FISH DIVERSITY IN ARTIFICIAL SEAGRASS AREA

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PERPUSTAKAAN
UNIVERSITI MALAYSIA SABAH

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I declare that this writing is the sole work of mine except for the quotation and summary which I have explained the source of each one of them.

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ABSTRACT

A field experiment was designed to assess the attraction of artificial seagrass on fishes. Artificial seagrass units were tied with 6 square metal mats, 1m x 3m, and were submerged on a plain area that only contain silt and sand nearby jetty of UMS, Sepanggar Bay. The fish identification was made up to genus level and fish abundances were recorded with the aid of photos. The characteristics of every fish were also observed during dives.

Two tests were applied by using Shannon Weaver Index and Pielou Evenness Index to know the fish diversity in the area. As the result the diversity of fish in the area was high but had decreased compared to the study in the previous year.

The interpretation of these data is that artificial seagrass successfully attracts various fishes, with the most occurrences was *Caesio sp.*. However the numbers of fishes in the area decreased based the data in previous study in this area, with some of the factors such as the condition of the artificial seagrass units in the area such as all the seagrass blades were lying on the seabed and the environmental problem such as algae bloom.

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ABSTRAK

Kajian telah dijalankan ke atas rumput laut tiruan untuk mengetahui sejauh manakah kawasan rumput tiruan ini dapat menarik ikan-ikan dari kawasan lain. Unit rumput laut tiruan ini terdiri daripada 6 petak besi sebesar 1m x 3m, ditaburkan di satu kawasan kosong yang hanya mengandungi pasir berdekatan dengan jeti Universiti Malaysia Sabah di Teluk Sepanggar. Identifikasi ikan sehingga ke genus telah dijalankan di kawasan tersebut dengan mengambil gambar foto ikan dan dicatatkan juga dengan bilangan ikan dengan menggunakan kertas berkalis air semasa menyelam.

Data-data ikan termasuk bilangan dan rupa bentuk amat diperlukan supaya kepelbagaian ikan di kawasan rumput laut tiruan dapat diketahui dengan menggunakan Index Shannon Weaver dan Index Kesamarataan Pielou. Keputusannya telah menunjukkan kepelbagaian ikan dalam kawasan tersebut adalah agak tinggi namunnya telah menurun berbanding dengan kajian sebelum ini.

Sebagai keputusan, rumput laut tiruan ini telah berjaya menarik sebilangan ikan yang berbilang spesies ke kawasan ini, di antara genus ikan yang paling banyak ialah *Caesio sp.*. Walaubagaimanapun kutipan data pada kajian sebelum ini telah menunjukkan bahawa bilangan ikan di kawasan ini telah berkurangan. Ini boleh disebabkan keadaan rumput laut tiruan itu iaitu rumput laut telah terdampar di dasar laut dan keadaan air laut di lokasi kajian seperti Pasang Surut Merah.

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LIST OF ABBREVIATION, SYMBOL AND UNIT

$\sum_{i=1}^{S}$	Sum of the number of spcies *S* started from the first spcies.
&	And
ADW	Ash-free dry weight
cm	Centimeter
DW	Dry weight
e.g.	Exempli gratia (Latin)
$E_{H'}$	Pielou Eveness Index
etc.	et cetera
H'	Shannon Weaver Index
ln	Natural logarithm
m	Meter
p_i	The relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community.
S	Number of species
sp.	Species

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ATTACHMENT

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CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Seagrass History

The earliest taxonomic studies on seagrasses were carried out in Europe by psychologists primarily interested in the abundant algal epiphytes on seagrasses and aquatic plants. The group was known as Helobiae. Systematic survey of the Helobiae, including seagrasses were carried out by Ascherson and Gürke (1889), who had studied incorporated and morphological and anatomical observations. The framework established in this study formed the basis of the groupings adopted by den Hartog (1970) in his comprehensive treatment of these plants.

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1.1.2 Ecology of Seagrass

Seagrasses are a kind of plant that lives beneath the ocean. Usually they can be found in most of the shallow coastal areas. They are present as colonies, but not individually.

In tropical areas, most of the seagrass colonies appear nearby mangroves at the coastal area. In order to grow faster and healthier, sufficient intake of nutrients is a must for seagrass. Mangrove area is the main source of nutrients due to the ability of mangroves to trap the sediments. The sediments will settle down in the area because the movement of the current in mangrove area is zero. The settlements will be fixed by microorganisms or detritus and produced as nutrients that are needed by marine flora, including seagrass, during high tide as nutrients outflow. Basically, there are certain composition of nutrients that are needed by seagrass; which are nitrate (Boon *et al.*, 1986) and phosphorus (Carignan & Kalff, 1982). Those nutrients can be attained either from the nutrients outflow of mangrove area, seabed and nutrients fixation by bacteria. Other than the organic matters and sun light, carbon dioxide is also required by seagrass in order to do the photosynthesis for food construction.

1.1.3 Seagrass Community

Seagrass meadows in many parts of the world support large numbers of juvenile fishes and provide a nursery habitat for many commercially important species (Pollard, 1984). Seagrass can provide protection for small fishes to prevent predation from other fishes. Besides, seagrass area can also provide food for juveniles and small fishes whether they are grazer or carnivores. Within seagrass area there are many

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invertebrates living in. Most of them are mobile such as gastropods, bivalves and cephalopods. For grazers, they will seek algae that grow on the seagrass leaves. Even the seagrass themselves can be the source of food for herbivores. As a result, seagrass can provide food for fishes, whether it is directly or indirectly.

1.1.4 Artificial Seagrass

Artificial seagrass is actually the mimic of natural seagrass. It has some of the functions and ability of natural seagrass. For example, it can provide nursery ground for juveniles, provide habitat for small fishes and arthropods, provide food for grazers, provide hiding place for small fishes to prevent predation of bigger fishes and prevent coastal erosion (Larkum & West, 1983).

Nevertheless, some of the functions of natural seagrass cannot be established by artificial seagrass. Artificial seagrass cannot produce gases to increase the gas regulation in the water. The leaf blade of natural seagrass can be the source of food for herbivores but not for artificial seagrass. Artificial seagrass does not have real roots as natural seagrass has for absorbing the nutrients and consolidate the sand structure to prevent coastal erosion. The details of the pros and cons between the natural seagrass and artificial seagrass will be discussed in the next chapter.

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1.2 Objective

i. To identify the genus of the fishes in the study site.

ii. To know the fish diversity by Shannon's diversity index in the artificial seagrass area.

iii. To compare the diversity of fish in the current and previous studies.

1.3 Significance of Study

The successiveness of seagrass attracting fish inhabits inside of it can be the main tool to increase the fish population in the area. Among the fishes there is probability that commercial fish also inhabits in the seagrass meadow area, indirectly increase the local fishery economics.

This artificial seagrass project expects that fishes can be attracted to this area under several factors such as food seeking, nursery ground, hiding from predators, or as the fishes' home. The attraction factors can be the reason on the build up of artificial seagrass communities in more areas to increase the productivity of fish and fisheries.

The identified fish genus can be important reference in the future. The data obtained can be the reference for any studies on seagrass or artificial seagrass. If there is any new genus or species of fish under the area of artificial seagrass area, it could be one of the contribution to the fish data base.

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CHAPTER 2

LITERATURE REVIEW

2.1 Artificial Seagrass = The Mimic of Natural Seagrass

The artificial seagrass is constructed based on the structures of real seagrass. The only differences are the real seagrass is running metabolism activities and doing photosynthesis during day time. The rest of the functions are the same with natural seagrass which will be described further in the following subchapters.

2.2 Shelter

Seagrass beds serve as nursery ground for juveniles of a variety of finfish and shellfish of commercial and sportfishing importance (Zieman, 1982).

Seagrass beds are spatially positioned between the inshore mangroves and marshes and the offshore coral reefs. Thus, a great variety of animals are permanent residents or finds temporary shelter within the leaf canopy at some stage of their life cycle. In the tropics, a number of fish and sea urchin species undertake a temporal migration from their daylight abode on the coral reef to a night-time feeding residence on the adjacent seagrasses. There are seasonal finfish and shellfish that shelter and

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feed within the seagrasses during their migratory movements. There are a great number of juvenile fish species which migrate offshore from the mangrove or marsh habitats and find refuge in the seagrass meadows before migrating offshore (Thayer *et al.*, 1978; Philips, 1984).

The previous study conducted by Bell *et al.* in 1987 determined that fish larvae were discriminating significantly between seagrass meadows and bare sandy substratum. In the study, Bell compared the fish abundances in between the artificial seagrass area, cages and bare sand. He had discussed that larger habitats (the cages) will receive more individuals than smaller habitats of the same shape (artificial seagrass units), provided there is equal availability of larvae. However, in practice, habitat shape may be even more important than habitat size. Their result showed that there is significant difference between the artificial seagrass area with bare sand area.

Kikuchi (1980) enumerated four reasons for this sheltering function: (1) Seagrass form a dense submerged meadow and increase the available substrate surface for epiphytic algae and fauna; (2) Dense vegetation reduces the water movement resulting from currents and waves and offers calm underwater space within it; (3) Because of the less disturbed water, mineral and organic particles sink to the bottom, creating relatively clear water; (4) The leaf mass reduces excessive illumination in the dynamic which facilitates the refuge effect for the prey species.

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2.3 Predation

Generally, the denser the seagrass bed, the greater the protection that is offered to macrofaunal species. Seagrass species with complex structure or a large biomass of associated epiphytes have high numbers of associated animals because they restrict the access of epibenthic predators. Experimental manipulations of seagrass density and predator abundance have indicated that both an active choice of dense patches of seagrass by most species and higher rates of predation in sparse patches are responsible for this relationship (Stoner, 1980; Bell & Westoby, 1986).

Research on both fresh water and marine predator-prey interactions has shown that structural complexity has an inhibitory effect on predator success (Orth, 1977; Nelson, 1979). Submerged vegetation is one structure that may influence predator efficiency by inhibiting the movement of predator or by reducing the visibility of prey (Stoner, 1980; Orth *et al.*, 1984). Seagrass provides a visual barrier between predator and prey which may reduce predator detection of prey and prey detection of predator.

Some predators can feed successfully in submerged structures such as seahorse because of its physical structures. The species *Hippocampus erectus* of seahorse relies on the dorsal fin for propulsion and paired pectoral fins for precise movements within structure. The caudal fin has been replaced by a prehensile tail which also aids in manoeuvrability. The prehensile tail is also used to grasp blades and pull them aside, which facilitates passage (James & Heck, 1993).

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However, visual predation in aquatic environment is strongly correlated with ambient lights levels (James & Heck, 1993). Most animals feed during either the day, night or "twilight" hours depending on their adaptations to the influence of light on their environment. In seagrass beds, the leaf mass reduces illumination in the daytime, offering a shaded environment for living animals (Kikuchi, 1980).

As the result, seagrass beds can provide hiding place for preys to avoid predators by the blades density and shading areas that the light is blocked by the seagrass community.

2.4 Nursery Ground

Seagrass provides shelter and food during the early life history stages when individuals are susceptible to predation. This has led to the view that seagrasses are important nursery areas for fish, including species of commercial and recreational value (Kikuchi, 1974; Adams, 1976; Weinstein and Heck, 1979; Beckley, 1983; Pollard, 1984). Few species of fish actually spawn among seagrasses (Kikuchi, 1966). Instead, most of the species usually spawn at the area away from seagrass habitat such as estuaries or bays.

In Australia, Dybdahl (1979) found that 65% of all individuals were juveniles and that of 73 of the 144 species of fishes and invertebrates present were of economic value. 86 of the 88 species collected by Ramm (1986) were represented by juveniles and 18 species were of economic value. Robertson & Mann (1982) described in detail

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how juveniles of 2 species, *Sillaginodes punctatus* and *Arripis trutta*, use seagrass as their growing area.

A common pattern of seagrass habitat is for juveniles to utilize seagrass beds but for adults to inhibit a variety of different inshore habitats. Examples of sequential use of habitats by different life history stages of fish are given by Robertson & Lenanton, (1984) and Middleton *et al.* (1984). Collectively, fish occurring in estuaries as juveniles make up a substantial proportion of the total commercial fish catch (Pollard, 1984).

Actually, seagrass provides nursery areas for a resource of much greater economic value than fish, which is the penaeid prawns. As juveniles, the two most important species in fishery, the tiger prawns *Penaeus esculentus* and *Penaeus semisulcatus* are found predominantly in seagrass beds (Coles *et al.*, 1987). In southern Queensland, juvenile king prawn *Penaeus plebejus* is also commonly associated with seagrass (Young, 1978).

Other decapod species of economic value, including the western rock lobster *Panulirus cygnus* and the blue swimmer crab *Portunus pelagicus*, also occur in seagrass as juveniles. Larger juveniles shelter on reefs during the day but forage over adjacent beds of *Heterozostera* and *Halophila* at night (Jernakoff, 1987). Blue swimmer crabs settle from the plankton into seagrass beds near the mouths of estuaries (Bell & Westoby, 1986), and small juveniles are common in intertidal seagrass. Cockles (*Anadara trapezium*) are another exploited species that settles into

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seagrass beds from the plankton. They are different from other species discussed before because they remain there permanently.

Some juvenile fish are not dependent on seagrass bed, but shelter it provides. Bell *et al.* (1987) found that several species are believed to use only seagrass as nursery area, settled and survived as small juveniles equally well on artificial shelter. The results of Bell *et al.* (1987) help put the role of seagrass beds as nursery areas into perspective. Even though seagrass may not be essential to some of the juvenile fishes, seagrass do provide the bulk of the shelter available in many estuaries. Without seagrasses, shelter will be lacking or greatly reduced. Without shelter, the settlement success of juvenile fish will be reduced.

2.5 Seagrass Epiphytes

Epiphytic organisms are important primary producers and potentially significant food sources. The skeletal remains of epiphytic crustose algae are also important as sources of $CaCO_3$ for sediments (Land, 1971). These algae are ubiquitous in their occurrence on seagrasses, and larger erect coralline algae such as *Metagoniolithon* spp. and *Jania* spp. are commonly found on some species of seagrass. In south-western Australia, up to 200 tonnes km^{-2} of calcium carbonate occur on the stems and leaves of *Amphibolis antartica*. Their skeletal remains are estimated to increase the depth of sediment by 0.5 mm m^{-2} $year^{-1}$ (Walker & Woelkerling, 1988).

Surface of seagrass leaves typically carry a complex layer of periphyton comprising of diatoms, macroalgae, encrusting algae, bacteria, fungi and settling

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REFERENCE

Adams, S. M., 1976. The ecology of eelgrass *Zostera marina (L.)* fish communities. I. Structural analysis. *J. Exp. Mar. biol. Ecol.* **22**, 269-91.

Allen, G. R. & Steene, R. C., 2002. *Indo Pacific Coral Reef Field Guide*. Tropical Reef Research, Singapore.

Allen, G. R., 2000. *Marine Fishes of South-East Asia*. Periplus Editions (HK) Ltd., Singapore.

Ascherson, P. & Gürke, M. (1889). Hydrocharitaceae. In 'Die natürlichen pflanzenfamilien' II (Eds A. Englar and K. Pramtl), edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. **Vol. 1**, 238-58.

Beckley, L. E., 1983.The ichthyofauna associated with *Zostera capensis* Setchell in the Swartkops estuary, South Africa, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *S. Afr.J. Zool.* **18**, 15-24.

Bell, J. D. & Westoby, M., 1986. Importance of local changes in leaf height and density to fish and decapods associated with seagrasses. *J. Exp. Mar. Biol. Ecol.*, **Vol. 104**, 249-74.

Bell, J. D., Westoby, M. & Steffe, A. S., 1987. Fish larvae settling in seagrass: do they discriminate between beds of different leaf density? *J. Exp. Mar. Biol. Ecol.*, **Vol. 111**, 133-44.

Bell, J. D.; Burchmore, J. J. & Pollard, D. A., 1984. Community structure and trophic relationships of the fish fauna of an estuarine *Posidonia Australis* seagrass habitat in port hacking, New South Wales. *Aquatic Botany*, **18**, 71-87.

Boon, P. I, Moriarty, D. J. W. & Saffigna, P. G. (1986). Rates of ammonium turnover and the role of amino acid deamination in seagrass (*Zostera capricorni*) beds of Moreton Bay, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. Australia. *Mar. Biol.* **91**, 259-68.

Borum, J., 1985. Development of epiphytic communities on eelgrass (Zostera marina) along a nutrient gradient in a Danish estuary. *Mar. Biol.* **87**, 211-8.

UMS
UNIVERSITI MALAYSIA SABAH

Carignan, R. & Kalff, J. (1982). Phosphorus release by submerged macrophytes: significance to epiphyton and phytoplankton, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Limnol. Oceanogr.* **27**, 419-27.

Carr, W. E. S. & Adams, C. A., 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Trans. Am. Fish. Soc.* **102**, 511-40.

Charles R. C. Sheppard, 2000. *Seas at the millennium: An environmental evaluation, Vol. III Global issues and process*. Elsevier Science Ltd, The Boulevard, Langford Lane Kidlington, Oxford OX5 1GB, UK.

Coles, R. G., Lee Long, W. J., Squire, L. C. & Bibby, J. M., 1987. Distribution of seagrasses and associated juvenile commercial penaeid prawns in north-eastern Queensland waters, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aust. J. Mar. Freshw. Res.* **38**, 103-20.

Connolly, R. M., 1994. Removal of Seagrass canopy: effects on small fish and their prey. *Journal of Experimental Marien Biology and Ecology,* **184** (1994) 99-110.

Connolly, R. M., 1994. The role of seagrass as preferred habitat for juvenile *Sillaginodes punctata* (Cuv. & Val.) (Sillaginidae, Pisces): habitat selection or feeding? *Journal of Experimental Marine Biology and Ecology,* **180** (1994) 39 - 47.

den Hartog, C., 1970. Seagrasses of the World. Verh. Kon. Ned. Akad. Wetens. Afd. Naturk. Ser. 2 **59**, 1-275+31 plates

Duka, L. A., 1978. Trophic complexes of fish larvae and fingerlings in the vegatative coastal zone of the Black Sea, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *J. Ichthyol.* **18**, 35-44.

Dybdahl, R. E., 1979. Technical report on fish productvity. An assessment of the marine faunal resources of Cockburn Sound, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. West. Aust. Dept. Conservation and Environment. Rep. No. 4.

UMS
UNIVERSITI MALAYSIA SABAH

Froese, R. & D. Pauly. Editors, 2007. *FishBase*. World Wide Web electronic publication.http://www.fishbase.org

Garrison, T., 2005. Oceanography: An invitation to Marine Science, 5th edition. Brooks/ Cole – Thomson Learning, USA.

Harmelin-Vivien, M. L., 1983. Etude comparative de l'ichtyofauna des harviers de phanerogames marines en milieux tropical et tempere, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Rev. Ecol.* (*Terre Vie*) **38**, 179-210.

Heijis, F. M. L., 1984. Annual iomass and production of epiphytes in three monospecific seagrass communities of Thalassia hemprichii (Ehrenb.) Aschers, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aquat. Bot.* **20**, 195-218.

Howard, R.K. & Koehn, J. D., 1985. Population dynamic and feeding ecology of pipefish (Syngnathidae) associated with eelgrass beds of Western Port, Victoria. Aust, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *J. Mar. Freshw. Res.* **36**, 361-70.

Huh Sung-Hoi & Kitting, C. L., 1985. Trophic relationships among concentrated populations of small fishes in seagrass meadows. *J. Exp. Mar. Biol. Ecol.* 1985, **Vol. 92**, pp. 29-43.

Huh, S. H. & Kitting, C. L., 1985. Trophic relationships among concentrated populations of small fishes in seagrass meadows. *J. Exp. Mar. Biol. Ecol.* **92**, 29-43.

James, L. P. & Heck, Jr., K. L., 1993. The effects of habitat complexity and light intensity on ambush predation within a simulated seagrass habitat. *J. Exp. Mar. Biol. Ecol.* **176**, 187-200.

Jernakoff, P., 1987. Foraging patterns of juvenile western rock lobster, *Panulirus cygnus* George. *J. Exp. Mar. Biol. Ecol.* **113**, 125-44.

Jones, J. A., 1968. Primary productivity of the tropical marine turtle grass, Thalassia testudinum Konig, and its epiphytes. Ph. D. Thesis, Miami University, Florida, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland.

UMS
UNIVERSITI MALAYSIA SABAH

Kikuchi, T., 1966. An ecological study on animal communities of the *Zostera marina* belt in Tomioka Bay, Amakusa, Kyushu, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Publ. Amakusa Mar. Biol. Lab.* **1**, 1-106

Kikuchi, T., 1974. Japanese contributions on consumer ecology in eelgrass (*Zostera marina* belt in Tomioka Bay, Amakusa, Kyushu, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Publ. Amakusa Mar. Biol. Lab.* **1**, 1-106.

Kikuchi, T., 1980. *Faunal relationships in temperate seagrass beds*. In 'Handbook of Seagrass Biology: an Ecosystem Perspective'. (Eds R. C. Philips and C. P. McRoy). Garland STPM Press, New York.

Klumpp, D. W. & Nichols, P. D., 1983a. A study of food chains in seagrass communities. II. Food of the rock flathead *Platycephalus laevigatus* Cuvier, a major predator in a *Posidonia australis* seagrass bed, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aust. J. Mar. Freshw. Res.* **34**, 745-54.

Land, L. S., 1971. Carbonate mud: production by epibiont growth on Thalassia testudinum, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *J. Sediment. Petrol.* **40**, 1361-3.

Larkum, A. W. D. & West, R. J. (1983). Stability, depletion and restoration of seagrass beds, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Proc. Linnean Soc. NSW* **106**, 201-12.

Larkum, A. W. D., McComb, A. J., Shepherd, S. A., 1989. *Biology of seagrass.* Elsevier Science Publisher B. V., Netherland.

Larkum, A. W. D., McComb, A.J., Shepherd, S. A., 1989. *Biology of seagrass*. Elsevier Science Publisher B. V., Netherland.

Livingston, R. J., 1982. Trophic organization of fishes in a coastal seagrass system, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Mar. Ecol. Prog. Ser.* **7**, 1-12.

UMS
UNIVERSITI MALAYSIA SABAH

Middleton, M. J., Bell, J. D., Burchmore, J. J., Pollard, D. A. & Pease, B. C., 1984. Structural differences in the fish communities of *Zostera capricorni* and Posidonia australis seagrass meadows in Botany Bay, New South Wales, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aquat. Bot.* **18**, 89-109.

Morgan, M. D. & Kitting, C. L., 1984. Productivity and itilization of the seagrass Halodule wrightii and its attached epiphytes, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Limnol. Oceanogr.* **29**, 1099-176.

Nelson, W. G., 1979. The importance of selective predation on amphipods: consequences for amphipod distribution and abundance. *J. Exp. Mar. Biol. Ecol.*, **Vol. 38**, pp. 225-45.

Orth, R. J., 1977. *The importance of sediment stability in seagrass communities. In, Ecology of marine benthos*, edited by B. C. Coull. University of South Carolina Press, Columbia, South Carolina, pp. 281-300.

Orth, R. J., K. L. Heck Jr. & J. V. Van Montfrans, 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships. *Estuaries*, **Vol.** 7, pp. 339-350.

Phillips, R. C. (1984). The ecology of eelgrass meadows in the Pacific Northwest: a Community Profile, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. U. S. Fish and Wildlife Service FWS/OBS-84/24. 85 pp.

Pollard, D. A., 1984. A review of ecological studies on seagrass-fish communities, with particular reference to recent studies in Australia, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aqut. Bot.*, **Vol. 18**, pp. 3-42.

Raja Dain Jazlands Shah Raja Abdul Rahman, 2006. *Keberkesanan rumput laut tiruan sebagai habitat hidupan marin*. Bachelor of Science Dissertation, University Malaysia Sabah (unpublished).

Ramm, D. C., 1986. *An ecological study of the ichthyoplankton and juvnile fish in the Gippsland Lakes, Victoria*, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. Ph.D. Thesis, University of Melbourne, Melbourne, Australia.

UMS
UNIVERSITI MALAYSIA SABAH

Randall J. E.; Allen, G. R. & Steene, G. C., 1997. *Fishes of the Great Barrier Reef and Coral Sea Revised & Expanded Edition.* Periplus Edition (HK) Ltd., Singapore.

Robertson, A. I. & Lenanton, R. C. J., 1984. Fish community structure and food chain dynamics in the surf-zone of sandy beaches: the role of detached macraphyte detritus. *J. Exp. Mar. Biol. Ecol.* **84**, 265-83.

Robertson, A. I. & Mann, K. H., 1982. Population dynamics and life history adaptation of Littorina neglecta Bean in an eelgrass meadow (*Zostera marina* L.) in Nova Scotia. *J. Exp. Mar. Biol. Ecol.* **63**, 151-71.

Silberstein, K., Chiffings, A. W. & McComb, A. J., 1986. The loss of seagrass in Cockburn Sound, Western Australia, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aquat. Bot.* **24**, 355-71.

Stoner, A. W., 1980. Perception and chioice of substratum by epifaunal amphipods associated with seagrasses, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Mar. Ecol. Prog.* **Ser. 3**, 105-11.

Stoner, A. W., 1982. The influence of benthic macrophytes on the foraging behaviour of pinfish, *Lagodon rhomboids* (Linnaeus). *J. Exp. Mar. Biol. Ecol.* **58**, 271-84.

Thayer, G. W., Stuart, H. H., Kenworthy, W. J., Ustach, J. F. & Hall, A. B. (1978). Habitat values of salt marshes, mangroves, and seagrasses for aquatic organisms. *In Wetland Functions and Values: The State of Our Understanding*, eds. P. E. Greeson, J. R. Clark, and J. E. Clark (eds.). Am. Water Res. Assoc. Minneapolis, MN, pp. 235-247.

Thomson, J. M., 1959. Some aspects of the ecology of Lake Macquarie. N. S. W., with regard to an alleged depletion of fish. IX. The fishes and their food, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aust. J. Mar. Freshw. Res.* **10**, 365-74.

Walker, D. I. & Woelkerling, W. J., 1988. A quantiatative study of sediment contribution by epiphtyic coralline red algae in seagrass meadows in Shark Bay, Western Australia, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Mar. Ecol. Prog. Ser.* **43**, 71-7.

UMS
UNIVERSITI MALAYSIA SABAH

Watson, G. F., Robertson, A. I. & Littlejohn, M. J., 1984. Invertebrate macrobenthos of the seagrass communities in Western Port, Victoria. *Aquatic Botany*. **18**, 175-97.

Weinstein, M. P. & Heck, K. L., Jr., 1979. Ichthyofauna of seagrass meadows along the Caribbean coast of Panama and in the Gulf of Mexico: composition, structure and community ecology, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Mar. Biol*. **50**, 97-107.

Young, P. C., 1978. Moreton Bay, Queensland: a nursery area for juvenile panaeid prawns, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. *Aust. J. Mar. Freshw. Res.* **29**, 55-75.

Zieman, J. C. (1982). The ecology of the seagrasses of south Florida: a community profile, edited by A. W. D. Larkum, A.J. McComb, S. A. Shepherd, Elsevier Science Publisher B. V., Netherland. U. S. Fish Wildlife, FWS/OBS-82/25, Washington, D. C. pp.123.

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