EXPLORING BIODIVERSITY & FISHERIES BIOLOGY
A Fundamental Knowledge for
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UPM UNIVERSITI PUTRA MALAYSIA

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PROFESSOR DR. AZIZ ARSHAD

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ABSTRACT

Research on fisheries biology receives less attention due to several underlying factors. However, the opportunity is still great as the scope under fisheries biology is very wide and furthermore, our waters is rich in fish species that are of importance to the fisheries industry. Malaysia dependence on capture fisheries is still strong, as aquaculture production stays at around 30% of the total fish production. Research on wide range of marine organisms that help to enhance the fish production ought to be encouraged. In comparison to finfish, molluscan shells and crustaceans are lagging behind in term of their biological information and have long been receiving less interest from the researchers. This is despite seafood demands for shrimps, crabs and shells are consistently high and on the increase. Taking the matter as an important issue, our research team in UPM has for the past two decades focused and engaged on biological research of this group of fish resources. Knowledge and output on the biological aspects of these invertebrate species is important in many ways; primarily it might help to propel the development of new species for shellfish aquaculture whether as a culture species itself or alternatively acting as a source of live foods for hatchery use. Acting along this objective and tagging up with national interest on increasing fish production, works on the reproductive and feeding biology as well as diversity and ecology are undertaken. The lecture will take a closer look at the research being assumed by us and will discuss the results and findings on several invertebrate species that we studied.

INTRODUCTION

The definition of fish according to Macmillan is an animal that lives in water and swims. It breathes by using its gills and moves by using its tail and fins. However, when we mention fisheries resources, it now well recognized that this would also include other aquatic resources such as shellfish and seaweeds. When we refer fisheries as a term, we also include the fish populations that are of commercial value encompassing marine, brackishwater and freshwater fisheries. Fisheries biology is a term to describe a scientific discipline that emphasize on the study of fisheries. The scope for fisheries biologists are quite diverse, and ranging from study on fish stocks or populations, its ecological surrounding and on the conservation and sustainable management of the resources. Research on the topic of fisheries biology in Malaysia is still not extensively been implemented. We are still lack of published information on the topic. This could possibly due to limited pool of the resource person, lack of interest on the subject amongst fishery researchers on the topic, and perhaps greater priority is given to aquaculture related research.

In term of application, the knowledge on fisheries biology extends beyond the management measures of the populations. It also encompasses the biology and ecology of the fish species. As a benefit, extensive fisheries biology knowledge of wild but potential aquaculture species would enhance the opportunity for the introduction of perhaps new aquaculture species. In addition, information on the varieties of live foods inhabiting the aquatic ecosystem would allow emergence of nutritious but cost effective live feed in the fish hatchery operation. Established facts on some of the important biological findings of the stocks give specific accounts on their behaviors and these would reciprocally consolidate the management policies been developed by the authority.

Fisheries production in Malaysian is still being dominated by the capture fisheries or catches that come from the sea. This has been going for many decades despite various measures and projects been implemented by the government to boost the aquaculture of the country. Amongst the problem faced by the aquaculture farmers are shortage of good quality and specific pathogen free seeds and spiraling costs of formulated fish feeds. At present aquaculture only contributes about 30% of the total fish production and we have to double the effort to enhance aquaculture sector through research and development as well as high technology input.

With greater concern hailed by fishery managers and established reports made on the overfishing state of capture fisheries, alarming increase in pollution status of the aquatic water body, lost of fish habitat through coastal development and uncertainties due to global climate change, its becoming more of a great apprehension that many of the existing commercial fisheries might be further threatened and the resources would one day be diminished. This would certainly require greater efforts to be channeled towards developing the aquaculture sector as this is the logical alternative for the continuation of the fish supply to the increasing human population. One of the remedial efforts is through the intensive research and development where researches are tailored and focused on the development of new technology and enhanced culture systems with the prime objective of increased production.

FISHERIES BIOLOGY RESEARCH

The overall mission of the UPM Fisheries Biology Research Group is to provide our stakeholders with the knowledge required to ensure the conservation of fish and aquatic resources that are faced with increasing societal demands and increasing loss or degradation of habitat. Our group has undertaken several research projects that

are of significant contribution to the fisheries sector of the country. Most of the emphasis is confined to the study on the biological aspects of the marine organisms mainly marine invertebrates. Both the crustaceans and molluscs are the two important taxa group of fish resources that we prioritized in our research activities. The contents and outputs of the research are given below.

BIOLOGY AND POPULATION STUDIES OF SERGESTID SHRIMPS OF *ACETES SPP.* (DECAPODA: SERGESTIDAE)

Acetes shrimp or locally known as geragau, udang baring, udang bubuk, udang siring is a minor planktonic crustacean group represented by a small number of species but formed one of the economically important organisms in Asia region. (Arshad *et al*., 2007; Amin *et al*., 2011). Although *Acetes* shrimp does not belonged to the highly priced shrimp commodity group, it is still important in term of its use as a the fish resources as these shrimps are continuously being exploited by small scale coastal fishermen for the making of shrimp paste, cencalok and several other products. A great number of small income fishermen thrive on this shrimp for their living income although in some fishing areas *Acetes* fishing is seasonal. In view of this social and economical importance, an extensive studies encompassing the taxonomy, morphometric variation, population genetics, reproductive cycle, sex ratio, fecundity, feeding habits, seasonal abundance, growth, mortality, recruitment, yield-per-recruit and status of the stock of *Acetes* spp. were undertaken between 2005 to 2007. Most of the important *Acetes* fishing and landing areas in Peninsular Malaysia are included in the research. Due to limited funds and logistics, we are unable to implement our extensive coverage in Sabah and Sarawak.

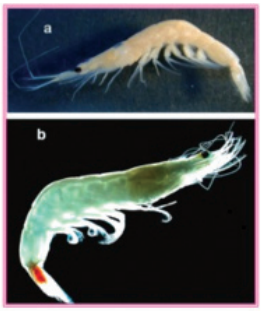


Fig . *Acetes indicus*. a, male (x60) and b, female (x60)

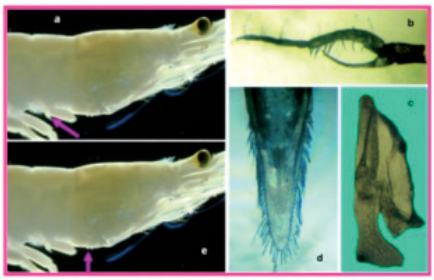


Fig a, Procurved tooth present in male (x40); b, One clasping spine in male (x40); c, petasma without pars astringens (x40); d, telson of female almost triangular (x40); e, third thoracic sternite is deeply channelled in female (x40).

(Morphological characteristics of *Acetes indicus*, with figures showing diagnostic features that are used in *Acetes* taxonomy)

Earlier works by Pathansali (1966) reported the presence of six *Acetes* species and our review on the species diversity of Peninsular Malaysia and East Malaysia listed five species of *Acetes* viz. *Acetes indicus*, *A. japonicus*, *A. intermedius*, *A. vulgaris* and *A. serrulatus*. *Acetes japonicus* was recorded from samples taken from Klebang Besar (Malacca) and Kuala Gula (Perak. The widely distributed *A. japonicus* was recorded from Klebang Besar (Malacca), Kuala Gula (Perak), Bagan Ajam (Penang), Kuala Sala (Kedah) and Sg Berembang (Perlis). *Acetes intermedius* were identified of samples collected from Seberang Takir (Terengganu) and Bintulu (Sarawak). Both *Acetes vulgaris* and *A. serrulatus* were confined to samples from Pontian and Kukup in Johor (Amin *et al*., 2011).

We also examined the morphological difference of *A japonicus* specimens at four different fishing sites on the western coast of Peninsular Malaysia and found there are significant difference in term of their total length, standard length and carapace length (Arshad *et al*., 2013). This perhaps explained the different sizes

of the *Acetes* shrimps being landed at different localities along the western coast of Peninsular Malaysia. Most of the *Acetes* resources is traditionally being exploited by coastal fishermen using push nets and set bag net although trawl net has also been adopted for the exploitation of this shrimp in the east coast of Peninsular Malaysia and Sarawak. We went on to examine the efficiency of using set bag net for trapping *Acetes* shrimps and reported that 90% of the catch of this traditional gear are comprised of *Acetes* shrimps (Oh *et al*., 2010; Amani *et al*., 2011). The results label set bag net as non-destructive fishing gear and very selective for *Acetes* fishing.

Our research team also examined the population genetic variation of *Acetes japonicus* of different localities using the Random Amplified Polymorphic DNA (RAPD) marker. A total of 90 samples of *Acetes japonicus*, comprised of 30 (15 males and 15 females) from Kedah, 30 (15 males and 15 females) from Perak and 30 (15 male and 15 females) from Malacca were used. The percentages of polymorphic bands of the three geographic populations investigated varied from 57.77% to 87.77%. Genetic distances between populations and cluster analysis from UPGMA grouped the populations into two major clusters. The Perak and Malacca populations were in one cluster, while the Kedah population was clustered by itself indicating it was genetically different. The genetic distance was the highest for the Kedah and the Malacca populations while the lowest were for the Perak and the Malacca populations which probably has a closed ancestral relationship (Aziz *et al*., 2010).

As reproduction is a very important biological characteristic of an aquatic organism, we embarked on the reproductive biology study of several *Acetes* species. Our findings on the sex ratio of *A. indicus* and *A. japonicus* in the coastal waters of Malacca showed results that are in favour of females in most months of the

year. The analysis of the annual variation of gonadosomatic index (GSI) showed the continuous breeding character of *A. indicus* and *A. japonicus* throughout the year. Size at first sexual maturity of female *A. indicus* was observed at 23 mm and that was > 17 mm of total length for female *A. japonicus*. The estimated mean fecundity of *A. indicus* was 1666.28 (± 46.32) eggs. The mean monthly GSI for females *A. indicus* showed positive and significant ($P < 0.05$) correlation with conductivity ($r = 0.67$), salinity ($r = 0.65$) and TSS ($r = 0.59$)). No significant ($P > 0.05$) correlation was found between the mean monthly GSI and the remaining two variables (temperature and dissolved oxygen). The results are included in Amin *et al*. (2009) and Amin *et al*. (2010). The results could be utilized by the relevant government agencies for the specific management of the resources.

Our biological study also includes the feeding habit and stomach's food items of *Acetes* shrimps. According the Simple Resultant Index (% Rs), the stomach contents of *A. indicus* were comprised of plant matters (22.85%), fine sand and mud (16.19%), crustacean appendages (19.03%), debris (15.46%), unidentified fragments (10.56%), zooplankton (6.78%), phytoplankton (6.47%), algae (3.49%), shrimp nauplii (1.25%) and mollusc larvae (0.91%). Similarly, diet compositions of *A. japonicus* were made up of plant matters (31.82%), debris (20.06%), phytoplankton (18.45%), fine sand and mud (11.75%), appendages of decapods (6%), unidentified fragments (5.86%), algae (4.17%) and zooplankton (1.80%). These various compositions of food items proved that the two shrimps are bottom feeder omnivore (refer Amin, 2008; Amani *et al*., 2011). Details feeding works and diets of *A. serrulatus, A. japonicus* and *A. intermedius* are reported in Oh (2011), Amani et al. (2011b) and Mashitah (2013) respectively. The finding of these researches also

shed information on the type of food items consumed by *Acetes* and this could be applied for the culture of a particular species.

Our research also looked at the exploitation status of the sergestid shrimps in the fishing area in Klebang Besar Malacca. This fishing ground is being threatened with rapid coastal development and risks of habitat degradation and habitat lost is very high and in some stretches of the coastal belt, *Acetes* fishing is no more practiced. The average monthly catch per unit effort (CPUE) of the estuarine push net (EPN) was estimated at 2.50 (± 3.42) kg/fisherman/hr. The total catch comprised of three major categories those were *Acetes* shrimps (90%), followed by fish juveniles (9%) and other shrimps (1%). The annual percent composition of *A. indicus*, *A. japonicas* and *A. intermedius* were found to be 57%, 41% and 2%, respectively. The peak catch was observed in the month of October to December. There was no significant correlation ($P > 0.05$) between monthly catches and environmental parameters (temperature, dissolved oxygen, salinity, conductivity and total suspended solid). The results are documented in Amin (2008) PhD thesis, and later published by Amin *et al*. (2008). The population parameter of *A. intermedius* of Bintulu Sarawak is reported in Mashitah *et al*. (2011) and Mashitah (2013).

Length and weight data are a useful and standard result of fish sampling programs. These data are needed to estimate growth rates, length and age structures, and other components of fish population dynamics. The length-weight relationship of *A. indicus*, *A. japonicus* and *A. intermedius* is reported in Amin *et al*. (2009). The length frequency distribution for *A. indicus* suggested that the population consisted of 'two dominant age group' with mean values of 20.80 (± 0.07) mm and 29.85 (± 0.09) mm of the total length, respectively. And the population of *A. japonicus* consisted of maximum two age groups, with means of 15.18 (± 0.90) mm and

21.56 (± 1.03) mm of total length. The population of *A. intermedius* also consisted of maximum two age groups, with means of 19.18 (± 0.05) mm and 26.92 (± 0.06) mm of the total length. The positive allometric nature of growth for *A. indicus* was observed. However, isometric nature of growth was found in combined sexes of *A. japonicus*. The positive allometric nature of growth was also observed in female and both sexes of *A. intermedius*. There were significant difference between males and females size-frequency distribution of *A. indicus* (Kolmogorov-Smirnov test: $d_{max} = 0.42$, $P < 0.05$), *A. japonicus* (Kolmogorov-Smirnov test: $d_{max} = 0.39$, $P < 0.05$) and *A. intermedius* (Kolmogorov-Smirnov test: $d_{max} = 0.40$, $P < 0.05$). (Amin, 2008; Amin *et al.*, 2008; Arshad *et al*., 2012).

The growth, mortality, recruitment and relative yield per recruit of *Acetes* spp. were investigated based on monthly length-frequency data, using FiSAT software. Higher natural mortalities of male *A. indicus* and *A. japonicus* versus the fishing mortalities observed from the study indicated the unbalance position in the stock. Exploitation level (E) of female was higher than males in *A. japonicus* population. This study indicated two major recruitment events per year where two cohorts were produced per year for *A. indicus* and *A. japonicus* populations. The recruitment pattern of *A. intermedius* was continuous with one major cohort per year. Results from the analysis of the exploitation rate (E) based on the fishing mortality estimates, and from the relative yield-per-recruit (Y/R), indicate that the *Acetes japonicus* fishery is over exploited although *A. indicus* and *A. intermedius* fishery were slightly below the optimum level of exploitation. This implies that any further unrestrained increase in fishing effort might overshoot the level giving maximum sustainable yield, thus driving the stock down and leading to economic losses. (Amin *et al*., 2009; Amin *et al*., 2010; Amin *et al*., 2012)

Aziz Arshad

POPULATION PARAMETERS AND FEEDING BIOLOGY OF SERGESTID SHRIMP, *Lucifer hanseni*

Another crustacean of fishery importance is another sergestid shrimp called *Lucifer*. It is sometimes known as ghost shrimp. This type of shrimp is particularly abundant in the shallow coastal waters of where it can often create problem with zooplankton sorting due to its mass seasonal occurrence. We embark into *Lucifer* research to gather biological information on its morphological characteristics and feeding habit, to finally determine its suitability as a live feed for the fish hatchery. Growth, mortality, recruitment, status of the stock and feeding habits of *Lucifer hanseni* were examined during November 2009 to October 2010 from five stations along the Tebrau Straits, Tg Pelepas, Johor. We examined the spatial distribution of this shrimp in the Straits and found the population to be highest in density in the seagrass ecosystem as compared to the mangroves.

(*Lucifer hanseni*, one of two species known to ocuur in Malaysian waters)

The growth, mortality and recruitment of *L. hanseni* were investigated based on monthly length-frequency data, using FiSAT software. The average natural mortality (2.84 yr^{-1}) was higher than the average value of fishing mortality (1.20 yr^{-1}) indicates the imbalance position in the stock. The value for exploitation level (E) was 0.30. This indicates that the fishery of *L. hanseni* in the Tebrau Straits is under exploited. This is based on the assumption that a stock is optimally exploited when fishing mortality (F) equals natural mortality (M), or E = (F/Z) = 0.5. The annual recruitment of *L. hanseni* showed continuous recruitment with three major peaks in March, July and October. The peaks were affected by environmental factors and the availability of food source (see Arshad *et al*., 2010)

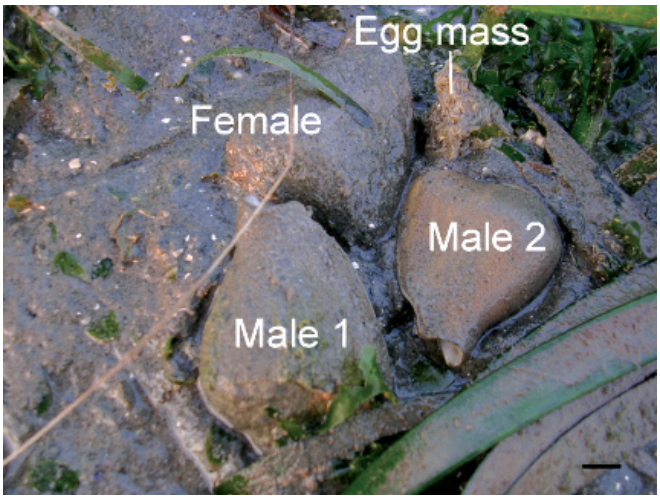
Feeding habits and diet composition of *L. hanseni* were also investigated. A total of 600 guts were examined. Diet composition was categorized into five main groups which were debris, phytoplankton, zooplankton, macroalgae and unidentified materials. According to simple resultant index (%SRI), the highest percentage of food items was debris (42.76%) followed by phytoplankton (34.96%), zooplankton (12.56%), unidentified materials (5.80%) and macroalgae (3.93%). The various composition of food items proved that *L.hanseni* is opportunistic omnivorous. *Lucifer hanseni* can switch their food preference depending on the abundance of certain types of food during the time (Norhafizah, 2013).

Based on the stomach content, it can be derived that this species also has the potential to be cultured in controlled environment and used them to feed the fish during their early development. The next option is to try and culture them in tank and then scale it up, we haven't had any trials to this extent yet.

BIOLOGY AND ECOLOGY OF DOG CONCH (*Strombus canarium* Linnaeus, 1758) (GASTROPODA: STROMBIDAE)

This research is in particular the first most extensive works ever carried out on this species of gastropod anywhere in the region. The dog conch, *Strombus canarium* is an important species within the seagrass bed ecosystem of the Merambong Shoal and its contribution to the productivity of the seagrass ecosystem is important (Cob *et al*., 2009a). Being the largest and most dominant herbivorous gastropod, they certainly might contribute significant role in the wellbeing and maintenance of the seagrass ecosystem. The species is also important economically, as people have been utilizing them for ages. It provides important artisanal, subsistence fisheries for the locals especially those who live along the shoreline.

The conch-collecting season at Merambong shoal in Tg Pelepas Johor was, however seasonal and restricted to only a few months, which was well anticipated by the locals (Cob *et al*., 2009d). Previously the conch was harvested for family consumption only, but now most collectors sold them to local retailers. Considering the importance, abundance and economic value of the species, it was surprising that the population was not being thoroughly studied before. The main objectives of this study were to investigate, analyzed and document the life history, biology and ecology of the species.



(Siput Gonggong, *Strombus canarium* (Cob, 2008)

The life history characteristics of the species, from eggs to adult, have successfully described (Cob *et al*., 2009e). *Strombus canarium* produced a long gelatinous tube of egg strand, in the form of an egg mass. The egg mass was spawned gradually, from one end to the other by dorso-ventral looping movements of the propodium, and a single female could lay up to 2 egg masses each time. The egg masses were mostly found securely attached to the seagrass. The eggs took between 4.5 to 5.5 days of incubation time before hatch, producing highly phototactic veliger larvae that swim actively towards the surface.

Our team then went on to examine the larval development. The planktotrophic stage ended for about 3 weeks, before metamorphosed and settled as early as day-18, with short period of metamorphic competence (5 - 6 days). Sequence of behavioral pattern related to metamorphosis was also observed and described. This behavior resulted in completely camouflaged juveniles that

physically blend into the surrounding sediments. At this stage the juvenile shell was very fragile, and they still unable to bury and hide into the sediment therefore camouflaging is important as their defense mechanism. This is why small juveniles are extremely difficult to sample in the field (Cob *et al*., 2009e).

At the time of settlement, specific metamorphic inducers must be in contact. Specific metamorphic cue is needed as no spontaneous metamorphosis was observed. In this study, metamorphic cue associated with sediment from nursery site was found to be the strongest. It was also important to note that sediment taken from other than the nursery ground was unable to induce metamorphosis. That is why, in their natural habitat the juveniles are found congregating at only specific areas within the shoal. The larvae might have specifically settled to this location. The nursery habitats were characterized by low to medium density of *Halophila* bed that mixed with low density of T*halassia* and/or *Halodule* grasses, and most importantly has high sediment organic content, high sorting coefficient and low in mean particle grain size. Throughout the study period the conch nursery sites were consistently found located within the microhabitat described above. This type of habitat (high sediment organic content) actually provides important source of food for the newly settled juveniles, as was observed during the laboratory culture experiment (Cob *et al*., 2010).

The growth rate of the species studied was relatively high compared with reported value for other *Strombus* species. In this study growth parameters were determined using different estimation method, i.e. Electronic Length Frequency Analysis (ELEFAN I) and Length-based Fishery Stock Assessment (LFSA) protocol in FiSAT software package. Both results were comparable to each other, and more importantly were also comparable to the actual growth rates derived from tagging experiment and laboratory culture of

the juvenile. There was much debate on the application of these methods for organisms other than fish, but this study proved that it was also useful and applicable to the gastropods (Cob *et al*., 2008a; Cob *et al.*, 2008c; Cob *et al*., 2009b).

Although the juveniles were normally limited to areas within the nursery habitat, adult populations on the other hand were more widely distributed within the shoal. They however normally present in patches of local colonies and were more abundant in sheltered areas compared with those facing open seas. Multivariate analysis found that adult population was highly correlated with area dominated by *Halophila* sp., mixed with low density of *Thalassia* sp. and *Enhalus acoroides*. The distribution / conch density was also found highly correlated with sediment organic content and negatively correlated with macroalgae (*Ulva*) density. This explains the general distribution pattern of the adults described in above paragraph. The result also suggests that food is one of the important factors, apart from reproduction, that determined their distribution along the shoal. Most of conch feeding session was spent on probing and selecting food materials within the top most layer of sediment and detritus surface, with very little time spend grazing on fresh macrophyte stands (Cob, 2008; Cob *et al*., 2012).

In many instances, *Strombus* are referred as detritivore that feeds directly on seagrass detritus. In this study *S. canarium* was however not consuming the detritus itself but rather grazed on the epibiota that live on its surface. Although stomach content analysis showed large amount of detrital materials, its low calorific value, high fiber content and low digestibility make its role as major source of nutrient uncertain. The detrital material might have accidentally been eaten and low digestibility accumulates them in the conch stomach (Cob, 2008).

The *S. canarium* population studied was highly seasonal in abundance. This explain why the fishery activity only viable during certain period of the year. Monthly length frequency distribution indicates high variation in conch densities, which was mostly due to variations in adult populations. There was significantly higher number of adults during wet season compared to dry season. The adults most probably have migrated to deeper areas during dry season (April to September) and migrate back into the shoal area to copulate and spawn during breeding season (October to March). Unfortunately, migratory behavior observation cannot be conducted for the population (Cob *et al*., 2009c).

Results from various experiment and analyses during this study have narrowed down to the conclusion that reproduction might be the main reason behind this fluctuation / migration of adults. There was high correlation between conch density and GSI. Although GSI alone cannot satisfactorily determined breeding season, combined with other biological, ecological and behavioral observations (condition index, condition factor, egg mass density, frequency of copulating pairs and population density), it can adequately be concluded that the species was indeed highly seasonal in reproduction. The reproductive season starts around early November to late March. The species is highly synchronized in their reproduction, which is important for their survivals. Nevertheless reproduction also occurred all year round, particularly around July to August where slight increased in GSI, density, coupling and spawning was observed. A few of the cohorts identified in population dynamic study were found originated (spawned) from this period. However, larval growth and development during this period (dry season) was inferior compared to wet season. This indicates that dry season is not a good season for reproduction (Cob *et al.*, 2008b).

Sexual dimorphism is obvious within the *Strombus* as they are dioecious. In this study, male and female *S. canarium* not only differed morphologically, but also showed differences in growth rates, sexual maturity and longevity. Apart from that, *S. canarium* showed sexual polymorphism where another morphs have been identified i.e. the imposex females. The later have larger, heavier and higher degrees of flaring compared with both normal males and females, and were easily recognized via the present of male genitalia on female reproductive organ. Details on imposex findings are reported in Cob *et al*. (2011).

Based on relative yield per recruit analysis, the population studied was currently still underexploited, which can be attributed to the low technology involved. There was no specific tools used where the conch were only manually collected. The collecting activity is also restricted to only a few days in a month (those with extreme low tides). Apart from that, the important factor that kept the landings low is the migratory behavior of the species, as was described earlier, which make the harvesting only viable within a few months in a year, i.e. during their breeding season.

On extensive data and information gathered in the research, our team has been succesfull in investigating the various aspects of biology and ecology of *Strombus canarium* and got them published. In general, it shares great similarity in terms of anatomy and biology with other *Strombus* species. Nevertheless, various aspects of biology and ecology unique to this tropical species have been established. There is certainly good prospect of introducing *S. canarium* for aquaculture. This includes sea-farming and restocking juveniles to the natural stock for fishery purpose, which has been practiced in the Caribbean for *S. gigas*. Among the important characteristics of *S. canarium* which make it very feasible for introduction into aquaculture are their;

Economic features: High quality and delectable meat, which is readily acceptable by the locals. The species was well distributed within the region thus good for market expansion. It has shell of high quality that can be sold as souvenir, collectible and other purpose (refer Cob, 2008)

Life History development: They live in colony and normally present in high numbers, therefore easily utilized. Spawning occur year round and egg mass available all season, easily collected, thus there will be no issues in terms of seed supply. Able to breed in captivity, with high fecundity and high percentage of egg-mass hatchability. They are herbivorous and detrivorous, which is a favorable trophic level for culture.

Nevertheless, more studies needed in order to assess the practicality, cost effective and viability of the production before engaging in any aquaculture project on the species. Both intensive and extensive culture methods for commercial hatchery production of seeds and grow out should thoroughly be investigated and evaluated. Several methods have been proposed for conch grow out: establishing protected areas for ocean ranching by reseeding of seagrass flat, stocking shallow channel-like raceways, or ponds along the shore with water circulation by the tidal fluctuation, and penning or embaying stocked juveniles.

TEMPORAL VARIATIONS IN REPRODUCTION, GROWTH, CONDITION INDEX AND SOME POPULATION PARAMETERS OF GREEN-LIPPED MUSSEL, *Perna viridis* (LINNAEUS 1758)

We embarked on this research primarily not only because green mussel is one of the commercially importance shellfish in the country, but also because there have been very few additional updates especially on the biology of this bivalves since some few earlier works in the 60s and 70s. Mussel farming to the fisheries sector can provide an alternative to the fluctuating supply of wild mussels. Cultivation on suspended ropes facilitates not only maintains continuity of production but also gives faster growth, better product, lower mortality, fuller use of the water column and the use of previously unproductive areas. In Malaysia, suspended rope culture has been conducted on experimental scale in several areas in Penang, Lumut, Perak and in the Straits of Johor. Spat falls in the Straits of Johor have been found to occur throughout the year with peaks from February to May and October to November in the east, and from June to August and November to December in the west (Choo, 1983).

Accurate forecasting of spat fall is critically vital for sustaining a good mussel farming. Therefore, a thorough study on the reproductive biology of *P. viridis* and defining the accurate times of collecting spat is essential to sustain the growing mussel culture industry in Malaysia. If proven to be successful, this will eliminate the need for hatchery technology which is thought to be uneconomical viable in the near future. Most of the previous studies tackling this problem have concluded their findings based on few culture experiments, plankton and spat collection only. In this research study the findings will be based on the more in detail research. The specific aim of this research was to investigate

the temporal reproductive cycle, growth rate, sex ratio, spat fall densities, condition index and population parameters of green-lipped mussel, *Perna viridis* under Malaysian condition (Barwani *et al.*, 2007).

Condition Index (which relates tissue dry weight to shell volume), of the green mussel *P. viridis* was concurrently studied with the histological observations of the gonads. Monthly samples of *P. viridis* were collected from the same culture site. Variations in average monthly Condition Index ranged from 21.06 to 26.72 g/cm^3. Rapid declining of the Condition Indices of the mussels was recorded in December, 2003 and January, 2004. This rapid declining indicates the spawning period which agrees with the results from the histological study (Barwani *et al*., 2007).

Studies on the gametogenesis, size at sexual differentiation, and size at first maturity of *P. viridis* from Sebatu, Malacca were performed using histological sections. More than three hundred specimens of *P. viridis* between 14.96 and 113.52 mm in total shell length were examined. No gonadal development was observed in individuals smaller than 17 mm. Sexual differentiations began at 18 mm with incipient acini formation. Specimens larger than 20.0 mm had well-developed gonads at different stages of maturation. Size at first maturity was smaller than previously reported at other localities. Active gametogenesis was recorded throughout the study period, with all stages of development usually occurring simultaneously within the same sample population (Barwani *et al*., 2007).

In the determination of gonadal index (GI), over 300 individuals were histologically prepared and analyzed. A clear fall in gonadal index was observed in the months of January and February, at this time most of the female were clearly spent. A second fall in GI with less intense was observed again during the months of September and October. Gonadal index results show that spawning event in *P.*

viridis is year around except during the months of May until August. The release of gamete between sexes was fairly synchronized, no differences in GI were observed between the male and female. 1000 specimen of *P. viridis* were used for sex ratio. The number of visually identified male, female and undetermined by looking at the mantle was 524, 412 and 64, respectively. The male: female ratio was 0.79:1 by visual identification. 316 individuals were histologically identified for sex ratio. The number of identified male, female and undetermined individual was 161, 151 and 4. The histological male: female ratio was 0.94:1. Two hermaphrodites specimen were recorded during the months of June and September, 2004. Both specimens had the occurrence of the male and female gametes on only one side of the mantle. No trace of hermaphroditism was observed neither in the second side of the mantle nor the mesosoma (Barwani *et al*., 2007; Barwani *et al*., 2013).

Spat fall study of *P. viridis* was carried out from February, 2004 until December 2004 on collector ropes suspended from the same culture site. Spat fall of the mussels was active during the entire study period with two peaks, one main peak during the months of March to June and a second peak during the months of August to December. Average, maximum and minimum settlement densities were 11,389, 29,788 and 1649 spat per meter respectively. Maximum settlement densities were counted during the month of April, while the minimum settlement densities were counted during the month of August (Barwani *et al*., 2007).

Population parameters like asymptotic length (L∞), growth co-efficient (K), mortalities, exploitation level (E) and recruitment pattern of green mussel *P. viridis* from the same site have been studied. The study was carried out using the length frequency based analysis of FiSAT software to evaluate the growth parameters, mortality rates and exploitation level. Asymptotic length (L∞)

was 102.38 mm and growth co-efficient (K) was estimated at 1.50 yr-1. Total mortality was 1.44 yr-1 for *P. viridis*. Natural mortality (M) and fishing mortality (F) were 1.67 yr-1 and 0.81 yr^{-1}, respectively. Exploitation level (E) of *P. viridis* was 0.32 while the maximum allowable limit of exploitation (E_{max}) value was 0.43. The exploitation level (< 0.50) is below the optimum level which indicates the under fishing condition of *P. viridis* in the coast of Sebatu/ Malacca, Malaysia (Barwani *et al*., 2007).

Average values recorded for temperature, dissolved oxygen, pH, and salinity were 29.44 ºC, 6.06 mg/l, 7.92, 30.12 ppt respectively. Highest values recorded for temperature, dissolved oxygen, pH, and salinity were 32.17 ºC, 7.61 mg/l, 8.44, 33.26 ppt respectively. Lowest values recorded for temperature, dissolved oxygen, pH, and salinity were 27.82 ºC, 4.94 mg/l, 7.32, 27.93 ppt, respectively. Chlorophyll-a, and total suspended solids (TSS) ranged from 1.50 to 9.40 mg/l, and 0.0253 to 0.0733 g/l, respectively (Barwani *et al*., 2007) .

We also work on the causal point for spat mortality and found pea crab, a natural parasite to the molluscs. Incidences of pea crab *Arcotheres latissimus* infestation in *P. viridis* at Sebatu was monitored from December 2003 until December 2004. Maximum infestation frequency was observed during the month of June. Size ranged of infested *P. viridis* from 19.26 to 92.18 mm. Wet weight of infested *P. viridis* ranged from 0.17 to 10.41 g. Wet weight of pea crabs ranged from 0.009 to 0.55 g. The information shed some light on the enemy of cultured mussel in our waters (Barwani *et al*., 2007).

BIOLOGY AND DISTRIBUTION OF PEN SHELLS (BIVALVIA: PINNIDAE)

Reserach on the taxonomy, biology and ecology of pen shells were conducted in Merambong shoal off the South-western state of Johor, Peninsular Malaysia. Several pen shells specimens were also acquired from other sites in Peninsular Malaysia to allow wider scope of sample collection. The study was conducted from August 2005 to April 2007. The site was chosen due to ample abundance of pen shells that live associatedly with the seagrass. A total of seven species have been recorded from the study areas comprising five species of *Pinna* and two species of *Atrina*. Ten internal and external morphological characteristics have been used for the taxonomic identification of pen shells (Idris *et al*., 2008b; Idris *et al*., 2009). *Pinna* species showed that of the ten characteristics analyzed, four characteristics were highly significant ($P<0.01$) (WL, DPML, PAMPDNL and WS). Similar result of four morphometric characteristics showed a highly significant ($P<0.01$) between the characters of three closely related species, *Pinna bicolor, P. deltodes* and *P. atropurpurea*. (Idris *et al*., 2008a; ; Idris *et al*., 2008c; Idris, 2009; Idris *et al*., 2012).

(*Pinna pectinata*, of the Pinna species found in Merambong Shoal, Johor)

Adductor muscle tissue used for the isolation of DNA and RAPD successfully detected polymorphisms in the pen shells populations. The result showed 19 primers have produced various banding patterns and thus provided sufficient information for reliable discrimination of the analyzed samples. The results indicated that the primers used generated a total of 160 fragments with 70% to 100% of polymorphic fragments. The genetic distance among these seven species of pen shells was in the range of 0.0197 to 0.3190. The dendrograms constructed from RAPD markers data were able to reveal the relationships between the pen shells populations (Idris, 2009)..

Enhalus acoroides, Halophila ovalis, Halophila minor, Cymodocea serrulata and *Thalassia hemprichii* were among the seagrasses associated with pen shells habitat in Merambong and Tanjung Adang shoals. However, pen shells can also be found in stony sand area of Merambong Island and live associated with

zoanthid, *Zoanthus pulchellus*. The sediment types from four study areas were classified as sandy loam. Monthly *in situ* physico-chemical seawater parameters recorded showed no significant different (P>0.05) during the study period. Pen shell were recorded and classified into three classes of distribution i.e clumped, random and rare.

Higher density was shown by *P. bicolor* in Merambong shoal (1) with the value of 0.83 ind/m^2 while *P. incurva* showed lower density with 0.03 ind/m^2 in Tanjung Adang shoal. *Pinna bicolor*, *P. deltodes* and *P. atropurpurea* were consistently found in these four study areas while, *P. deltodes* Menke and *P. incurva* Gmelin were both a new distribution record for Sungai Pulai seagrass beds. Merambong shoal population recorded higher diversity and richness as compared to the Tanjung Adang shoal and Merambong Island, but the value of evenness was similar between Merambong shoal, Tanjung Adang shoal and Merambong Island. Five major phyla comprising 37 species of fouling organisms were recorded. Members from phylum Crustacea and Mollusca were higher in percentage of distribution when compared to the Annelida, Echinodermata and Chordata. Phylum Mollusca showed the highest diversity while phylum Annelida was recorded the highest species richness. A symbiotic adult alpheid shrimp, *Synalpheus carinatus* was recorded inhabiting the mantle cavity of the pen shells (Idris, 2009).

Pinna bicolor reaches sexual maturity at shell length of 170 mm. *Pinna bicolor* is dioecious and no hermaphrodite individual was found during the study period. Five stages of gonad development were observed and clearly been identified. *Pinna bicolor* showed a clear spent phase in the month of October 2006, December 2006 and March 2007 while the developing and spawning phases were

observed throughout the whole study period. Monthly *in situ* physico-chemical parameters and rainfall recorded during the study did not significantly correlated with the reproductive activity of *P. bicolor* in Merambong Shoal. Pearson Correlation analysis also did not show any significant correlation between gonad index (GI) and physico-chemical parameters of seawater in Merambong shoal (Idris, 2009)..

Growth rate in natural habitat has been found to be indeterminate and rapid when compared to *P. bicolor* in culture tank. For the length-weight relationships, the growth coefficient *"b"* was found to be significantly higher than the isometric value (3.111) at 5% level and this is an indication of isometric growth in *P. bicolor* from Merambong shoal. The adductor muscle of *A. vexillum* was found the biggest in size when compared to other species (Idris 2009).

The study on penshells, *Pinna* spp. has generated new information on the biology and ecology characteristics of the bivalves. There has been no earlier works on the species and our research group has managed to carry out comprehensive studies that allow us to further research on the culture of penshells and its seed production.

DISTRIBUTION, LARVAL ABUNDANCE, SPAWNING AND EARLY DEVELOPMENT OF SADDLE OYSTER *Placuna ephippium* (PHILIPSSON, 1788)

Placuna ephippium from family Placunidae has never been previously studied in Malaysia although it has long been known to the local coastal communities in Pulai River Estuary, Johor as 'Senteng' and has been collected for food for generations by the fishermen there during low tide period. *P. ephippium* has a kind sweet taste and possesses succulent meat and adductor muscle. It is a delicacy among local fishermen communities. This bivalve species was selected as one of the studied species because of its high potential as new aquaculture product with its great taste and durability in high impact area. The research that we embarked in also allowed us to survey other molluscs species of economic importance that are quite abundant living in the Marambong Shoal seagrass beds. Merambong Shoal has been under constant threat of fauna extinction due to habitat lost since intensive development that taken shape for the construction of Port Tanjung Pelepas.

The distribution of this species and other molluscan in Merambong Shoal seagrass bed has been studied, along with the diversity and coverage of marine macrophytes, the sediment texture profile of Merambong Shoal, and their correlations with bivalve distribution. The abundance in density and distribution of 15 epifaunal bivalve species from 10 families have been estimated, and the coverage of 7 seagrass species and 1 genus of macroalgae on the shoal during low tide were calculated. *Placuna ephippium* showed great abundance in certain section of the seagrass beds in particular the sheltered part of the shoal. In general, epifaunal bivalves abundance and macrophyte coverage were more heterogeneous in the southern shoal while more homogenous at the northern shoal.

Temporal larval abundance of Placunidae and other bivalves were explored aiming to discover the natural spat fall season and explore the theory of seagrass meadow being a nursery for non-habitant bivalve larvae. The correlations between temporal bivalve larval abundance, environmental parameters and rainfall were investigated. Placunidae larvae were found from September to January of the study period and none during other months. The highest abundance of Placunidae was recorded in November 2007 with density 226 larvae m-3. Major peak on total bivalve larval abundance was noticed between November and January 2008. Through with research, our team has been able to document the larval diversity present on the Merambong seagrass beds. Larvae of six bivalve families were identified by umbonal shell morphology with Mytilidae larvae highest in abundance during November (7345 larvae m-3). No significant correlation was found between bivalve larvae abundance and seawater parameters like temperature, salinity, DO, pH and TSS. There are significant correlations between total larvae abundance and total rainfall within a week and two weeks prior to sample collection ($P < 0.01$) (Nur Leena, 2013),

Early development of *P. ephippium* was recorded and described. *Placuna ephippium* broodstocks were collected during low tide in Merambong Shoal seagrass bed. Thermal cycling procedure had successfully induced the spawning of this species. The average size of the spherical eggs before fertilisation was 57.65 ± 5.97 μm in diameter and 90.91 ± 2.04% eggs were fertilized successfully. Embryos developed into straight-hinged larvae 22 hours after fertilisation. Umbo started to take shape from Day-2. Larval shells are inequivalve with right valve almost flat and left valve inflated. Larvae developed into pediveliger on Day-9 and started to form plantigrade on Day-11. Rapid decreases were observed in survival rate during settlement (Nur Leena, 2013).

The results have shed some lights into the adoption of this species of bivalves as one of the candidates for the bivalves mariculture. Controlled reproduction can be initiated but not to deny more information on the larval rearing of this *Placuna ephippium* needs to be sorted out in order to allow us to practice its culture or restocking to the wild habitats.

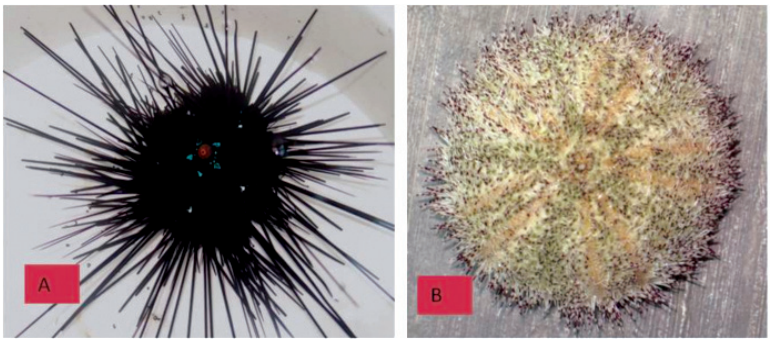
BREEDING, SEED PRODUCTION, CULTURE OF THE COMMERCIALLY IMPORTANCE SEA URCHINS

This particular research is amongst the most recent works that we undertake in UPM. Sea urchin is a marine invertebrate that belongs to phylum Echinodermata. Sea urchin has its own commercial importance as the gonad is used to produce sea urchin roe sushi and is considered as a prized delicacy mainly in Japan (Kaneniwa and Takagi, 1986). Sea urchin gonads are rich in valuable bioactive compounds, such as polyunsaturated fatty acids (PUFAs) and *β*-carotene. PUFAs, especially eicosapentaenoic acid (EPA,

C20:5) (n-3)) and docosahexaenoic acid (DHA C22:6 (n-3)), have significant preventive effects on arrhythmia, cardiovascular diseases and cancer (Pulz and Gross, 2004). On the other hand, the high levels of AA and EPA recently detected in *Diadema setosum* and *Salmacis sphaeroides* supported the development of aquaculture of this urchin (Chen *et al*., 2009), since PUFAs are important for human nutrition.

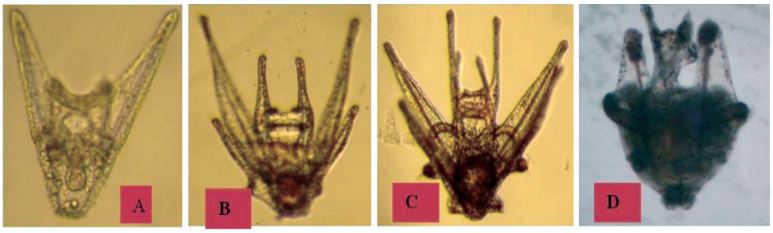
Eleven species of sea urchins have been documented in Malaysian waters including *Diadema setosum* and *Salmacis sphaeroides,* (Rahman and Yusoff, 2010). However, very few systematic works have been done on the abundance, distribution and population growth patterns of *D. setosum* and *S. sphaeroides* in Malaysia (Rahman et al., 2012a, 2013) but no published information on their breeding, nursing, seed production and culture techniques are available. Due to the higher nutritional values of sea urchin gonad, it is very important to develop appropriate techniques for breeding and nursing. In view of this, two projects have been undertaken (i) to develop a viable methodology for breeding, seed production and culture of *D. setosum* and *S. sphaeroides* in captivity (ii) to determine the biochemical composition of gonads in a view to develop nutraceutical and pharmaceutical products.

Sexually matured adults of the sea urchins, *D. setosum* (Figure below) and *S. sphaeroides* (Figure below), were collected from Pulau Pangkor, Perak and Merambong shoal, Johor.

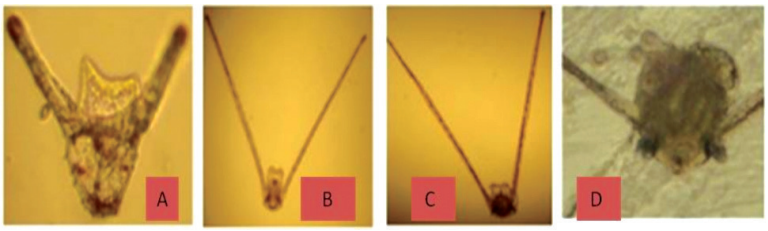


(Matured adults of tropical sea urchins: A) *D. setosum* (Rahman et al. 2012a), B) *S. sphaeroides* (Rahman *et al*. 2012b).

Gametes from both female and male urchins were obtained by injecting 0.5 M KCl into the coelomic cavity. Eggs were collected and fertilization was done at limited sperm concentration and the resulting embryos and larvae were reared. When the larvae attained feeding stage (four-armed pluteus), they were cultured in glass bottles on a rotating roller with a larval density of 1-2 individual/ml. Larvae were supplemented with a cultured phytoplankton, *Chaetoceros calcitrans* at concentrations of 4,000-8,000 cells per ml of medium daily until attaining metamorphic competence within 1 month post-fertilization.

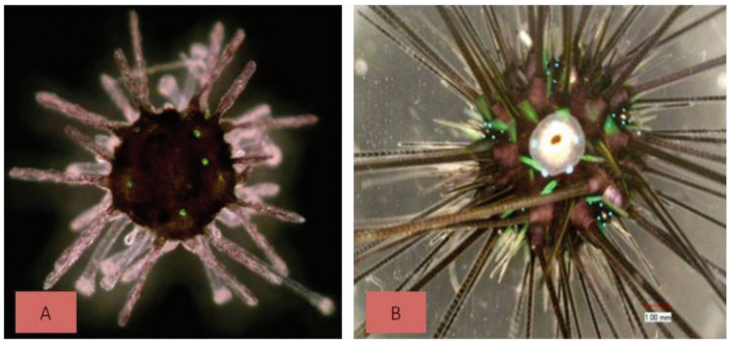


(Larval developmental stages of *S. sphaeroides*: A) 4-arm pluteus, B) 6-arm pluteus, C) 8-arm pluteus, D) Competent larva with complete rudiment growth (Rahman et al. 2012b).

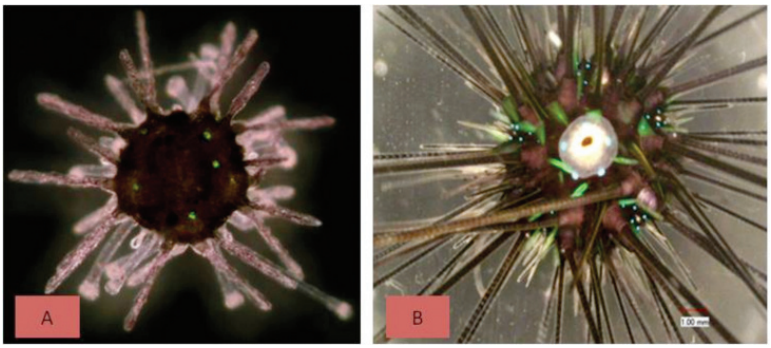


(Larval developmental stages of *D. setosum*: A) 4-arm pluteus, B) POA (Postoral arm)-elongated stage-1, C) POA-elongated stage-2, D) Competent larva with complete rudiment growth and development

Induction of metamorphosis was performed on coralline red algal extracts + *Chaetoceros* diatom (50:50) in petri dishes (9.0 x 3.0 cm) containing FSW. Majority of the competent larvae were metamorphosed to young juvenile within 1 day post-settlement and then cultured on coralline algal stones in aerated aquaria for three months by which time they attained appropriate juvenile sizes (Fig. 3a,b) for stocking in grow out culture aquaria.

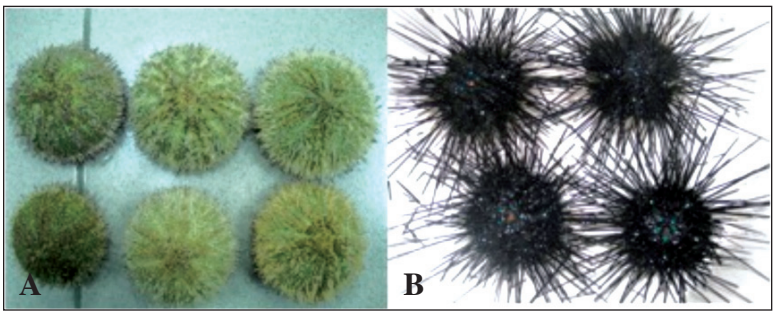


(Juveniles of *S. sphaeroides*: A) 1-day-old juvenile, B) 3-month-old juvenile (Rahman *et al*. 2012b).



(Juveniles of *D. setosum*: A) 1-day-old juvenile,
B) 3-month-old juvenile)

In order to develop the appropriate aquaculture techniques, the 3-month old juvenile urchins are reared in aquaria (46 x 30 x 30 cm) at different stocking densities and algal feeding regimes. After two years of rearing in captive condition, all the urchins attained adult sizes with adequate matured gonads for harvesting.

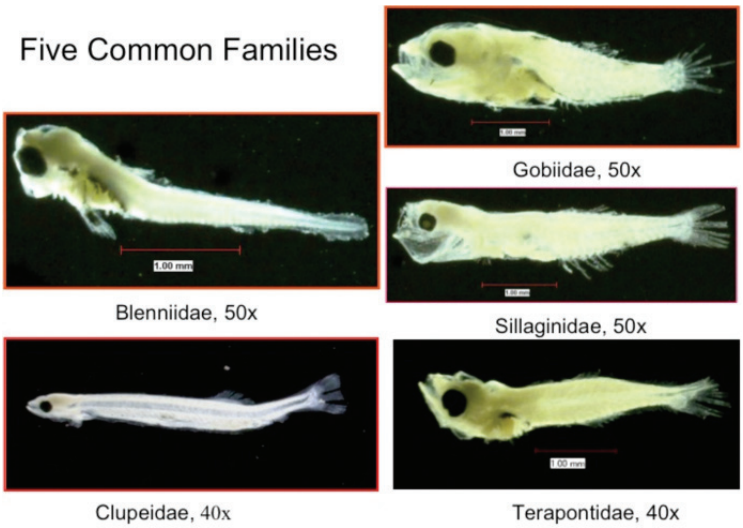


(Sexually matured adult sea urchins after the culture period of two years in captive aquaria-rearing condition: A) *S. sphaeroides*,
B) *D. setosum)*

This study demonstrates the first successful culturing of *S. sphaeroides* and *D. setosum* through the detailed larval development, metamorphosis and juvenile rearing in captivity (Rahman *et al*, 2012b). Therefore, the results obtained from the designated project will immensely be helpful towards the development of breeding, seed production and culture techniques of commercially important sea urchins and other marine invertebrates, which are yet to be fully determined and explored in the Malaysian coral reef communities. In addition, development of appropriate rearing and culture techniques would immensely be helpful to produce adequate quantities of nutraceutical and pharmaceutical products from these high-valued Echinoderms.

FISH LARVAL COMPOSITION, DISTRIBUTION AND DIETS IN THE SEAGRASS-MANGROVE ECOSYSTEM

In addition to the research done on the invertebrates, our group also embarked on the diversity, ecology and biology of fish larvae. The interest to assume the works came from our integrated research in Merambong Shoal, Johor. Fish larval composition, spatio-temporal distribution, density, family richness, Shannon-Wiener index and feeding habits were determined by analyzing samples collected from the seagrass-mangrove ecosystem of Johor Strait, Peninsular Malaysia between October 2007 and September 2008. Five stations were established to represent the different ecological complexities of the Merambong seagrass ecosystem. In total, 24 families of fish larvae belonging to six Orders were identified from seagrass-mangrove ecosystem of Johor Straits (Ara, 2011; Ara *et al*., 2013b; Ara *et al*., 2013c).



(Some important fish larvae collected from the Merambong Shoal seagrass beds)

In total, 24 families were identified from the seagrass ecosystem of the Johor Straits. In comparison to all ecological complex, seagrass ecosystem recorded highest fish larval abundance. Overall, five families viz. Clupeidae, Blenniidae, Terapontidae, Gobiidae and Sillaginidae were the top five dominant taxa in the study area. Shannon-Wiener index varied significantly betwen monsoon and inter-monsoon seasons and peaking in the months October-January and May-August. The highest density of larval fishes was recorded at seagrass station and the spatial variations in larval density were significant ($p < 0.05$) between seagrass and other four sampling sides. Among the 24 families, 18 families were found to have correlation either positively or negatively with the surrounding water parameters. The highest and significant regression coefficient was observed in Sillaginidae which indicated its abundance was

influenced by the surrounding water parameters (Ara, 2011; Ara *et al.*, 2011b; Ara *et al*., 2011c).

For this research, 267 Blenniidae, 401 Clupeidae, 126 Gobiidae and 117 Terapontidae stomachs were biologically examined. Analyses of prey in the stomachs identified 24 important items belonging to six major groups viz. phytoplankton, zooplankton, algae, plant like matter, debris and unidentified materials. According to the Simple Resultant Index analysis, the predominant food item in the stomach of all four families (Blenniidae, Clupeidae, Gobiidae and Terapontidae) was phytoplankton (> 60%). This was followed by zooplankton in Blenniidae (18.24%) and Clupeidae (8.60%). On the other hand, the second diet composition was unidentified plant-like matter in Gobiidae (14.73%) and Terapontidae (8.02%).

Among phytoplankton, *Dacytyloccopsis fasicularis* (26.31%) was large in quantity in stomach sacs of Bleniidae and this was followed by *Nitzschia baccata* (23.38%). Conversely, *Nitzschia* sp. showed the highest quantity (26.33%) in the stomach sacs of Clupeidae larvae. In Gobiidae larvae, Chromophyta (28.30%) was observed as the highest quantity. Similarly, Chromophyta (29.12%) was the highest quantity in the stomach sacs of Terapontidae. Overall, two most dominant phytoplankton (*Dacytyloccopsis fasicularis* and *Nitzschia* sp.) was observed among the four larval families. It is revealed that diverse food items were found in the stomachs of Bleniidae, Clupeidae, Gobiidae and Terapontidae larvae and phytoplankton formed more than 60% in the diet composition (Ara *et al*., 2009; Ara *et al*., 2010; Ara *et al*., 2011a; Ara *et al.*, 2013a; Arshad *et al*., 2013).

The fish larval works give us further information on the importance of seagrass ecosystem for the breeding and nursing of finfish species. This would perhaps highlight the importance of this ecosystem to fisheries as a contrast to the expansion of Port Tg

Pelepas Johor that are seen threatening the existence of seagrass ecosystem in the area.

SUMMARY

The fisheries biology research undertaken by the researchers from the Department of Aquaculture, Universiti Putra Malaysia has managed to establish extensive information on the biology, diversity and ecology of several important crustaceans mainly sergestids *Acetes* spp. and *Lucifer* sp., and molluscs in particular Strombus shell, green mussel, pen shell and saddle oyster. Findings on the sergestids would be of importance on the possibility of developing both sergestid species as a source of live food for the fish hatchery. In addition, the knowledge on the specific bivalves and gastropod species could be further utilized in promoting them as an alternative to the existing culture species. Vast amounts of publications have been generated during the implementation of the projects. Some of the new findings from the research are not yet fully known to the relevant authorities and it is our major expectation from the beginning that all our research findings would be of great benefit to the development of fisheries sector of the country.

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BIOGRAPHY

Aziz Arshad [PhD, Prof.] was born on the 9th of October 1959 in Arau, Perlis. He began his earlier primary education in Paya Primary School, Perlis from 1966 to 1972 and finished his secondary education at Derma Secondary School, Kangar Perlis in 1977. He graduated in Fisheries Science as the pioneer batch from the Universiti Pertanian Malaysia in March 1983, gained his MS degree from University of Wales Bangor in 1987 and obtained his doctorate in Marine Invertebrate Ecology in April 1999. He is currently serving as Professor of Fisheries Biology in the Department of Aquaculture, Faculty of Agriculture and filling up the role as an expert and resource person in Fisheries Biology.

To date, he has reached his 30 years of service with UPM. He has been fulfilling almost all the major responsibilities laid on him as a lecturer in UPM. He started to develop his teaching skill as an invertebrate biologist and invertebrate culture when first attached to the Faculty of Fisheries and Marine Science, UPM. At present faculty, he is entrusted to conduct courses such as Biology of Aquatic Invertebrates, and Fisheries Science for the undergraduate program. Besides teaching, he also supervised final year projects and to date more than 150 undergraduate students has completed their final year projects under his supervision. He has managed to graduate 9 PhD and 5 Master students as their principal supervisor.

As a researcher, fisheries biology is his main subject of interest. Typically, he tailored all his research projects to include fish as the main research subject. His focus of research for the last decade has been on the biology and ecology of crustacean and molluscs. His untiring efforts have been reflected by the intensive publications accumulated by him for the past five years. The research team where he is part of it has close linkages and networking with other

international scientists and had been invited in past to present the research findings at both local and international meetings.

In total, he has handled and completed 16 research projects during his entire career with UPM with majority of them are on the topic of fisheries biology. His involvement in research has further extended by several collaborative works with other research colleagues from outside country. His authority in fisheries biology and marine ecology subject has received some degree of recognition from other universities through their appointment as external examiner for postgraduate students and reviewer for academic curriculum. Throughout his engagement in academic activities, he has written and co-authored 150 papers in peer reviewed journals. He has attended various local and international conferences and seminars as well as participating in exhibition on research products that portrayed the highlight of his achievements in research. His expertise and interest has also been generously shared with the public particularly to fish farmers as well as extension workers on the culture protocols, seed production and larval management aspects of the invertebrate culture.

His proficiency and competence in the subject area is academically recognised and been entrusted to referee several papers for both national and international journals. He was also an assessor for MOSTI research proposal application under Agriculture (Aquaculture) and Sea to Space category at university and national levels respectively, a national panel member for the curriculum development for Higher Secondary School Examination (STPM) Biology Subject for the Ministry of Education.

On the contribution to the nation and public, he is a life member for Malaysian Fisheries Society (MFS) and Malaysian Society of Applied Biology (MSAB), an honorary treasurer of the Asian Fisheries Society till present. He indulged himself with

non-governmental societies and contributed his expertise and effort to propel the beneficial fishery agenda forward. Throughout his involvement, he was assuming the post of treasurer, secretary and vice president of the Malaysian Fisheries Society from 1992 – 2006. He was also appointed to serve as chairperson and member of organising committee of both national and international meetings.

In 2006, he received the Excellent Service Award from the university. He has been fairly prudent on his work performance. Since 2001, he has consistently been achieving an excellent status performance for his services to the department, faculty and university. In 2007, he won the Vice Chancellor University Excellence Award for Best in Professional Services. Despite all the past achievements, he is aspired towards superior contribution and achievement in the academic excellence of his career.

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He would also like to extend his deep appreciation and gratitude to all the co-researchers in UPM from the Department of Aquaculture (Fatimah Md Yusoff, Muta Harah Zakaria, S M Nurul Amin, and Aminur Rahman) and UPMKB (Japar Sidik Bujang, Mohd Hanafi Idris) and in UKM's Faculty of Science and Technology (Mazlan Abd Ghaffar and Zaidi Che Cob) who have been together with him during the research period, contributing in term of innovative ideas and suggestive comments on the implementation of the projects. Without their cooperation and supports, it would be impossible for him to carry forward the research agendas with great success.

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There will be no success without the pillar of the family supports. To that, the author would like to honour his wife, Norhan Abu Bakar for her moral supports, patience, encouragement and continuous shower of loves and understanding. Their five children

(Dania, Ainan, Iylia, Azmil and Azim) have always being the source of constant inspiration to his career advancement in the university. Last but not least, in memory of both parents who are not able to share the moments with him but whose contribution has never been out of his thought and appreciation.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

11. Prof. Dr. Abdul Salam Abdullah
Natural Toxicants Affecting Animal Health and Production
29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
Pest Control: A Challenge in Applied Ecology
9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
Managing Challenges in Fisheries Development through Science and Technology
23 July 1994

14. Prof. Dr. Hj. Amat Juhari Moain
Sejarah Keagungan Bahasa Melayu
6 Ogos 1994

15. Prof. Dr. Law Ah Theem
Oil Pollution in the Malaysian Seas
24 September 1994

16. Prof. Dr. Md. Nordin Hj. Lajis
Fine Chemicals from Biological Resources: The Wealth from Nature
21 January 1995

17. Prof. Dr. Sheikh Omar Abdul Rahman
Health, Disease and Death in Creatures Great and Small
25 February 1995

18. Prof. Dr. Mohamed Shariff Mohamed Din
Fish Health: An Odyssey through the Asia - Pacific Region
25 March 1995

19. Prof. Dr. Tengku Azmi Tengku Ibrahim
Chromosome Distribution and Production Performance of Water Buffaloes
6 May 1995

20. Prof. Dr. Abdul Hamid Mahmood
Bahasa Melayu sebagai Bahasa Ilmu- Cabaran dan Harapan
10 Jun 1995

21. Prof. Dr. Rahim Md. Sail
Extension Education for Industrialising Malaysia: Trends, Priorities and Emerging Issues
22 July 1995

22. Prof. Dr. Nik Muhammad Nik Abd. Majid
The Diminishing Tropical Rain Forest: Causes, Symptoms and Cure
19 August 1995

23. Prof. Dr. Ang Kok Jee
The Evolution of an Environmentally Friendly Hatchery Technology for Udang Galah, the King of Freshwater Prawns and a Glimpse into the Future of Aquaculture in the 21st Century
14 October 1995

24. Prof. Dr. Sharifuddin Haji Abdul Hamid
Management of Highly Weathered Acid Soils for Sustainable Crop Production
28 October 1995

25. Prof. Dr. Yu Swee Yean
Fish Processing and Preservation: Recent Advances and Future Directions
9 December 1995

26. Prof. Dr. Rosli Mohamad
Pesticide Usage: Concern and Options
10 February 1996

27. Prof. Dr. Mohamed Ismail Abdul Karim
Microbial Fermentation and Utilization of Agricultural Bioresources and Wastes in Malaysia
2 March 1996

28. Prof. Dr. Wan Sulaiman Wan Harun
Soil Physics: From Glass Beads to Precision Agriculture
16 March 1996

29. Prof. Dr. Abdul Aziz Abdul Rahman
Sustained Growth and Sustainable Development: Is there a Trade-Off 1 or Malaysia
13 April 1996

30. Prof. Dr. Chew Tek Ann
Sharecropping in Perfectly Competitive Markets: A Contradiction in Terms
27 April 1996

31. Prof. Dr. Mohd. Yusuf Sulaiman
Back to the Future with the Sun
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