Effect of Environmental Conditions on the Spat Recruitment Pattern of Green Mussel (*Perna viridis L.)* at Sebatu, Melaka, Peninsular Malaysia

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Abstract: A two year study was carried out to determine the effects of water quality on spat recruitment pattern at the Aquaculture Industrial Zone for mussel culture at Sebatu, Melaka. Study was carried out at three rack clusters operated by USMA, Kumpulan Ekonomi Nelayan and Individuals. The main physico-chemical parameters monitored were temperature, salinity and pH which indicated stable levels throughout the study period i.e. 29.2±1.1°C, 29±1.8 ppt and 8.6±0.8, respectively. As for the dissolved oxygen, high values ranging between 5.9 and 12.1ppm was recorded with water current velocities ranging from 0.050.5 knots. Total suspended solids recorded a mean level of 41±3.3 mg/L throughout the study period which is well within the suitable level for mussels. As for the concentration of chlorophyll-a, levels in the coastal area were observed to be much higher as compared to the seaward area with average values of 3.7±2.6 µg/L and 2.3±0.9 µg/L, respectively. There was a notable reduction in the number of mussel spatfall peaks from two peak seasons per year as predicted in previous years to one peak/year (September to October) in this study. As for spat density, results showed that racks facing the sea attracted more spat as compared to the racks in the middle of the cluster or those facing the coast. The highest density recorded was 2547 spats per meter rope which showed 20-40% decrease in the density recruited as compared to studies carried out previously. Several recommendations to rehabilitate this area in terms of management and relocation of the racks have also been suggested in view of its declining productivity.

Keywords: Physico-chemical,mussels, spat, recruitment, Sebatu

Abstrak: Kajian telah dijalankan untuk menentukan kesan kualiti air ke atas corak rekruitmen benih di kawasan ternakan kupang, Zon Industri Akualutur Sebatu Melaka selama dua tahun. Kajian ini dijalankan di tiga kluster rak yang diusahakan oleh USMA, Kumpulan Ekonomi Nelayan dan perseorangan. Parameter fiziko-kimia utama yang dipantau adalah suhu, saliniti dan pH yang menunjukkan paras yang stabil di sepanjang tempoh kajian dengan bacaan 29.2±1.1 °C, 29±1.8 ppt and 8.6±0.8. Sementara itu paras oksigen terlarut menunjukkan julat bacaan yang tinggi iaitu antara 5.9-12.1ppm dengan kelajuan arus 0.050.5 knots. Jumlah pepejal terampai mencatatkan paras purata 41±3.3 mg/L di sepanjang tempoh kajian yang merupakan paras yang sesuai untuk ternakan moluska. Bagi kepekatan klorofila pula, paras di kawasan pantai (3.7±2.6 µg/L) didapati lebih tinggi daripada kawasan yang jauh dari pantai (2.3±0.9 µg/L). Terdapat sedikit penurunan ketara dalam bilangan spat semasa puncak kejadian benih kupang iaitu dari dua musim puncak setahun seperti yang diramalkan dalam tahun-tahun sebelumnya kepada satu puncak/tahun (September hingga Oktober) dalam kajian ini. Bagi kepadatan benih pula, keputusan menunjukkan rak-rak yang menghadap ke laut menarik lebih benih berbanding dengan rak-rak yang terdapat di tengah kluster atau yang berhampiran dengan pantai. Kepadatan tertinggi yang direkodkan adalah 2547 benih/ meter tali yang menandakan 20-40% penurunan dalam kepadatan rekruitmen berbanding dengan kajian sebelum ini. Beberapa cadangan untuk memulihara kawasan ini berdasarkan pengurusan dan pemindahan lokasi rak telah dicadangkan selaras dengan penurunan dalam produktiviti.

Introduction

The green mussel (*Perna viridis*) is ranked the second most commercially important molluscan shellfish after the blood cockle (*Anadara granosa*) in Malaysia. Mussel landings have been observed to be dwindling in the recent years: 7,530 tonnes in 2006, 6,905 tonnes in 2007 and 8,994 in 2008 (Annual Fisheries Statistics, 2006; 2007; 2008). However, the retail value showed an increase from RM 6.2 million in 2006 to RM 9.7 million in 2007 and 15.4 million in 2008 (Annual Fisheries Statistics, 2006; 2007 and 2008), presumably due to higher prices offered for mussels as a result of stiffer competition among mussel growers in several growing areas of Peninsular Malaysia. Since several decades ago, the mussel culture industry in Malaysia had been merely confined to the Straits of Johor which is also reckoned as the main mussel spatfall ground. However, in the recent years, mussel farms have mushroomed in other areas as well, namely in Melaka, Kedah, Perak, Penang and even in Sabah (East Malaysia) which is associated with the outcome of the transplantation program carried out by the Department of Fisheries Malaysia (Devakie,

1988; Ng and Kamal, 1989). The transplantation program had created a positive impact on the mussel industry whereby new culture areas and natural mussel spatfall grounds have mushroomed in several other locations in Melaka (Sebatu), Perak (Kuala Rungkup) and Penang (Penaga). As for farmers from areas without natural spatfall, they had to resort to procuring the spat from the above mentioned sites where additional costs involving purchase of spat (attached onto rope cultches) and transportation had to be borne by them.

Lately, the proposed large scale green mussel culture project by the Department of Fisheries Malaysia in the southern state of Melaka on the west coast of Peninsular Malaysia had influenced farmers from several other states to expand their existing culture areas on a larger scale. The Melaka State Department of Fisheries had gazetted an area of 550 hectares in Sebatu, Jasin as an Aquaculture Industrial Zone (AIZ) solely for mussel cultivation. According to the initial plan, a total of about 320 rack culture systems were planned to be built in this area throughout the 9th Malaysia Plan for spat collection and grow out. However, several problems such as low or no spatfall, sudden mass mortalities and slow growth rates were reported by farmers from Sebatu, Melaka. Similar problems had also been reported to have affected mussels in several other adjacent locations such as Kg. Balak, Pasir Panjang and Port Dickson in Negeri Sembilan and even in distant locations such as Sg. Dinding in Perak.

Existing information on all aspects pertaining to mussel culture grounds in Malaysia is outdated and not applicable as reference for the current situation, especially with the present global warming phenomenon which had increased the earth's temperature and in turn caused climatic and aquatic environmental changes worldwide. Apparently, mussel farmers in the above mentioned areas have been experiencing unpredictable sea conditions (strong waves and currents) which are possibly associated with the above phenomenon. Such environmental changes are also known to affect the spawning and spat recruitment pattern of the mussels. Laura *et al.* (2007) had reported that global climate change scenarios can induce stress and impair the ability of mussels to grow and reproduce besides altering intertidal community characteristics. In the north-western European estuaries, study (Philippart *et al.*, 2003) revealed that the recent rise in seawater temperatures has affected bivalve recruitment success due to low reproductive output. In Malaysia, information on the growth parameters and natural spat density of green mussels can be dated back to the late 70s (Choo, 1979) and information on environmental conditions in mussel culture grounds is lacking. A recent study undertaken by the Universiti Putra Malaysia (Al-Barwani *et al.*, 2007) was on the population dynamics of mussels in waters off Malacca but was not related to the environmental conditions. A related study was undertaken by Universiti Malaysia Terengganu (Zaleha *et al.*, 2008) on the carrying capacity in relation to the ecology of Sebatu, Melaka. In view of the limited data on environmental conditions at the mussel spatfall and growing area at Sebatu, Melaka, this study was proposed and carried out for the purpose of correlating water quality to the mussel spat recruitment pattern in the area. From the data obtained, it is expected that the gazetted Aquaculture Industrial Zone for mussel culture in this area could be well planned, managed and carried out on a more sustainable and environmental friendly manner.

Materials and Methods

This study focuses on two major aspects, namely water quality and as well as the natural spat recruitment pattern in the coastal waters of the Aquaculture Industrial Zone in Sebatu, Melaka. Monthly samplings on water quality and spat density were carried out from April 2007 to May 2009 and the data was recorded, updated periodically and stored in the computer for analysis.

Water quality

Twelve sampling stations for water quality were fixed randomly in this area (about 550 hectares) in a zig-zag manner (Fig 1). Water quality was monitored to determine the physico-chemical and biological parameters and hydrology. *Insitu* parameters were recorded using the Hydrolab Datasonde 5 (DS5). Physico-chemical parameters studied included salinity, pH, temperature, depth, turbidity/transparency, total suspended solids (TSS) and dissolved oxygen (DO). Biological parameters included: chlorophyll-content, identification of algal species and observation on biofoulers and predators. Hydrology (current velocity and direction) at the culture site was also recorded using the Valeport model 105.

Mussel spat recruitment pattern

Three rack clusters belonging to Usahawan Siswazah Malaysia (USMA), Kumpulan Ekonomi Nelayan (KEP) and Individuals were chosen for the study. Rope collectors were hung at three randomly selected racks in each cluster i.e seaward facing rack, middle rack and coastal rack (Fig 1 and Table 1). The study racks marked were: 3 racks in the USMA cluster; tagged as USMA Sea, USMA Middle and USMA Coastal; 3 racks in the KEP cluster: tagged as KEP Sea, KEP Middle and KEP Coastal and 3 racks in the Individual cluster: tagged as INDIVIDU Sea, INDIVIDU Middle and INDIVIDU Coastal. A total of 4 rope collectors marked as A, B, C and D were suspended at each of the three points (sea, middle and coastal) of the study rack (12 collectors per cluster). All the rope collectors hung from the study racks were sampled monthly to determine the spat density. Settled spat were detached from the ropes and counted. In this study, spat density with a count of 1000 spat or more per meter rope was set as high to reflect the peak season of the settlement in that area. For commercial purposes in South Australia, this density was chosen to be economic as it allows for sufficient growth without overcrowding (Andy, 2000).

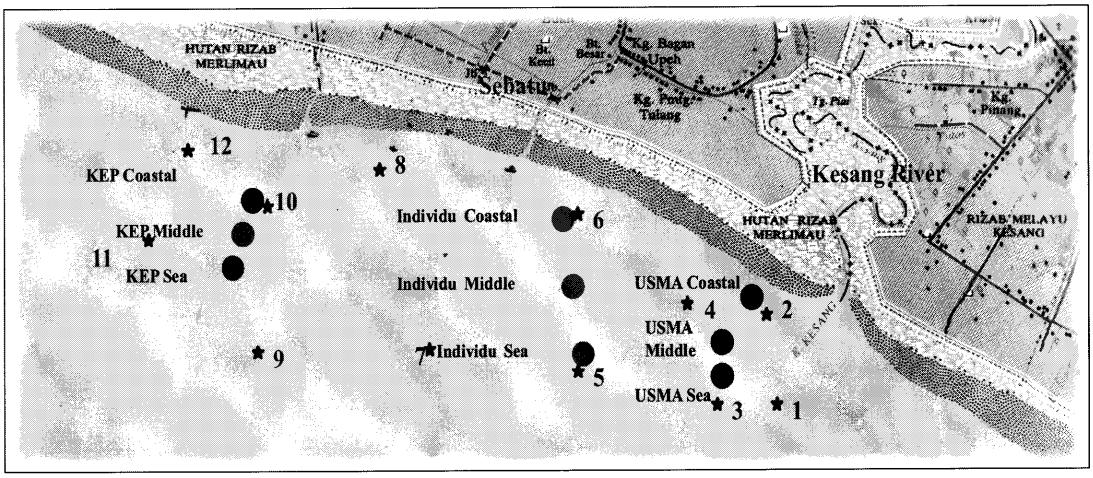

Figure 1: Sampling stations at the Aquaculture Industry Zone (AIZ) at Sebatu, Melaka (positions not according to scale)

Table 1: Positions of Sampling Stations at AIZ Sebatu, Melaka

No	Rack Cluster	Position	Longitude	Latitude
1	USMA	Coastal	2° 5'48.36°N	102° 28'49.74°E
2	USMA	Middle	2° 5'39.84°N	102° 28'38.34°E
3	USMA	Sea	2° 5'33.24°N	102° 28'39.48°E
4	Individu	Coastal	2° 6'1.56°N	102° 28'5.76°E
5	Individu	Middle	2° 5'47.82°N	102° 28'10.26°E
6	Individu	Sea	2° 5'30.12°N	102° 28'14.46°E
7	KEP	Coastal	2° 6'8.52°N	102° 26'44.46°E
8	KEP	Middle	2° 6'3.06°N	102° 26'45.66°E
9	KEP	Sea	2° 5'58.80°N	102° 26'46.50°E

Results

Water quality

Physical and chemical parameters

The mean levels for physico-chemical parameters such as temperature, salinity and pH indicated stable readings throughout the study period, i.e. 29.2±1.1 °C, 29±1.8 ppt and 8.6±0.8, respectively. A high pH value of around 9.29.7 was recorded between October 2007 and May 2008 which was due to the instability of the Hydrolab Datasonde 5 (DS5) equipment. After calibration, the pH value returned to normal range (7.5-8.5) until the end of the study period. As for the dissolved oxygen, high values ranging between 5.9 and 12.1ppm was noted which is probably associated with the condition of the area being constantly dominated by strong currents and waves due to its unsheltered location. The above results are shown in Fig 2. Total suspended solids gave a mean value of 41±3.3 mg/L throughout the study period. It was observed that the TSS level was found to be high (0.104 g/L) in the month of September in 2007 and in 2008 which corresponded to the high turbidity value (212 NTU) also in the same months for both years (Fig 3). The mean water depths recorded during low and high tides at the study area were 1.9±0.7 m and 5.0±0.5 m, respectively.

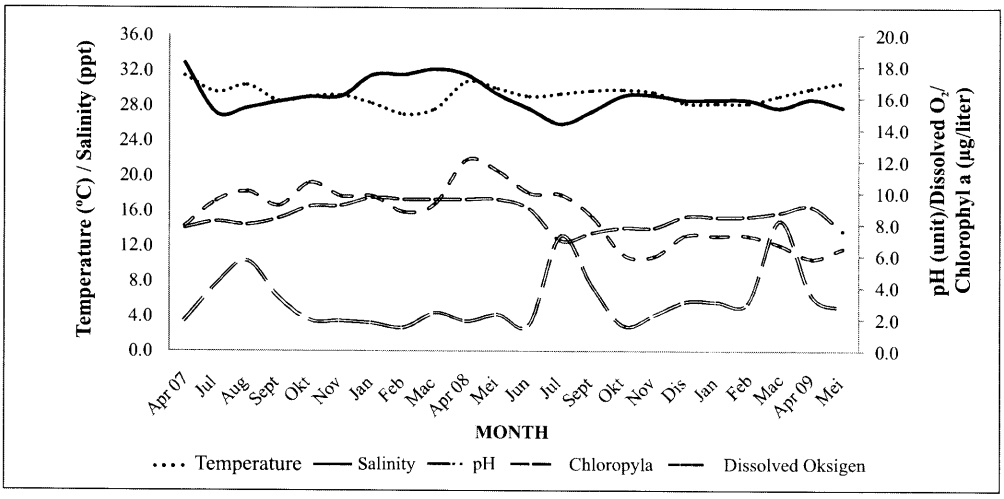

Figure 2: Water quality results at AIZ Sebatu (April 2007 - May 2009)

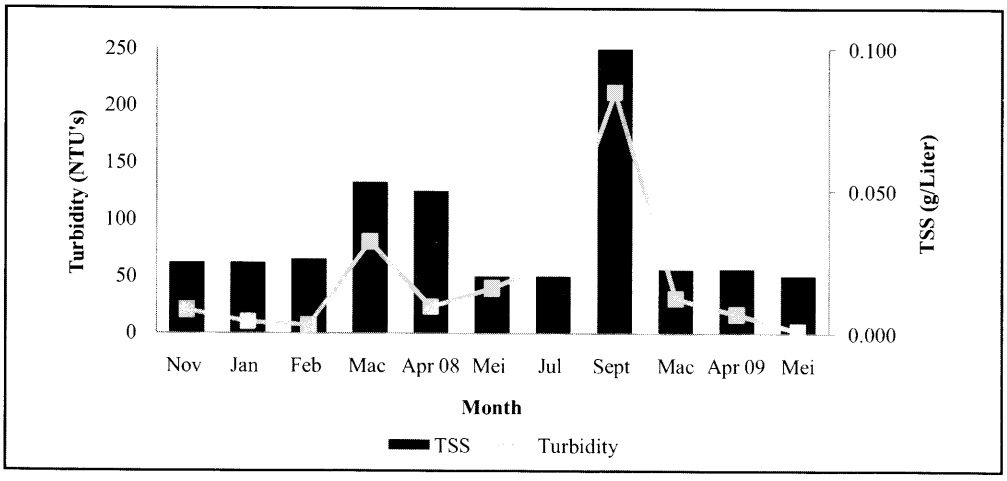

Figure 3: Total Suspended Solids (TSS) and turbidity at ZIA Sebatu

Biological parameter

The mean chlorophyll-a levels were found to be high (3.4-5.7 µg/L) and (4.1-7.3 µg/L) in the months of JuneSeptember in 2007 and 2008, respectively. But in 2009, high levels (3.5-8.3 µg/L) were noted in the months of FebruaryApril 2009. The chlorophyll-a levels in the coastal area were compared with the seaward side of the study area (Fig. 4). The results showed that the concentration of chlorophyll-a in the coastal area was much higher as compared to the seaward area exhibiting average values of 3.7±2.6 µg/L and 2.3±0.9 µg/L, respectively.

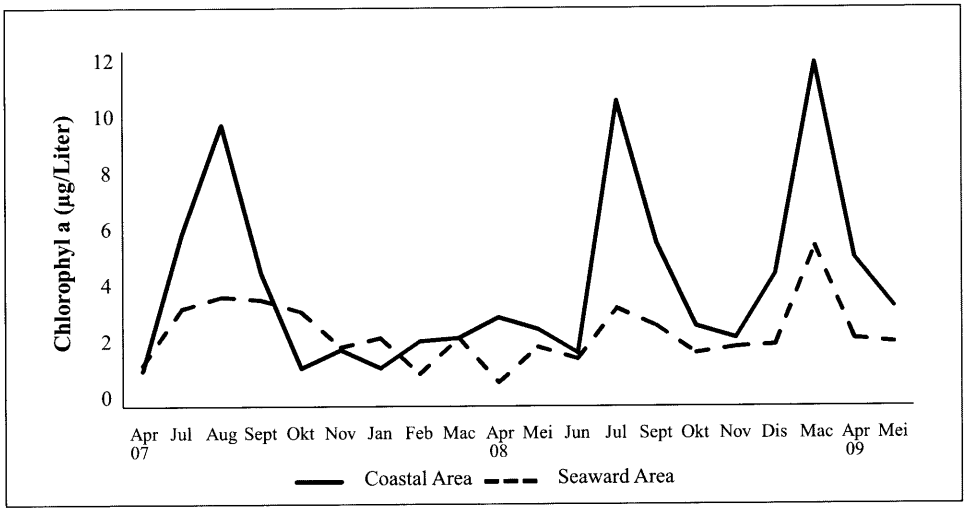

Figure 4: Chlorophyll-a comparison at coastal vs seaward side of AIZ Sebatu

Algal samples taken from the waters of AIZ, Sebatu for the purpose of determining species diversity showed that the *Coscinodiscus* spp was the dominant species with a density ranging from 500 3565 ind/ml.

Hydrology

Data on the water current at the study area showed that the currents were not too strong and ranged from 0.05 to 0.5 knots. Current flow was observed from north to south and south to north alongshore during high and low tides, respectively (Fig. 5).

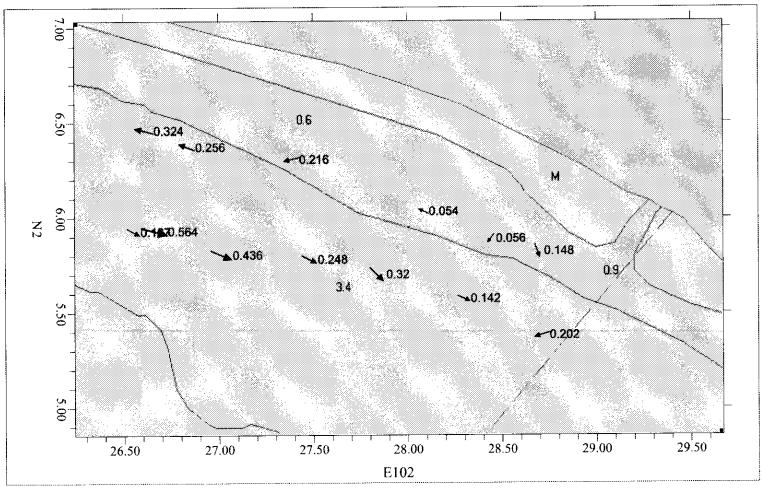

Figure 5: Current velocity and direction at AIZ Sebatu, Melaka

Spat recruitment pattern

Spatfall peaks

Spatfall was generally observed throughout the study period at all the three rack clusters. However, the peak season differed for the different rack clusters during the 2 year study period while no peaks were observed in 2007. Two spat settlement peaks were observed in 2008, i.e. in the month of January and in the months of SeptemberOctober at the KEP cluster only (Fig 6). As for the INDIVIDU cluster, only one peak season in the months of SeptemberOctober was observed. A slightly high pulse at the USMA cluster was noted only for the month of October 2008. The expected peak season for the natural spat settlement which usually coincided with the monsoon period i.e., between December and February, did not occur in late 2008 or early 2009.

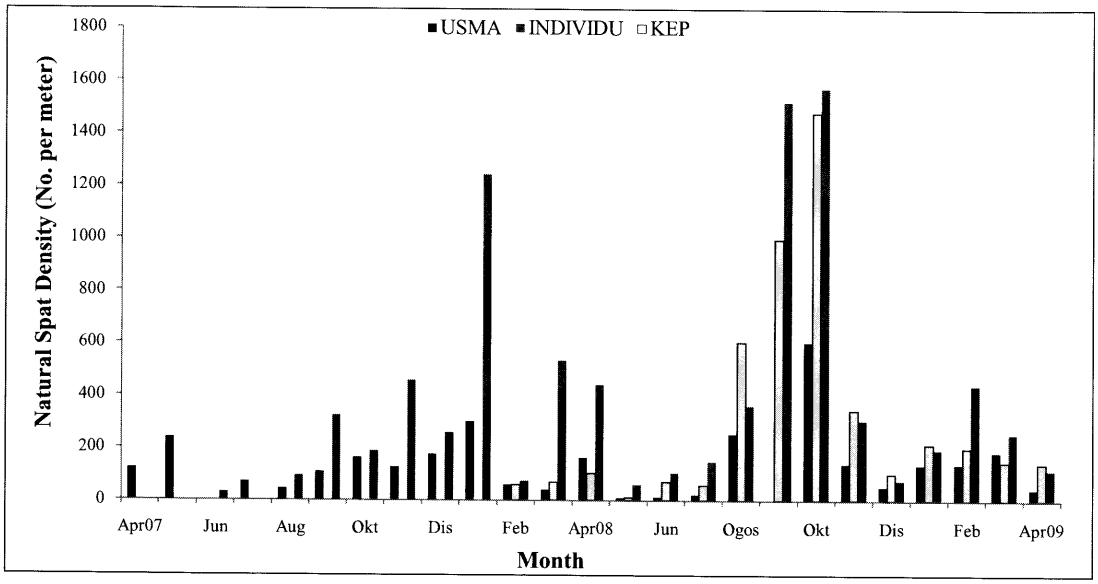

Figure 6 : Spatfall peaks at the rack clusters (USMA, KEP and INDIVIDU)

Spat density

An analysis of the natural mussel spat density in the KEP cluster showed varying densities of spat settlement: in January 2008 (1612 spats per meter rope), March 2008 (1478 spats per meter rope) as well as September-October 2008 (1673-2547 spats per meter of rope). The range of densities of natural spat at the KEP cluster throughout the period of study was 5-1293 spats per meter rope for the coastal rack, 43 -1747 spats per meter rope for the middle rack and 39-2547 spats per meter rope on the seaward side. Almost all readings showed that the KEP rack located on the seaward side exhibited higher densities followed by those in the middle position and the lowest spat density recorded at the coastal racks as shown in Fig 7. Spat settlement at the USMA cluster only occurred in the month of October 2008 (Fig 8) with the highest density at 1223 spats per meter rope recorded throughout the study period for the seaward facing racks. For racks located in the middle position and at the coastal area, the densities recorded in October were low i.e. 421 spats and 166 spats per meter rope, respectively. The range of natural spat densities at the USMA cluster over the duration of study was 3-303 spats, 4-421 spats and 18-1223 spats per meter rope for racks in the coastal area, middle and seaward positions, respectively. The study of spat density at the INDIVIDU cluster was carried out only in February 2008 due to problems in obtaining approval for use of the racks from the owners. For this cluster, peak spat settlement was noted to be between August and October 2008 with a density between 930-1501 spats per meter rope (Fig 9). There were no coastal racks at the INDIVIDU cluster as the bamboo structures were destroyed by strong currents and waves during the monsoon season. The spat density at the seaward racks was much higher as compared to racks placed in the middle of the cluster. The range of natural spat densities recorded at the INDIVIDU cluster during the study period was 9-1451 and 11-1501 spats per meter rope at the middle and seaward facing racks, respectively.

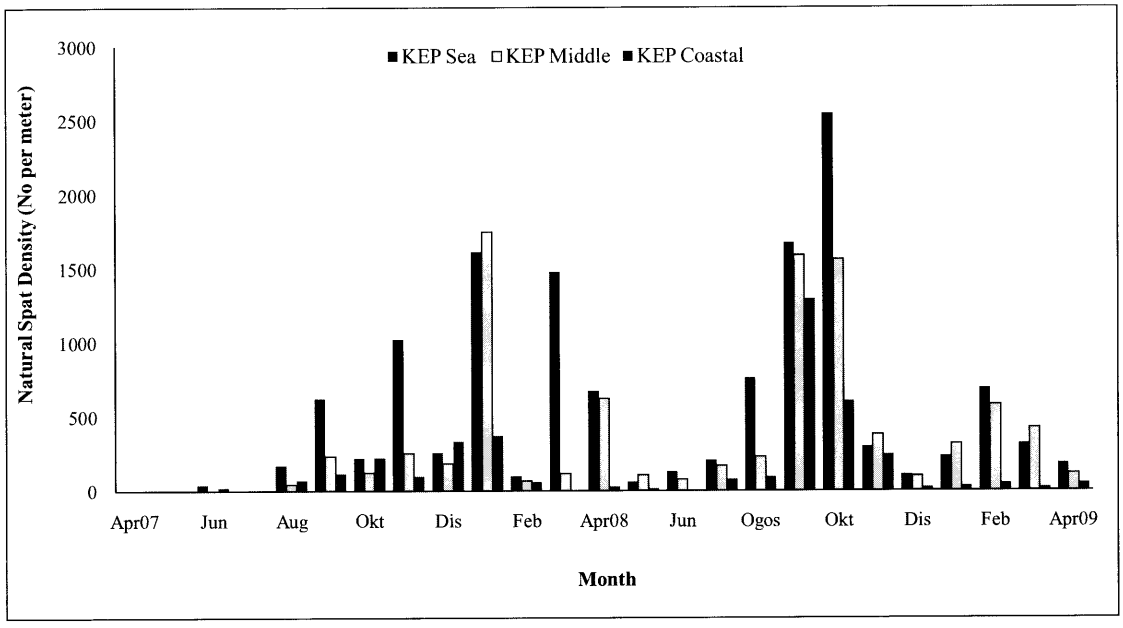

Figure 7: Density of natural spat at KEP cluster

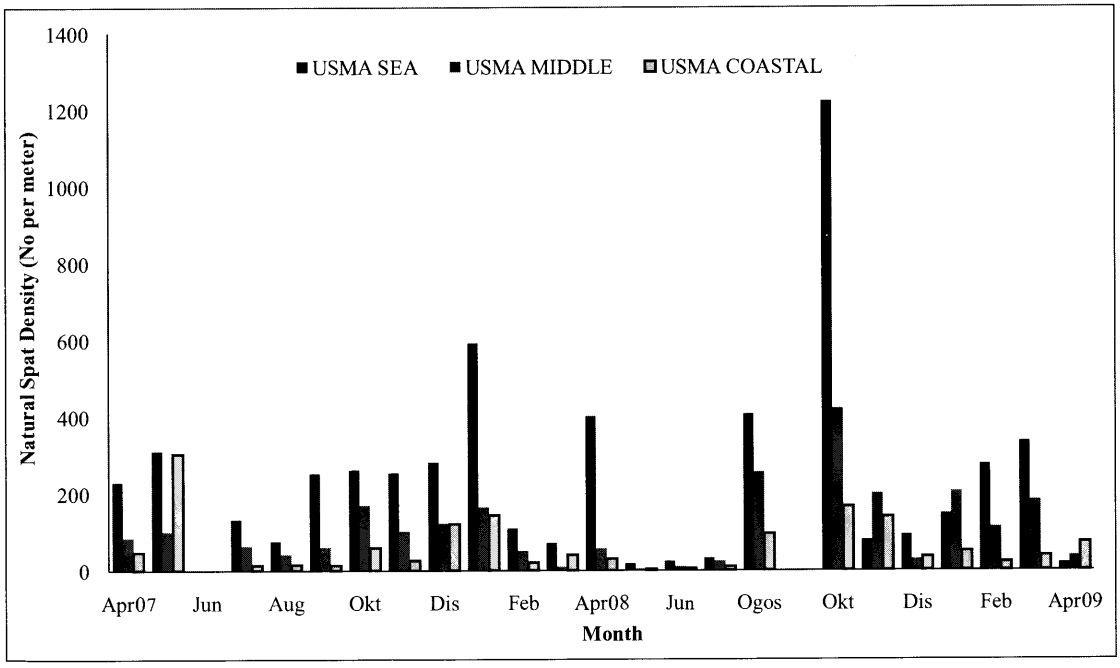

Figure 8: Density of natural spat at USMA cluster

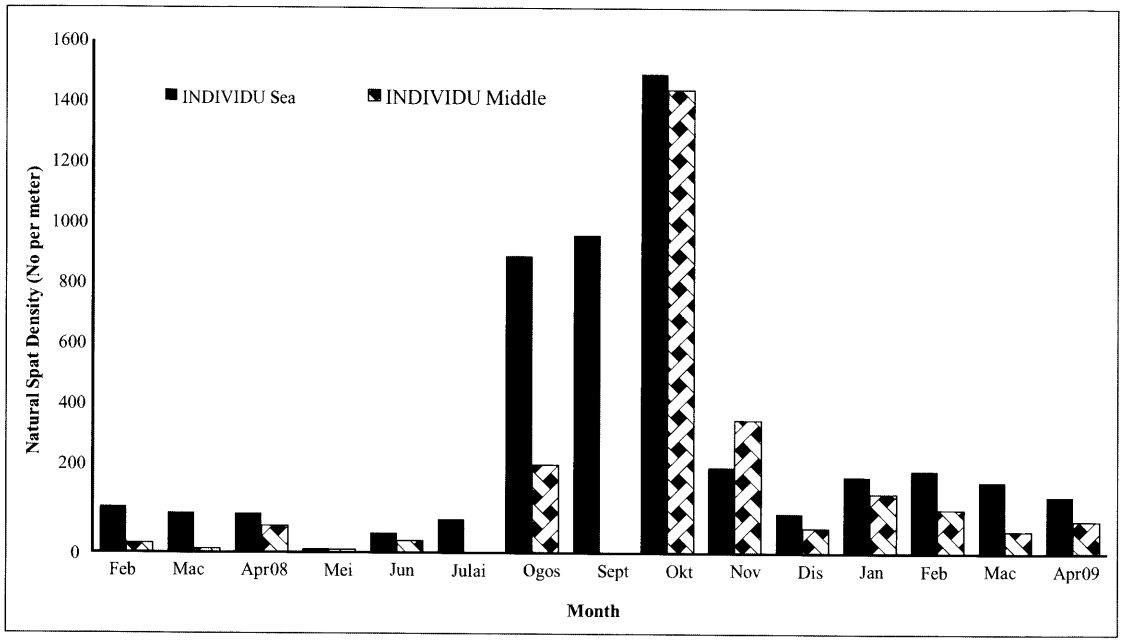

Figure 9: Density of natural spat at INDIVIDU cluster

Discussion

Water quality

All physico-chemicall parameters such as temperature, oxygen, pH, salinity and turbidity were in the suitable range for the growth of green mussel cultured at the AIZ, Sebatu. As for total suspended solids (TSS), the level was found to vary directly with the turbidity level recorded in September 2008. When the level of suspended solids was high at 0.104 g/L, the turbidity reading was also noted to be high at 212 NTU's during the same month. However, these values are considered to be within the permissible level for aquaculture. According to Davis and Hidu (1969), the level of suspended solids in marine conditions with concentration of 0.5 g/L or less can be considered suitable and could increase the growth rate of shellfish larvae or spat in a natural environment. According to Shin *et al.* (2002), *Perna* viridis could tolerate high concentrations of 1200 mg/l of suspended solids without mortality within a test period of 96 h. Mussels being coastal bivalves typically occurring at depths of less than 10m, Power *et al* (2004) stated that they are tolerant to a wide range of turbidity and pollution. Such an adaptation of survival in waters with high sediment loadings is attributed to the high efficiency of particle rejection by its labial palps (Seed and Richardson, 1999).

The concentration of chlorophyll-a in the coastal area was found to be much higher as compared to the seaward area exhibiting average values of 3.7±2.6 µg/L and 2.3±0.9 µg/L, respectively. Generally, coastal areas tend to receive rich nutrient loads from streams and rivers which enhance higher algal growth. Another interesting aspect noted in this study was that high concentrations of chlorophyll-a exhibited peaks of algae bloom during certain months (April to May, 2009) of the study period. These blooms somewhat appeared to have affected the growth of the green mussel shells in the culture area as shown in Fig 10. The farmers had observed that their mussels appeared growing abnormally or were stunted around April and May 2009. However, two months later i.e. in July 2009, there were signs of re-growth (light green in colour) at the shell margin of the mussels. The growth abnormality coincided with the peaks of algae bloom (noted from chlorophyll-a data) occurring in the area. Generally, based on the chlorophyll-a concentrations (diet availability), the AIZ Sebatu area can be categorised as an average area in terms of suitability based on the guidelines provided by NIWA (Graeme *et al.*, 2000).

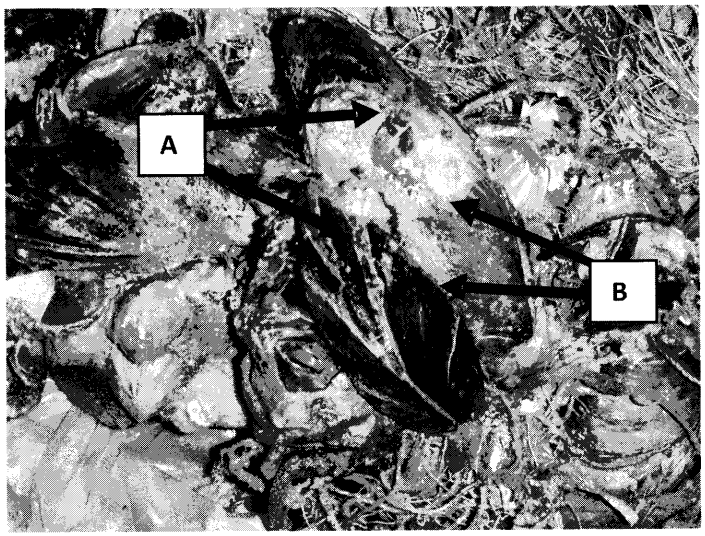

Figure 10: Stunted growth of mussels at Sebatu, Melaka
A: Growth of new shell; B: Stunted shell

Spat recruitment pattern and density

From the 70s to 80s, even though no data had been compiled on the number of spat that settled on the rope collectors, Choo (1979) in her study had estimated the density (Fig 11) to be in the range of 3000-4000 spats per meter rope. In comparison, the results obtained in this study showed that the highest density recorded was 2547 spats per meter rope (Fig 12) which showed a 20-40% decrease in the density recruited. In other parts of the world, Baker *et al.* (2002) reported that in Tampa Bay (estuary along Gulf of Mexico), intertidal densities of *P. viridis* attained peaks ranging between 3,675 and 4,117 spats per square meter. The authors also noted significantly higher densities at 9,000-12,000 spats per square meter when they found several layers of mussels on pilings at the Little Manatee River in the Gulf coast of Florida. A report from NIMPIS (2002), indicated that *P. viridis* formed dense populations (up to 35,000 spats per square metre) on a variety of structures including vessels, wharves, mariculture equipment, buoys and other hard substrata. A study in India (Rajagopal *et al.*, 1998) showed that the maximum green mussel spatfall recorded was 5224 spats dm^{-2} ($dm^2 = 100cm^2$) which was in the month of May.

Figure 11: Density of natural spat on rope collectors in the 80's

Figure 12: Density of natural spat on rope collectors at AIZ Sebatu (April 2007 April 2009)

From the results obtained, it can be seen that the productivity rate of the green mussel in the AIZ at Sebatu has started to decline. The current productivity is expected to further decline if no immediate actions are taken to rehabilitate the area. The decline in productivity can be clearly seen with a notable reduction in the number of spatfall peaks: from two peak seasons per year to one peak per year (September to October). Previous studies in Malaysia showed that natural spawning occurred twice a year in the months of March and April and October and November; during inter monsoon months of this region (Sivalingam, 1977; Low *et al.*, 1991). The results from the current study are comparative to a study undertaken by Barwani *et al.*, (2007) at Sebatu which also showed that there was only one seasonal pulse in July-August with one cohort being produced per year. However, studies in other neighbouring countries like east coast of India on the same bivalve (*Perna viridis*) reported two peak spawnings May-June and October-November (Rajagopal *et al.*, 1998) and in the off shore waters of Naf, Bangladesh (Mohammed *et al.*, 2010), spawnings peaks were noted in May and August with two cohorts (March to June and July to September). In the Gulf of Thailand, two main peak spatfalls have been noted in January and in July (Prakoon *et al.*, 2009). This clearly indicated that the spatfall seasons in Sebatu as compared to other vicinities are inconsistent and not predictable for setting out the cultch materials in preparation for spat collection. Thus, a long term rehabilitation program is needed for this area to ensure continued natural spat production. The main problem identified was that the primary source of broodstocks was gradually becoming extinct in the neighbouring areas of Sg. Muar (Johor) and in Sempang and Sebatu (Malacca). The main contributing factors to this problem was the big flood which hit the area in 2006 causing total mortality to the broodstock in Sg. Muar and the uncontrollable harvesting by fishermen at Sg. Muar. It was reported that the fishermen were harvesting up to 1 ton per day (pers communication with Mr. Ali Hj Abdul Samad,) irrespective of size and volume. It had reached the maximum exploitation rate in the absence of local programs to sustain the broodstock source at the project site itself where all the mussels of marketable size whether on the rope collectors or 'nibong' logs were harvested for sale due to the high market demand. The gradual depletion of the broodstock source at the culture site to fulfill the local market demands for spat supply had indirectly created a negative impact on the current development and progress of the project. An illustratration shown in Fig 13 below explains as to why it is necessary to sustain the natural broodstock resource in the said area.

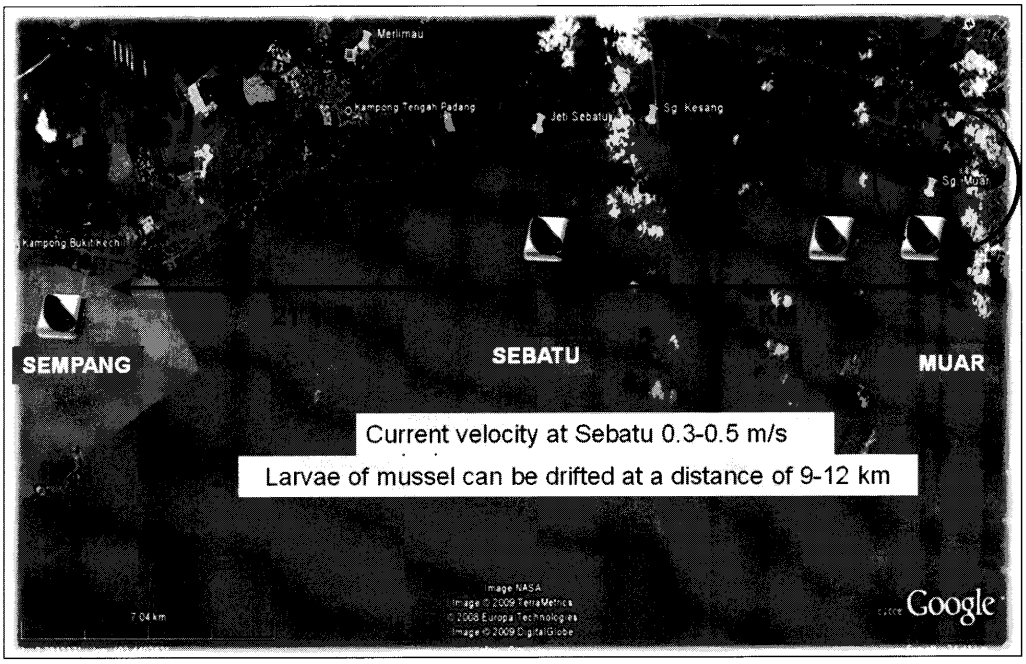

Figure 13: Illustration of tidal current influence on mussel larvae drift

A current speed of 0.3 to 0.5m/sec was recorded at the AIZ, Sebatu area from the northern to southern side of Sebatu, i.e. Sempang, Melaka (north) and Sg. Muar, Johor (south), respectively. Kamaruzaman (1995) reported that in the open waters of the Malacca Straits, tidal currents were generally weak, flowing mainly northwesterly at 1.00 to 1.25 knots. The mussel larvae produced during the spawning seasons would be drifting in the water column and carried by the tide up to a distance of 9 to 12 km. From the topography of Sg. Muar, it is obvious that the current flowing from the estuary to the sea is directly heading towards the Sebatu coastal waters. And if the mussel breeding had occurred at the Sg. Muar estuary area, the water current from the estuary would have drifted the larvae (with every rise and fall of the tide) to Sebatu area and remain within an area of 9-12 km for a period of 14-21 days (about 2 weeks of planktonic life after which they attach onto the rope collectors). Similarly, if the mussel broodstock in the Sempang, Melaka were to spawn, the larvae will be carried to Sebatu which is about 21km away. Thus, it is necessary to conserve the primary broodstock resources at Sempang and Sg. Muar for the sustainability of aquaculture in the long run. Conservation of the broodstock resource in the Sebatu waters (about 10-20% on every culture rack) as well as maintaining 100% of the mussels that are attached naturally to the 'nibong' logs or bamboo and submerged rocks in the area in the long run would contribute to the natural spat supply in the 2 areas i.e. Sempang and Sg, Muar. In other words, all the three areas are very dependent on each other for natural spat supply from the mussel broodstock, which in a matter of time would naturally increase the productivity of the area.

The density of natural spat was found to be significantly different for the seaward facing racks which were higher as compared to those facing the shore. This can be associated with several factors. After 20 years of being a breeding ground for mussels, the water depth in the area was found to be shallower with increased slime/mud in the coastal waters due to installation of racks. The soil sampled from the area showed sandy loam category which is suitable for cockle culture. However, the area is open and unsheltered and there is insufficient natural food and as well as the risk of pollution from the land runoffs which render the area unsuitable for cockle culture. Lately, in line with department's intention to gazette the Sebatu area as an AIZ specifically for breeding of mussels, additional 3 new clusters of racks were built: the Fishermen's Economic Group (*Kumpulan Ekonomi Nelayan,* KEP*)* cluster, the INDIVIDUAL fishermen's

cluster, and the *Usahawan Malaysia* (USMA) rack cluster. However, the area chosen for the installation of the USMA rack cluster (near Sg. Kesang, Muar) was found to be unsuitable due to its close proximity to the coast and shallow waters. Theoretically, a good location considered for racks will be during the lowest tide, the minimum depth of water required is at least 3.0 meters. At this depth, the rope collectors of 1.5 meter length can be suspended to provide an allowance of 1.5 meters between the rope end and the sea bed. In this case, during the low tide most of the upper part of the suspended spat collectors near the water surface was exposed. The percentage of exposure depended on the water depth where the racks are constructed. The scenario mentioned above clearly explains as to why there was a distinct difference in the spat density on collectors facing the seaward side as compared to those facing the coast. More drifting of the larvae was observed in the seaward area compared to the coast. Another inhibiting factor for racks placed near the coast would be even if there were spat settlement, high mortality would set in due to the accumulation of slime/mud on the spat. This biofouling invasion was caused as a result of being in close proximity to shallow waters as well as the quality of water and chemical factors which contributed to the active existence of biofouling organisms. With sufficient food present for the mussels in the area, regular management activities such as culling the spat density, predator/competitor/biofouler control and cleaning of the cultured mussel using a jet spray should be carried out on a regular basis. Failure to implement a good management practice would result in the failure of the project to be sustained over a longer period. On the other hand, the success in implementing good management practices would increase the productivity of the project.

Recommendations and Conclusion

For over 20 years, the fishermen in Sebatu, Melaka had been cultivating the green mussel as their main source of income. And currently, they have begun to experience a lot of problems with the gradual decline in the productivity of mussels. This had no doubt upset some of the fishermen to some extent that they have already given up in continuing with the project. From the study, it is clear that social problems such as theft, improper management of the culture, unplanned development of the area as well conflicts related to aquaculture and fishing activities among local fishermen have already set in. To overcome these problems at the AIZ Sebatu and to ensure the continuity of the project, corrective actions need to be taken for long term sustainability.

- Rehabilitating its neighbouring mussel beds in Sg Muar, Johor for continued presence of broodstocks
- Procuring mussel seeds from other natural seed areas but would involve additional costs to the farmers.
- Installation of new racks on the seaward side, where the water quality and exchange is better with good influx of food.
- Limiting the number of racks according to the study on carrying capacity conducted by Universiti Malaysia Terengganu (Zaleha *et al.*, 2008).
- Carrying out dye tracker study on industrial waste flow at every jetty facility in the Sebatu vicinity. The objective is to look at the possible effects of pollutants such as waste effluents especially from industries which would adversely affect the mussel project. Cooperation from several related agencies such as
- Drainage and Irrigation Department, Department of Environment as well as local authorities are required.
- Removing decrepit racks as well as those identified as not productive from the culture area. Indirectly, this action would enable better water flow for the mussel stocks as well as to ease the movement of the fishing boats in that area.
- Reviewing the arrangement of the racks as well as the distance between the racks as stipulated in the regulations of the Marine Culture System by the Department of Fisheries Malaysia. Rack plots should not face each other as this will restrict water flow in between the racks. The applicable inter-rack distance is currently 20 meters. However, it is recommended that this distance be increased to 50-100m to create better water exchange and flow. The recommended arrangement for racks in the area is as illustrated in Fig 14.

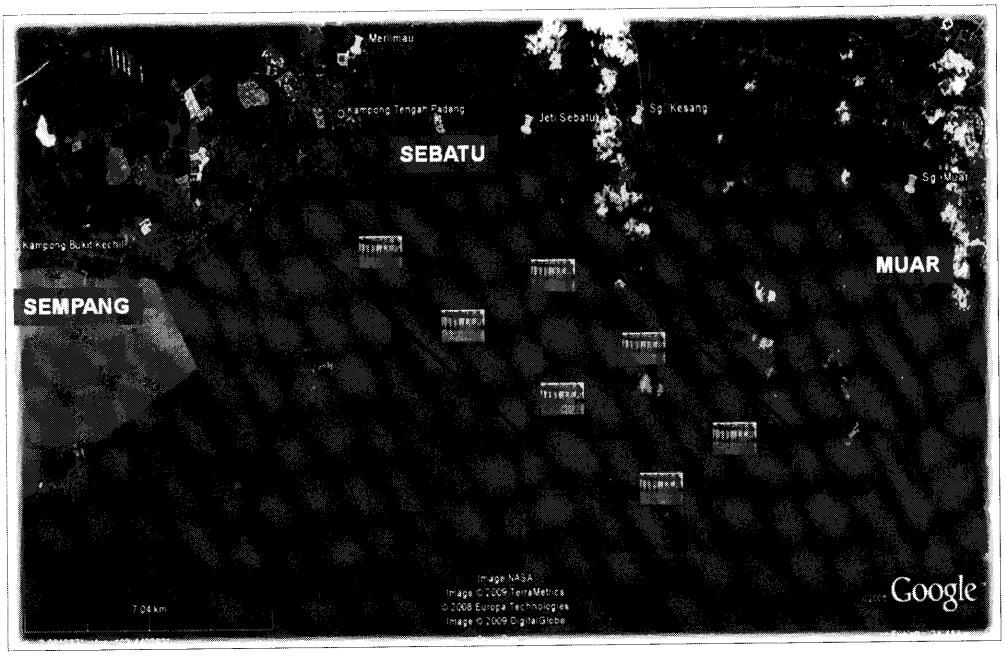

Figure 14: Suggested positions for racks to create better water flow at AIZ Sebatu

It is hoped that the above proposed actions would help in improving and restoring the nostalgia of AIZ Sebatu as one of the main mussel culture and spatfall areas in Malaysia. It is hoped that the results and recommendations from this study can assist and benefit the relevant parties.

Acknowledgement

Our utmost appreciation goes especially to the State Director of Fisheries, Melaka, Mdm. Rosmawati Ghazali for her commitment in terms of management, administration and financing in ensuring the success of this study. We also wish to thank the officers and staff of the Fisheries Department, Melaka who were involved directly and indirectly during the course of this study. A million thanks to the management of USMA Melaka who have cooperated and provided their full support during this study. Appreciation are also due to the Head of the National Prawn Fry Production and Research Centre (*NAPFREC),* Mr. Che Utama Che Musa for his continued support and encouragement and to the Senior Research Officer, Mr. Ismail b. Ishak from the Fisheries Research Institute Penang for his guidance and comments. And last but not least, many thanks to the staff of the Mollusc Unit of NAPFREC who had always given their full cooperation throughout the study period.

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