: 317–327.
- Poutiers, J.M. 1998. Bivalves (Acephala, Lamellibranchia, Pelecypoda). In *FAO Species Identification Guide for Fishery Purposes*, ed. K.E. Carpenter and N.H. Niem, pp. 124-127. Rome, Italy: Food and Agriculture Organization of the United Nations.
- Purchon, R.D. 1968. *The biology of mollusca*. Pargamon Press Ltd. London pp.561.
- Rainer, J. S. and Mann. R. 1992. A comparison of methods for calculating condition index in eastern oysters *Crassostrea virginica* (Gmelin, 1791). *Journal of Shellfish Research* 11: 55-58.
- Retno, H., I. Widowati., and Y. Ristiadi. 2005. Gonad Histology of *Polymesoda erosa* (Bivalvia:Corbiculidae) from Laguna Segera Anakan. *Oceanography Biology Laboratorium, Universitas Diponegoro Semarang. Bulletin of Oceanography*. Vol.10 (3): 119-125.
- Reynolds, T., Barker, G., Barton, H., Hunt, C., Kealhofer, L., Paz, V., Piper, P., Rabett, R., Stimpson, C. and Szabó, K. The first modern humans at Niah, 50, 000 – 35, 000 BP. In: Barker, G., Gilbertson, D., Reynolds, T., eds. *The*

Niah Caves, McDonald Institute for Archaeological Research, Cambridge, in press.

- Riak, K.M. 2004. *Ecological studies of migrant shorebirds in man made lake system and intertidal mudflat of Kapar and Pantai Remis, West coast of Peninsular Malaysia*. PhD Thesis, Universiti Putra Malaysia.
- Rinyod, A.M.R. and Rahim, S.A.K.A. 2011. Reproductive cycle of the razor clam *Solen regularis* Dunker 1862 in the western part of Sarawak, Malaysia based on gonadal condition index. *Journal of Sustainability Science and Management* 6: 10-18.
- Rizal, S. 2010. *The Utilization of Brachiswaterpond for Experimental Test for Mud Clams Culture Polymesoda erosa (Solander, 1786) in Mahakam Delta, East Kalimantan Province*, MSc Thesis, Universitas Diponegoro, Semarang.
- Sahin, C., Düzgüneş, E. and Okumuş, İ. 2006. Seasonal variations in condition index and gonadal development of the introduced blood cockle *Anadara inaequalis* (Bruguiere, 1789) in the Southeastern Black Sea Coast. *Turkish Journal of Fisheries and Aquatic Sciences* 6: 155-163.
- Said, A.B. 2006. *Seasonal Variations in Reproduction, Growth, Sex Ratio, and Condition Index in Perna Viridis (Linnaeus, 1758) (Mollusca: Mytilidae)*, PhD Thesis, Universiti Putra Malaysia.
- Sastry, A.N. 1979. Pelecipoda (excluding Ostreidae), In A.C. Giese & J.S. Pearse (eds.). *Reproduction of marine invertebrates*. Vol. V, Academic, New York pp. 113-292.
- Seager, V. and Nelson. 2005. *Biology of the New Zealand greenshell mussel*. Learning Resource for Unit Standard 16340v2. Auckland, New Zealand, pp. 39.
- Seed, R. 1968. Factors influencing shell shape in the mussel *Mytilus edulis*. *Journal of Marine Biology Association U.K.* 48: 561-584.
- Seed, R. 1969. The ecology of *Mytilus edulis* L. (Lamellibranchiata) on Exposed Rocky Shores 2. Breeding and Settlement, *Ecologia*. 3: 277-316.
- Seed, R. 1976. Ecology of Marine Mussels. In: B.L Bayne (Ed.), *Marine Mussels: Their Ecology and Physiology*. Cambridge University Press, London, 13-65.
- Seed, R. and Suchanek, T.H. 1992. Population and Community Ecology of *Mytilus*. In: Gosling, E. (Ed.), *The Mussel Mytilus: Ecology, Physiology, Genetics and Culture*. Elsevier, Amsterdam: 87-160.
- Severejn, H.J, Garcia, Y., and Ewald, J.J. 1994. Taxonomic Revision of *Polymesoda solida* (Philippi, 1846) (Bivalvia: Corbiculidae), A New Name for *Polymesoda arctata*, The Estuarine Clam of Lake Maracaibo and Other

Estuaries of the Tropical Atlantic Coasts of America. Rev. Científica de la Facultad Experimental de Ciencias. Universidad del Zulia 2, 53-65.

Shanmugam, A. and Vairamani, S. 2009. Mollusc in mangroves: A case study. In *International Training Course on Coastal Biodiversity in Mangrove Ecosystems: Unu-Inweh-Unesco International Training Course Manual*, ed. Kathiresan, K.K. and Khan, S.A, pp. 371-380. Annamalai Nagar, India: Annamalai University (CAS in Marine Biology, Parangipettai).

Sivalingam, P.M. 1977. Aquaculture of the Green Mussel, *Mytilus viridis* Linnaeus, in Malaysia. *Aquaculture*. 11: 297-312.

Slim, F.J., Hemminga, M.A., Ochieng, C., Jannink, N.T., de la Moriniere, C., van der Velde, G., 1997. Leaf litter removal by snail *Terebralia palustris* (Linnaeus) and sesarmid crabs in an East African mangrove forest (Gazi Bay, Kenya). *Journal of Experimental Marine Biology and Ecology* 215: 35– 48.

Siddall, S.E. 1980. A clarification of the genus *Perna* (Mytilidae). *Bulletin of Marine Science* 30: 858-870.

Skilleter, G.A. 1996. Validation of rapid assessment of damage in urban mangrove forests and relationships with molluscan assemblages. *Journal of the Marine Biological Association of the United Kingdom* 76: 701-716.

Stanley, S.M. 1972. Functional morphology and evolution of byssally attached bivalve mollusks. *Journal of Paleontology* 46: 165-212.

Szabó, K. and Amesbury, J.R. 2011. Molluscs in a world of islands: The use of shellfish as a food resource in the tropical island Asia-Pacific region. *Journal of Quaternary International* 239: 8-18.

Tokeshi, M., N. Ota and T. Kawai. 2000. A comparative study of morphometry in shell-bearing molluscs. *Journal of Zoology London* 25: 31-38.

Trol, B.L. and Gomez, E.D. 1985. Reproductive Cycle of the Cockle *Anadara antiquata* L. Clatagan, Batan Gas, Philippines, *Journal of Coastal Research* 3: 241-245.

Van Benthem Jutting, W.S.S. 1953. Systematic studies on the non-marine mollusca on the Indo-Australian Archipelago. IV. Critical revision of the freshwater bivalves of Java. *Treubia* 22: 19-73.

Walter, C. 1982. Reproduction and Growth in the Tropical Mussel *Perna viridis*. (Bivalvia: Mytilidae). *Kalikasan, Philippine Journal of Biology*. 11: 83-97.

Whedon, W.F. 1938. The digestive system of *Mytilus californianus* Conrad. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural and Behavioral Physiology* 25: 509-522.

White, K.M. 1942. The pericardial cavity and the pericardial gland of the Lamellibranchia. *Proceeding of Malacological Society London* 25: 37-88.



- Wong, W.H. and Levinton, J.S. 2004. Culture of the blue mussel *Mytilus edulis* (Linnaeus, 1758) fed both phytoplankton and zooplankton: a microcosm experiment. *Journal of Aquaculture Research* 35: 965-969.
- Yang, H.S., D.H. Kang, H.S. Park and K.S. Choi. 2011. Seasonal changes in reproduction and biochemical composition of the cockle, *Fulvia mutica* (Reeve, 1884), in cheonsu Bay off the west coast of Korea. *J. Shellfish Res.*, 30: 95-101.
- Yankson, K. 1982. Gonad Maturation and Sexuality in the West African Blood Cockle *Anadara senilis* (L.) *Journal of Molluscan Studies* 48: 294-301.
- Yap, C.K., Razeef, S.M.R., Edward, F.B. and Tan, S.G. 2009. Heavy metal concentrations (Cu, Fe, Ni and Zn) in the clam, *Glaucanome virens*, collected from the northern intertidal areas of peninsular Malaysia. *Malaysian Journal of Applied Biology* 38: 29-35.
- Yu, M. 2005. Soil and Water Pollution-Environmental Metal and Metalloids. In *Environmental Toxicology*. Florida: CRC Press, USA, pp. 185-249.

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## LIST OF PUBLICATIONS

### Publications

Hadi Hamli, Azimah Abdul Rahim, Mohd Hanafi idris, Abu Hena Mustafa Kamal, and Wong Sing King, 2015. Morphometric variation among three local mangrove clam species of Corbiculidae. *Songklanakar Journal of Science and Technology*, 37(1): 15-20.

Azimah Abdul Rahim, Mohd Hanafi Idris, Abu Hena Mustafa Kamal, S.K. Wong and A. Arshad, 2012. Analysis of Condition Index in *Polymesoda expansa* (Mousson 1849). *Pakistan Journal of Biological Sciences*, 15: 629-634.

Azimah A. R., M.H. Idris, M. K. Abu Hena and S.K. Wong. Determination of Gonad Development of Mud Clam *Polymesoda expansa* (Mousson 1849) at Kelulit, Miri, Sarawak. *Chiang Mai Journal of Science*. (Accepted).

### Poster Presentation

Azimah Abdul Rahim and Mohd Hanafi Idris. Preliminary Study on Seasonal Pattern and Condition Index of Mangrove Clam *Geloina expansa* in Kelulit, Miri, Sarawak. 1<sup>st</sup> Graduate Science Student Research Conference 2010, Universiti Brunei Darussalam. 13-15 December 2010.

Azimah Abdul Rahim, Mohd Hanafi Idris, Abu Hena Mustafa Kamal and Wong Sing King. Seasonal Pattern in Condition Index and Gonadal Development of Mangrove Clam *Geloina expansa* in Kekulit, Miri, Sarawak. 1<sup>st</sup> International Fisheries Symposium 2011, Permai Inn Kuala Terengganu. 3-5 October 2011.