



UNIVERSITI PUTRA MALAYSIA

***FEEDING HABITS OF LONG-SPINED BLACK SEA URCHIN,
DIADEMA SETOSUM FROM PANGKOR ISLAND, PENINSULAR
MALAYSIA***

FARHANAH BINTI ABDUL GHAZALI

FP 2012 101

**FEEDING HABITS OF LONG-SPINED BLACK SEA URCHIN,
DIADEMA SETOSUM FROM PANGKOR ISLAND, PENINSULAR
MALAYSIA**



FARHANAH BINTI ABDUL GHAZALI

**DEPARTMENT OF AQUACULTURE
FACULTY OF AGRICULTURE
UNIVERSITI PUTRA MALAYSIA
SERDANG, SELANGOR**

2012

**FEEDING HABITS OF LONG-SPINED BLACK SEA URCHIN,
DIADEMA SETOSUM FROM PANGKOR ISLAND, PENINSULAR
MALAYSIA**



FARHANAH BINTI ABDUL GHAZALI

153758

**This project is submitted in partial fulfillment of the requirements for the
degree of Bachelor of Agriculture (Aquaculture)**

**DEPARTMENT OF AQUACULTURE
FACULTY OF AGRICULTURE
UNIVERSITI PUTRA MALAYSIA
SERDANG, SELANGOR**

2012

ACKNOWLEDGEMENT

First and foremost, I am humbly thankful to Allah Almighty for His immense, wisdom, strength, and love I have been blessed with in my whole life.

I am grateful and would like to express my gratitude to Prof. Dr. Aziz Arshad, my supervisor for the guidance, knowledge and countless hours for refining my writing, correcting my experiment methodology and draft, help me to increase my critical thinking, fully support my final project and valuable advice along the course of my study. This final project would not be success without the support of my supervisor.

I am honorably grateful to Dr. Aminur Rahman who helps me while I am doing my research. He is the one who guide me, kept an eye on my progression and help to conduct my project. He is available every time I need help regarding my project. Besides that, I would like to thank PhD students and the Institute of Bioscience (IBS) the place where I run the project. Special thanks to Amani AbdulAziz, Dr. Roushon Ara for helping me analyze the data and Norfakhrina Mohd Noor for giving me some ideas in my thesis writing.

Lastly, I give my special thanks to my beloved family and friends. I'm grateful to have their love, patience, constant support and happy to have them around me. Only Allah will repay all the kindness and love. I dedicated my work to both of my parents.

ABSTRACT

The tropical sea urchin, *Diadema setosum* is considered as a commercially important Echinoid nowadays due to its nutritional and pharmaceutical values. In the present study, feeding habits and range of food items consumed by *D. setosum* were investigated through the examination of gut content of 60 live urchins. Sea urchin samples were collected from the intertidal reefs of Pangkor Island, Peninsular Malaysia during January-May, 2011. The diet compositions of *D. setosum* were grouped into 10 categories including algae, sea urchin spines, plant-like matters, juvenile of sea cucumber, juvenile of sea urchin, gastropod, crustacean appendages, coral fragments, debris and unidentified items. Majority of the gut was filled up with food. Analysis on the percentage of numerical of occurrence (C_i) showed that the highest value was algae (66.94%), while coral fragments (18.78%) were the second highest followed by plant-like matter (4.75%), sea urchin spines (4.47%), debris (1.68%), unidentified items (1.3%), juvenile of sea cucumber (0.39%), crustacean appendages (0.23%), and the least was juvenile of sea urchin (0.16%). Besides this, percentage frequency of occurrence (F_i) values for algae, sea urchin spines, plant-like matters, juvenile of sea cucumber and juvenile of sea urchin, gastropod, crustacean appendages, coral fragments, debris and unidentified items were 34.11, 12.99, 7.91, 1.97, 0.77, 5.17, 0.65, 23.46, 7.39, and 5.58%, respectively. The results obtained from the present study indicate that *D. setosum* is an omnivorous marine invertebrate as it consumes a variety of food items associated with their natural habitat.

ABSTRAK

Landak laut tropika, *Diadema setosum* dianggap sebagai Echinoid yang mempunyai nilai komersial pada masa kini di sebabkan oleh nilai nutrisi dan farmaseutikal. Dalam kajian terkini, penyelidikan terhadap tabiat pemakanan dan julat makanan yang di makan oleh *D. setosum* telah dijalankan ke atas kandungan perut bagi 60 ekor sampel landak laut hidup. Sampel landak laut telah di ambil di kawasan karang sekitar Pulau Pangkor, Semenanjung Malaysia pada bulan Januari sehingga Mei 2011. Komposisi diet *Diadema setosum* telah dikategorikan kepada 10 kumpulan yang mana termasuk alga, duri landak laut, tumbuhan, peringkat juvenil timun laut dan peringkat juvenil landak laut, siput, anggota badan krustasia, serpihan karang, kotoran dan item yang tidak dikenalpasti. Keseluruhan perut dipenuhi dengan makanan. Analisis ke atas peratusan yang di makan (C_i) menunjukkan nilai yang paling tinggi adalah alga (66.94%) dan serpihan karang (18.78%) merupakan yang ke dua tertinggi diikuti dengan tumbuhan (4.75%), duri landak laut (4.47%), kotoran (1.68%), item yang tidak dikenalpasti (1.3%), juvenil timun laut (0.39%), anggota badan krustasia (0.23%), dan yang terakhir adalah juvenil landak laut (0.16%). Selain itu, nilai peratusan kekerapan makan (F_i) untuk alga, duri landak laut, tumbuhan, peringkat juvenil timun laut dan peringkat juvenil landak laut, siput, anggota badan krustasia, serpihan karang, kotoran dan item yang tidak dikenalpasti adalah 34.11, 12.99, 7.91, 1.97, 0.77, 5.17, 0.65, 23.46, 7.39, dan 5.58% untuk setiap satu makanan. Keputusan yang diperolehi melalui kajian terkini menunjukkan bahawa *D. setosum* berkemungkinan adalah invertebrat laut omnivor kerana sifatnya yang memakan pelbagai jenis makanan yang terdapat di sekitar habitat semulajadinya.

TABLE OF CONTENTS

Contents	Page
ACKNOWLEDGEMENT	i
ABSTRACT	ii
ABSTRAK	iii
LIST OF TABLES	iv
LIST OF FIGURES	v
1.0 INTRODUCTION	1
2.0 LITERATURE REVIEW	4
2.1 Taxonomy	4
2.2 External and internal morphology	5
2.3 Distribution	8
2.4 Echiniode life cycle	8
2.5 Life cycle diversity	9
2.5.1 Larval diversity	10
2.6 Pelagic population dynamics	11
2.7 Feeding ecology	12
2.8 Structure of the gut	13
2.9 Role of microorganism in digestion	15
3.0 MATERIALS AND METHODS	
3.1 Study site	16
3.2 Sample collections and analysis	18
3.3 Gut content analysis	19
3.4 Data collection and analysis	20

3.5 Summary of gut analysis	21
4.0 RESULTS AND DISCUSSIONS	
4.1 Diet composition	23
4.2 Monthly variation of diet composition	29
5.0 CONCLUSION	35
REFERENCES	36



© COPYRIGHT UPM

LIST OF TABLES

		Page
Table 1	The mean percentage values of diet composition in the gut of <i>Diadema setosum</i>	23
Table 2	Monthly variations diet items for F_i in <i>D.setosum</i>	29
Table 3	Monthly variations diet items for C_i in <i>D.setosum</i>	30



LIST OF FIGURES

		Page
Figure 2.2a	External anatomy of a regular sea urchin. A. Oral view. B. Aboral view. (After Reid, W. M. In: Ruppert and Barnes, 1994).	6
Figure 2.2b	Internal anatomy of a regular sea urchin, side view. (modified after Reid, W. M., In: Ruppert and Barnes, 1994).	7
Figure 2.4	Dorsal view of the echiopluteus larva, showing the larval arms, ciliated band, and gut. Anterior is oriented towards the top of the figure. Modified from Mortensen (1921).	9
Figure 3.1a	Geographical location of study site at Pulau Pangkor, Perak. (Source: 2malaysia.com)	16
Figure 3.1b	Sampling site and collection of <i>D. setosum</i>	17
Figure 3.1c	Equipment used to collect sea urchin	17
Figure 3.2a	Adult long-spined black sea urchin, <i>Diadema setosum</i>	18
Figure 3.2b	Gut sample sealed in 5% buffered formalin	19
Figure 4.1a	Combined mean percentage of both frequency and numerical occurrence of food items consumed by <i>D. setosum</i> .	24
Figure 4.1b	Mean percentage of frequency of occurrence of different types of food items for five months.	25
Figure 4.1c	Mean percentage of the numerical abundance of different types of food items for five months.	26
Figure 4.1d	Drawing picture of internal morphology. Picture above shows the Aristotle lantern consists of five teeth.	27
Figure 4.2a	The graph of frequency of occurrence from January until May	30
Figure 4.2b	The graph of numerical abundance from January until May.	31

Figure 4.2c Food items found in the gut of *D. setosum*. a,b: juveniles; c: crustacean appendages; d: coral fragments; e: gastropods; f,g: algae; h: sea urchin spines



CHAPTER 1

INTRODUCTION

Sea urchins from the class Echinoidea are mainly omnivorous marine invertebrates that feed on both plants and animals. They usually feed on detritus, ingesting substrate and scraping algal films off hard substratum (Pearse, 1970) along with the decomposing matter. There are six species of *Diadema* (Gray, 1825).

Diadema setosum (Leske, 1778) belonging to the family Diadematidae is one of the regular echinoids widely distributed in the Indo-West Pacific Ocean, where it occurs from the Red Sea (Gulf of Suez, Gulf of Aqaba, northern and southern Red Sea), and the east coast of Africa, to Japan and Australia (Lessios *et al.*, 2001; Rahman *et al.*, 2012). This species lives mainly near to the reefs and encrusting coral rocks. It is an unselective omnivore that goes from place to place for searching food usually at night (James and Pearse, 1969). When *D. setosum* established in coastal waters it might cause harm to diverse. Moreover, this species can accumulate in colonies with large quantities, causing bioerosion to its surrounding habitat and compete with native species (Mokady *et al.*, 1996). The classification of *D. setosum* was identified using the description given by (Coppard and Campbell, 2006).

The sea urchin aquaculture industry is mainly based on the production of marketable gonads (Roe or Uni) that are considered as a priced delicacy and valuable seafood product in Asian and European markets (Buitrago *et al.*, 2005). Aquaculture of sea urchin requires an understanding on the quality and quantity of algal and prepared food for the gonad production. The extreme gonad colour depends upon the level of echinenone, which directly influence the market value (George *et al.*, 2001).

The study of nutrition had been done in many aspects including feed type (Fernandez and Boudouresque, 1997) and comparison between different algal diets (Frantzis and Gremare, 1992). Feeding ecology of urchin species had been done through gut content analysis or direct observation (Mortensen, 1943).

Until now, a very few studies have been conducted on the feeding ecology of *D. setosum*. Abbott *et al.* (1974) studied the feeding behavior of *D. setosum* and found that both drift plants and attach algae were its major foods. Sea urchin research is quite new in Malaysia. However, very few systematic works have been done on the population characteristic and distribution patterns of *D. setosum* in peninsular Malaysia (Kee Alfian, 2003; Wei *et al.*, 2008; Rahman *et al.*, 2012) but no published information on their feeding ecology are available. The present works has therefore been undertaken to investigate the biological and ecological aspects of food and feeding habits of *D. setosum*, which would add basic information on the species especially to those who want to culture it.

Hence the specific objectives of the present study are:

1. To investigate the stomach contents of *Diadema setosum*.
2. To determine the seasonal variation of diet composition of *D. setosum*.



REFERENCES

- Abbott, D. P., Ogden, J. C., Abbott I. A. (1974). Studies on the activity pattern, behavior, and food of the echinoid *Echinometra lucunter* (Linnaeus) on beachrock and algal reefs at St. Croix, U. S. Virgin Islands. Spec. Publ. No. 4, West Indies Lab., Fairleigh Dickinson University, St. Croix, U. S. Virgin Islands. 111.
- Amani, A. A., Amin, S. M. N., Arshad, A. (2011). Stomach Contents of Sergested Shrimp *Acetes japonicas* from the Estuary of Tanjung Dawai Peninsular Malaysia. *Journal of Fisheries and Aquatic Science*, **6**, 771-779.
- Amemiya, S., Tsuchiya, T. (1979). Development of the echinothurid sea urchin *Asthenosoma ijimai*. *Mar Biol.*, **52**, 93-96.
- Amy, R. L. (1983). Gametes sizes and development time table of five tropical sea urchins. *Bull Mar Sci.*, **33**, 173-176.
- Anisimov, A. P. (1981). Morphological and cytochemical characteristics of the alimentary canal epithelium of sea urchin *Stronglycentrotus intermedius* and *Stronglycentrotus nudus* (Echinodermata: Echinoidea). *Biol Morya.*, **3**, 32-42.
- Bauer, J. C., Agerter, C. J. (1994). Isolation of potentially pathogenic bacteria flora from tropical sea urchins in selected west Atlantic and east Pacific sites. *Bull Mar Sci.*, **55**, 142-150.
- Buchanan, J. B. (1969). Feeding and the control of volume within the tests of regular sea urchins. *J Zool Lond.*, **159**, 51-64.
- Buitrago, E., C. Lodeiros, K. Lunar, D. Alvarado, F. Indorf, K. Frontado, P. Moreno., Z. Vasquez. (2005). *Aquaculture International*. **13**, 359-367.
- Burke, R. D. (1981). Structure of the digestive tract of the pluteus larva of *Dendraster excentricus* (Echinodermata, Echinoidea). *Zoomorph.*, **98**, 209-225.
- Carpenter, R. C. (1981). Grazing by *Diadema antillarum* (Philippi) and its effects on the benthic algal community. *J. Mar. Res.*, **39**, 749-765.
- Clark, A., Rowe, F. W. E. (1971). Monograph of the shallow water Indo-West Pacific Echinoderms. British Museum (Natural History), London.
- Clark, H. (1921). The echinoderm fauna of Torres Strait; its composition and its origin. Carnegie Institution Publisher, Washington, DC, 214-224.
- Clark, H. (1946). The echinoderm fauna of Australia; its composition and its origin. Carnegie Institution Publisher, Washington, DC, 566-567.

- Coppard, S. E., Campbell, A. C. (2004). Taxonomic significance of the spine morphology in the echinoid genera *Diadema* and *Echinothrix*. *Invert Biol.*, **123**, 357-371.
- Coppard, S. E., Campbell, A. C. (2006). Taxonomic significance of test morphology in the echinoid genera *Diadema* Gray, 1825 and *Echinothrix* Peters, 1853 (Echinodermata). *Zoosystema.*, **28**, 93-112.
- Crook, A. C., E. Verling., D. K. A. Barnes. (1999). Comparative study of the covering reaction of the purple sea urchin, *Paracentrotus lividus*, under laboratory and field conditions. *J. Mar. Biol. Assoc. U. K.*, **79**, 1117-1121.
- De Ridder, C., Jangoux, M. (1982). Digestive systems: Echinoidea. In: Jangoux, M., Lawrence, J. M. (eds). Echinoderm nutrition. Balkema, Rotterdam, 213-234.
- Ebert, T. A. (1980). Relative growth of sea urchin jaws: an example of plastic resource allocation. *Bull Mar Sci.*, **30**, 467-474.
- Emler, R. B., McEdward, L. R., Strathmann, R. R. (1987). Echinoderm larval ecology viewed from the egg. *Echino Stud.*, **2**, 55-136.
- Fernandez, C., Boudouresque, C. -F. (1997). Phenotypic plasticity of *Paracentrotus lividus* (Echinoidea: Echinodermata) in a lagoon environment. *Marine Ecology Progress Series*. **152**, 145-154.
- Flaming, P., P. Gosselin., M. Jangoux. (1998). The podia, organs of adhesion and sensory perception in larvae and post-metamorphic stages of the echinoid *Paracentrotus lividus* (Echinodermata). *Biofouling*. **12**, 161-171.
- Frantzis, A., Gremare, A. (1992). Ingestion, absorption and growth rates of *Paracentrotus lividus* (Echinodermata: Echinoidea) feed different macrophytes. *Marine Ecology Progress Series*. **95**, 169-183.
- Fong, W., Mann, K. H. (1980). Role of gut flora in the transfer of amino acids through a marine food chain. *Can J Fish Aquat Sci.*, **37**, 88-96.
- George, S. B., J. M. Lawrence. A. L. Lawrence, J. Smiley., L. Plank. (2001). *Aquaculture*. **199**, 353-369.
- Grignard, J. C., Flaming, P., D. J. W., Jangoux, M. (1996). Distribution and abundance of the echinoide *Diadema setosum* (Echinodermata) on sediment-stressed corals reefs in Singapore. *Asian Mar. Biol.*, **13**, 123-132.
- Guib, R. A. (1981). Studies on the diet and food preferences of *Diadema setosum* and *Tripneustes gratilla* in Calatagan, Batangas. *M. Sc. Thesis, University of Philippines*, 109.

- Hansson, H. (2012). *Diadema antillarum* Phillip, 1845. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Hay, M. E. (1981). Spatial patterns of grazing intensity on a Caribbean barrier reef: herbivory and algal distribution. *Aquat. Bot.*, **11**, 97-109.
- Herring, P. J. (1972). Observations on the distribution and feeding habits of some littoral echinoids from Zanzibar. *J. Nat. Hist.*, **6**, 169-175.
- Hiratsuka, Y., Uehara, T. (2007). Feeding ecology of four species of sea urchins (genus *Echinometra*) in Okinawa. *Bull. Mar. Sci.*, **81**, 85-100.
- Holland, N. D., Ghiselin, M. (1970). A comparative study of gut mucous cells in thirty-seven species of the class Echinoidea (Echinodermata). *Biol Bull.*, **138**, 286-305.
- Hyman, L. H. (1955). The invertebrates: Echinodermata. The coelomate Bilateria. In Booloottian, R. A. (Eds). *Physiology of Echinodermata* (p. 335). New York, London.
- James, D., Pearse, J. (1969). Echinoderms from the Gulf of Suez and the Northern Red Sea. *Journal for Marine Biology Assessment*. **11**, 78-125.
- Kee, A.A.A. (2003). Biology and ecology aspects of Sea Urchin (*Diadema setosum*) in Tioman Islands. Master's Thesis, National University of Malaysia, Bangi, Selangor.
- Kroh, A. (2012)a. *Diadema mexicanum* A. Agassiz, 1863. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Kroh, A. (2012)b. *Diadema palmeri* Baker, 1976. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Kroh, A. (2012)c. *Diadema* Humphreys, 1797. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Kroh, A. (2012)d. *Diadema setosum* Leske, 1778. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Kroh, A. (2012)e. *Diadema savignyi* Michelin, 1845. In: Kroh, A. and Mooi, R. (2012). World Echinoidea Database.
- Lawrence, J. M., Hughes-Games. (1972). The diurnal rhythm of feeding and passage of food through the gut of *Diadema setosum* (Echinodermata: Echinoidea). *Israel J Zool.*, **21**, 13-16.

- Lawrence, J. M., Sammarco, P. W. (1982). Effects of feeding on the environment: echinoidea. In: Jangoux, M., Lawrence J. M. (eds). Echinoderm nutrition. AA Balkema, Rotterdam, 499-519.
- Lesions, H. A., Garrido, M. J., Kessing, B. D. (2001). Demographic history of *Diadema antillarum*, a keystone herbivore on Caribbean reefs. *Proc R Soc Lond B.*, **268**, 1-7.
- Lesions, H. A., Kessing, B. D., Wellington, G. M., Greybeal, A. (1996). Indo-Pacific echinoids in the tropical eastern Pacific. *Corals Reefs.* **15**, 133-142.
- Lesion, H. A., Pearse, J. S. (1996). Hybridization and introgression between Indo-pacific species of the sea urchin *Diadema*. *Mar Biol.*, **126**, 715-723.
- Lesker, R., Giese A. C. (1954). Nutrition of the sea urchin, *Stronglycentrotus purpuratus*. *Biol Bull.*, **106**, 328-340.
- Lewis, J. B. (1964). Feeding and digestion in the tropical echinoid *Diadema antillarum* Philippi. *Can. J. Zool.*, **42**, 550-557.
- Lubchenco, J. (1978). Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. *Am. Nat.*, **112**, 23-39.
- Lubchenco, J. Cubitt, J. (1980). Heteromorphic life histories of certain marine algae as adaptations to variations in herbivory. *Ecology.* **61**, 676-687.
- McClanahan, T. R. (1988). Coexistence in a sea urchin guild and its implication to coral reef diversity and degradation. *Oecologia.* **77**, 210-218.
- McClanahan, T. R. (1998). Predation and the distribution and abundance of tropical sea urchin populations. *J Exp Mar Biol Ecol.*, **221**, 231-255.
- McEdward, L. R., Janies, D. A. (1997). Relationships among development, ecology, and morphology in the evolution of echinoderm larvae and life cycles. *Biol J Linn Soc.*, **60**, 381-400.
- McEdward, L. R., Miner, B. G. (2001). Larval and life cycle patterns in echinoderms. *Can J Zool.*, **78**, 1125-1170.
- Mokady, O., Lazar, B., Loya, Y. (1996). Echinoid bioerosion as a major structuring force of Red Sea coral reefs. *Biological Bulletin.* **190**, 367-372.
- Mortensen, T. (1931). Contributions to the study of the development of the larval forms of the echinoderms I-II. Mem de l'Academie Royale des Sciences et des Lettres de Danemark, Copenhagen, Section des Sciences, 9me serie t. IV. No. 1 1-39.

- Mortensen, T. (1937). Contributions to the study of the development of the larval forms of the echinoderms III. Mem de l'Academie Royale des Sciences et des Lettres de Danemark, Copenhagen, Section des Sciences, 9me serie t. VII. No. 1 1-65.
- Mortensen, Th. (1940). A monograph of the Echinoidea III. Aulodonta with additions to Vol. II (Lepidocentroida and Stirodonta). Reitzel, Copenhagen, 392.
- Mortensen, Th. (1943). A monograph of the Echinoidea. III. 3., C. A. Reitzel, Copenhagen. 446 p.
- Muthiga, N. A. (2003). Coexistence and reproductive isolation of the sympatric echinoids *Diadema savignyi* (Michelin) and *Diadema setosum* (Leske) on Kenyan coral reefs. *Mar Biol.*, **143**, 669-677.
- Nader, M. R., Indary, S. E. (2011). First record of *Diadema setosum* (Leske, 1778) (Echinodermata, Echinoidea, Diadematidae) from Lebanon, Eastern Mediterranean. *Aquatic Invasions (2011)*. **6**, supplement 1, S23-S25.
- Ogden, N. B., Ogden, J. C., Abbott I. A. (1989). Distribution, abundance and food of sea urchins on a leeward Hawaiian reef. *Bull. Mar. Sci.*, **45**, 539-549.
- Okazaki, K. (1975). Normal development to metamorphosis. In: Czihak, G. (ed). The sea urchin embryo. Biochemistry and morphogenesis. Springer-Verlag, New York, N. Y, 177-232.
- Olson, R. R., Cameron, J. L., Young, C. M. (1993). Larval development (with observation on spawning) of the pencil urchin *Phyllacanthus imperialis*: a new intermediate larval form. *Biol Bull.*, **185**, 77-85.
- Onoda, K. (1936). Notes on the development of some Japanese echinoids with special reference to the structure of the larval body. *Jap J Zool.*, **6**, 637-654.
- Paulay, G., Boring, L., Strathmann, R. R. (1985). Food limited growth and development of larvae: experiments with natural sea water. *J Exp Mar Biol Ecol.*, **93**, 1-10.
- Pearse, J. S. (1970). Reproductive periodicities of Indo-Pacific invertebrates in the Gulf of Suez. III. The echinoid *Diadema setosum* (Leske). *Bull Mar Sci.*, **20**, 697-720.
- Pearse, J. S., Cameron R. A. (1991). Echinodermata, Echinoidea. In: Giese, A. C., Pearse, J. S., Pearse, V. B. (eds). Reproduction of marine invertebrates, Echinoderms and Lophophorates, Vol. 6. The Boxwood Press, Pacific Grove, CA, 514-662.

- Pearse, J. S. (1998). Distribution of *Diadema savignyi* and *Diadema setosum* in the tropical Pacific. In: Mooi, R., Telford, M. (eds) Echinoderms. AA Balkema, Rotterdam, 777-782.
- Pedrotti, M. L. (1995). Food selection (size and flavor) during development of echinoderm larvae. *Invert Reprod Dev.*, **27**, 29-39.
- Phang, S. M., Lim, P. E., Ooi, J. L. S., Yeong, H. Y., Ng, W. S., Kupper, F. C. (2008). *Malaysian Journal of Science*. **27**, 47-60.
- Podolsky, R. D. (1994). Temperature and water viscosity: physiological versus mechanical effects of suspension feeding. *Science*. **265**, 100-103.
- Pouline, E., Feral, J. P. (1996). Diversity of Antarctic echinoids: importance of dispersal strategies. *Ocean Acta.*, **19**, 464.
- Prim, P., Lawrence, J. M. (1975). Utilization of marine plants and their constituents by bacteria isolated from the gut of echinoids (Echinodermata). *Mar Biol.*, **33**, 167-173.
- Rahman, M.A., Amin, S.M.N., Yusoff, F.M., Arshad, A., P. Kuppan, Shamsudin, M.N. (2012). Length weight relationships and fecundity estimates of long-spined sea urchin, *Diadema setosum* from the Pulau Pangkor, Peninsular Malaysia. *Aquatic Ecosystem Health & Management*. **15**, 311-315.
- Randall, J. E., Schroeder, R. E., Starck, W. A. (1964). Notes on the biology of the echinoid *Diadema antillarum*. *Caribb. J. Sci.*, **4**, 421-433.
- Rassoulzadegan, F., Fenaux, L. (1979). Grazing of echinoderm larvae (*Paracentrotus lividus* and *Arbacia lixula*) on naturally occurring particulate matter. *J Plank Res.*, **1**, 215-223.
- Rupert, E. E., Barnes, R. D. (1994). Invertebrate zoology. 6th ed. Saunders College Publisher, Philadelphia.
- Schlösser, S. C., Lupatsch, I., Lawrence, J. M., Lawrence, A. L., Shpigel, M. (2005). Protein and energy digestibility and gonad development of the European sea urchin *Paracentrotus lividus* (Lamarck) fed algal and prepared diets during spring and fall. University of California, Davis.
- Strathmann, R. R. (1978). Evolution and loss of feeding larva stages of marine invertebrates. *Evolution.*, **32**, 894-906.
- Strathmann, R. R. (1989). Existence and function of a gel filled primary body cavity in development of echinoderms and hemichordates. *Biol Bull.*, **176**, 25-31.

Strathmann, R. R., Fenaux, L., Strathmann, M. F. (1992). Heterochronic development plasticity in larval sea urchins and its implications for evolution of nonfeeding larvae. *Evolution*. **46**, 972-986.

Tegner, M. J., P. K. Dayton. (1977). Sea urchin recruitment patterns and implication of commercial fishing. *Science*. **196**, 324-326.

Wei, T.K, Affendi, Y.A., Ching, C.V. (2008). A comparative population study on the Sea Urchin (*Diadema setosum*) of the Marine Park Centre jetty and adjacent reefs in Pulau Tioman, Pahang, Malaysia. The South China Sea: Sustaining Ocean Productivities, Maritime Communities and the Climate. International Conference, 2008 November 25–29. Kuantan, Pahang, Malaysia.

Yokes, B., Galil, B. (2006). The first record of the needle spined urchin *Diadema setosum* (Leske, 1778) (Echinodermata: Echinoidea: Diademataidae) from the Mediterranean Sea. *Aquatic Invasions*. **1**, 188-190.