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Distribution Patterns of Freshwater Prawn, *Macrobrachium* spp. Following Stock Enhancement Programme in Sabah, Malaysia

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***Abstract*— *The decline of the freshwater prawn, Macrobrachium spp. in rivers can be attributed to overfishing, habitat loss and pollution. In order to offset the pressure, a community-based stock enhancement project was initiated by Borneo Marine Research Institute (BMRI), University Malaysia Sabah, to increase the number of Macrobrachium spp. in Petagas River, Putatan, Sabah. This study was conducted to determine the distribution and abundance of different life stages of the freshwater prawn, Macrobrachium spp. following stocking programme. The different life stages of the freshwater prawns were caught using hand net and modified prawn trap. A total of 539 specimens were caught and separated into postlarvae (PL), juvenile and adult. Abundance of PL (53.47%) was found at the downstream region of Petagas River, juvenile (18.06%) was found at the midstream region while adult prawn (81.63%) was found at the upstream region. The distribution of PL prawn was found to be increased with increasing salinities (R^2=0.95) while for juvenile (R^2= 0.98) and adult prawns (R^2=0.921) were inversely correlated. The CPUE of PL, juvenile and adult were positively correlated with the increase of stocking juvenile following stocking programme with R^2=0.89, R^2=0.73 and R^2=0.87 accordingly. The stock enhancement programme is suggested to be implemented continuously to improve the population of Macrobrachium spp. in the Petagas River. This study will provide baseline information on the effectiveness of stock enhancement programme of freshwater prawn especially in Malaysia.**

Keywords— ***stocking, life stages, Macrobrachium rosenbergii.***

I. INTRODUCTION

In Asian countries, stock enhancement is rarely successful, except in the case of enhancement with species capable establishing their breeding populations (De Silva *et al*., 2005). In Thailand, approximately 70 million of postlarvae of *M. rosenbergii* were stocked into some of the rivers and reservoirs in the stock enhancement programme. Regrettably, there are few quantitative and qualitative data or statistics available on the impacts of these stock enhancement attempts and its cost-effectiveness and impacts on rural communities have been rarely evaluated (Choonhapran *et al.* 2003). While in Malaysia, stock enhancement of *M. rosenbergii* and other freshwater fish are mostly in rivers (Utusan, 2012b; Borneo Post, 2013; Kosmo, 2015; Sinar Harian, 2015). The main objectives of this practice in Malaysia are to increase the population of the stocking species, conservation and preservation of fisheries resources and to assist in the improvement of socio-economic status of fishermen that live along the riverine areas (Borneo Post, 2014). The source of stock for the enhancement may be derived from capture, but more typically is obtained from a hatchery operation. These features can be referred to culture-based fishery (FAO, 2005).

The *Macrobrachium* spp. can be found in tropical and subtropical regions throughout the world. They are mostly found in inland freshwater areas including rivers lakes, swamps, ponds, canals and as well as in estuarine regions. *Macrobrachium* spp. have been said to be transferred from their origin to the other part of the world for research (FAO, 2002; Wowor and Ng, 2007). In the natural environment, migration of the gravid females from freshwater to estuaries occurs and the eggs hatch out in a higher salinity environment. The larvae are free swimming and consume zooplankton and larval forms of crustaceans. Then, the larvae undergo metamorphosis into postlarvae (PL) and tend to be a benthic organism. At this stage, they migrate upstream towards freshwater to less saline water and grow into adults. They can swim and walk on the sub-stratum and over the damp areas such as rocks, verticals surfaces and sometimes on damp land (FAO, 2002). The salinity ranges preferred for PL was found between 14 to 30 ppt (Sandifer *et al*., 1975; Willführ-Nast *et al*., 1993). While for juveniles and adult are almost the same between 0 to 20 ppt (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003; Chand *et al*., 2015).

A community-based stock enhancement programme of *Macrobrachium* spp. was initiated by the Borneo Marine Research Institute (BMRI), University Malaysia Sabah from year 2012 in Petagas River, Putatan. The main purpose of this programme was to improve the Petagas River condition and its aquatic resources *via* stock enhancement and awareness programmes. Since there was limited data on assessment of stock enhancement in Malaysia, therefore the present study was conducted to assess the stock enhancement programme of *Macrobrachium* spp. by determining its distribution and abundance along the Petagas River, correlation with water parameters and CPUE following the stocking timeline.

II. MATERIALS AND METHOD

Sampling Site

The study was carried out at Petagas River, Putatan located between latitude 05º54.847' and 05º53.889' North and longitude 116º02.744' and 116º04.644' East along the Petagas River (Figure 1).

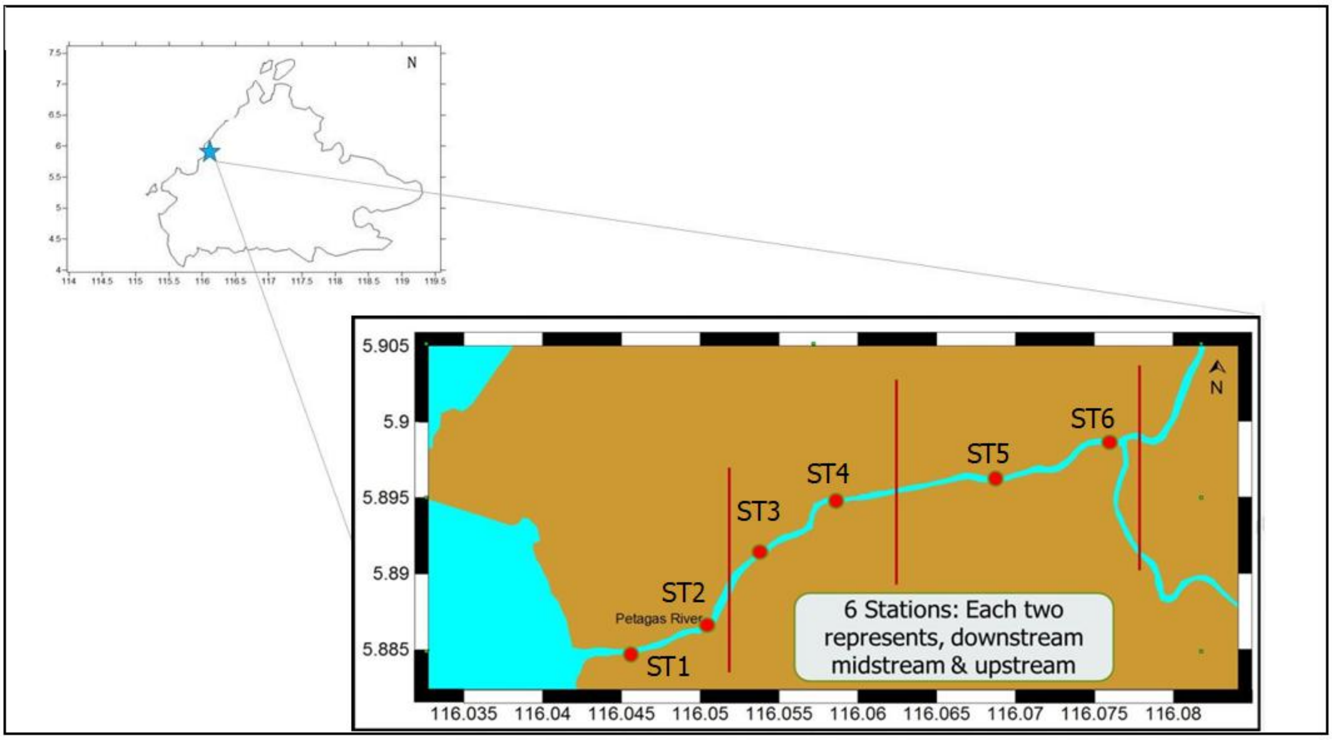


Fig 1. The study site and stations of Petagas River, Sabah at which the samplings were conducted.

Six stations were chosen and selected based on the presence of *Macrobrachium* spp. during the preliminary sampling. The stations were used to determine the distribution and abundance of different life stages of *Macrobrachium* spp. in Petagas River. These stations were divided into three regions i.e upstream, midstream and downstream dependent on their salinity ranges during high tide and low tide.

Sampling Period

Sampling was carried out on three consecutive days after each stocking phases of *Macrobrachium* spp. juveniles into the Petagas River from September 2013 to May 2015 (Table 1). The assessments of stock enhancement were made after the Phase 3 to 6 releases. No assessment was made on Phase 1 and 2 because the present study was conducted after a year of the BMRI stock enhancement programme started in 2012. Besides, local community also revealed that mass mortality of prawns occurred in few incidents after the releases where local people used '*tuba*' for fishing. '*Tuba*' is derived from leguminous plants, genus *Derris* found in Southeast Asia and the southwest Pacific islands. The roots of *D. elliptica* contain rotenone, a strong insecticide and can poison fish (Fryer and Stenton, 1923). This activity might cause mortality of the *Macrobrachium* spp. juveniles that were released during Phase 1 and 2.

Tab. 1: Assessment of stock enhancement of Macrobrachium spp. juvenile following the stocking programme timeline

Stocking Phases by BMRI	**Dates**	**Number of juveniles**	**Assessment**	**Month of sampling**
Phase 1	23 Apr 2012	5,000	No assessment	-
Phase 2	06 Dec 2012	6,000	No assessment	-
Phase 3	22 Sept 2013	10,000	Assessment 1	September 2013
Phase 4	18 Jan 2014	3,000	Assessment 2	February 2014
Phase 5	7 Dec 2014	3,300	Assessment 3	December 2014
Phase 6	8 May 2015	10,000	Assessment 4	May 2015
Phase 7	17 Dec 2015	5,000	No assessment	-

Sampling Regime

For the sampling of adult prawn, modified prawn trap (locally known as *bubu)* was used (modified from Bentes *et al*., 2011). Each bubu was 200 cm in length with a diameter of 20 cm and entrance funnel with a mouth diameter of 5 cm. The body and funnel of the trap was covered with 5 mm mesh size. The bubu was made by High-density polyethylene (HDPE)/ plastic green net. The traps with two openings were found to be the most efficient capture device in the Petagas River. Two *bubu* traps were deployed and weighed at each station to prevent the traps from being washed away by the tides or currents. The modified traps were first deployed at high tide and hauled during the high tide the following day which resulted in a total soak time of approximately 24 hours. At the end of the 24 hours, the modified traps were removed, and the prawns caught were placed in a labeled plastic bags and transported to the laboratory in thermal box and crushed ice.

For the sampling of PL and juvenile prawn, littoral dip netting method was adopted by using hand net (Davenport *et al*., 1999; Short, 2004; Arumugam, 2012; Grenfell, 2013; Suguri *et al*., 2015; Tantri *et al*., 2016). A dip net or hand net with a mesh size of 1.5 mm and catch area approximately of 25 x 15 cm^2 was used to collect prawns at each station. The net must reach the bottom of the littoral zone as PL and juveniles of the prawn are now a benthic organism. Dip netting was carried out in water depths between 0.1 to 1.0 m. In order to minimize the bias in collecting data using this method, the dip netting or hand netting was carried out in same amount of catch effort by netting 10 times in each sampling stations, up to a maximum distance of 10 m on either side of the littoral zone. The PL and juvenile of *Macrobrachium* spp. caught were categorized by their total length (PL<14mm>juvenile) follows (Rao, 1991; Kawamura et al., 2015). Abundance of prawn caught was estimated by catch per unit of effort. Total length (TL-measured in mm from the anterior part of the rostrum to the posterior part of the telson) was recorded.

The *In-situ* parameters of the river water (salinity, temperature, pH and dissolved oxygen) were measured at the bottom of water column where the traps were laid at all stations (ST1-ST6) using HANNA Multi-parameter Model HI9828.

Statistical Analyses

Statistical analyses were undertaken using IBM Statistical Package for the Social Sciences (SPSS) Statistics 23 software. Normality tests were carried out using the Shapiro-Wilks ($\alpha < 0.05$) on all the datasets. The data that did not conform to the assumptions of parametric testing were then run using non-parametric tests analyses. Kruskal-Wallis and Mann-Whitney *U* test were carried out in SPSS to assess whether there were statistical differences in the abundances of different life stages of *Macrobrachium* spp. caught at all stations and time. Since the methods of catching (PL-Juveniles) and adult of *Macrobrachium* spp. were different, thus, the set of data on both methods were separated.

III. RESULT

Distribution and Abundance of Different Life Stages of Macrobrachium spp.

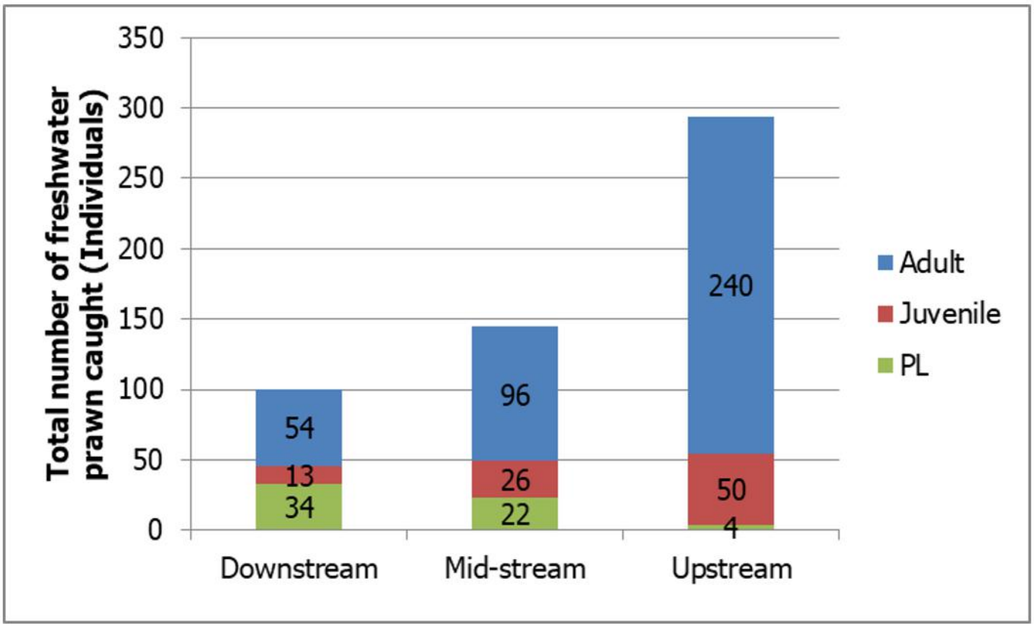
A total of 539 individuals of different life stages of freshwater prawns were caught at different three main regions of Petagas River with 101, 144 and 294 respectively (Figure 2a.). The range of total length of PL was found between 8.4 to 13.9 mm (11.28±1.54 mm) while for juvenile was between 15.8 to 29.2 mm (20.41±3.73 mm). The total length of adult specimens ranged from 56.2 to 120.3 mm (97.2±12.16 mm) (Table 2). At the downstream stations highest percentage (53.47%; n=34) of PL was found (Figure 2a. and 2b.). The lowest abundance of PL was found at the upstream station (1.36%; n=4). The abundance of juvenile freshwater prawn was found to be highest at the midstream stations (18.06%; n=26) followed by upstream (17.01%; n=50) and the lowest by the downstream stations (13%; n=13). Statistical analyses showed a significant different between abundance of juvenile and PL with regions (Kruskal-Wallis; $p<0.05$) except for PL at downstream and midstream regions (Mann-Whitney *U*-test; $p>0.05$). For adult stage, the highest abundance was found at the upstream station (81.63%; n=240) while the lowest at the downstream station (33.66%; n=54) (Figure 2a.) and Figure 2b.). Statistical analyses showed that there were significant differences between the abundance of adult with the river regions (downstream, midstream and upstream) (Kruskal-Wallis; $p<0.05$).

Tab. 2 The total length of sampled prawn in Petagas River

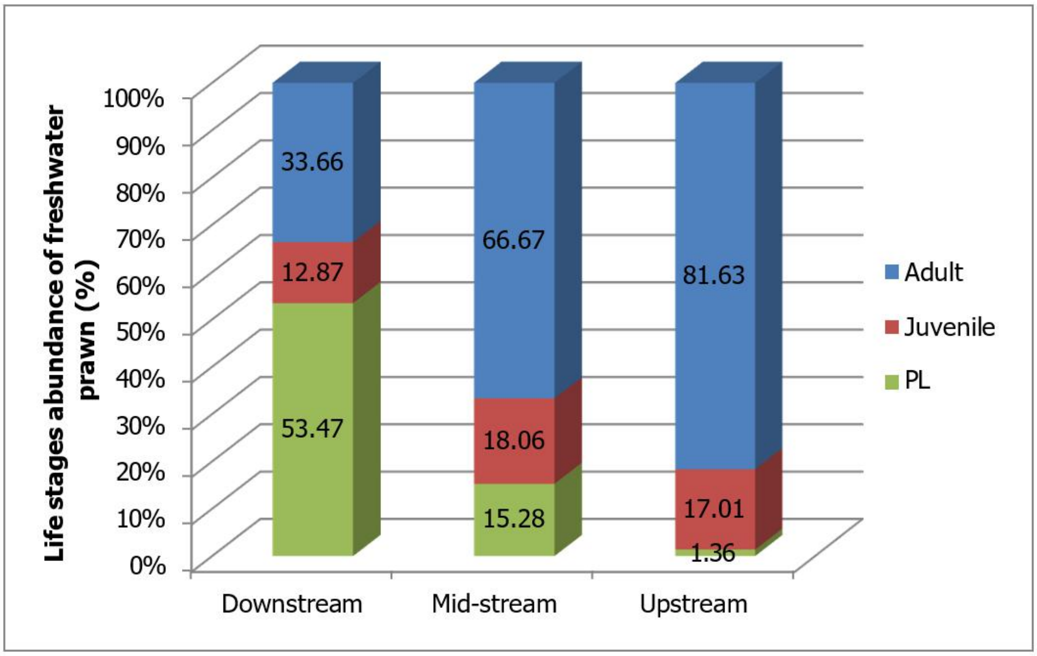
Life stages of prawn	n	Total length (mm)		
		Min	Max	Mean ± Std
Adult	390	56.2	120.3	97.2±12.16
Juvenile	89	15.8	29.2	20.41±3.73[a]
PL	60	8.4	13.9	11.28±1.54[b]

*Abbreviation used on the table: n= total number of specimens, Min= minimum, Max= maximum, Std= standard deviation.

[a,b] showed a significant different ($p<0.05$) of TL between juvenile and PL.



(a)

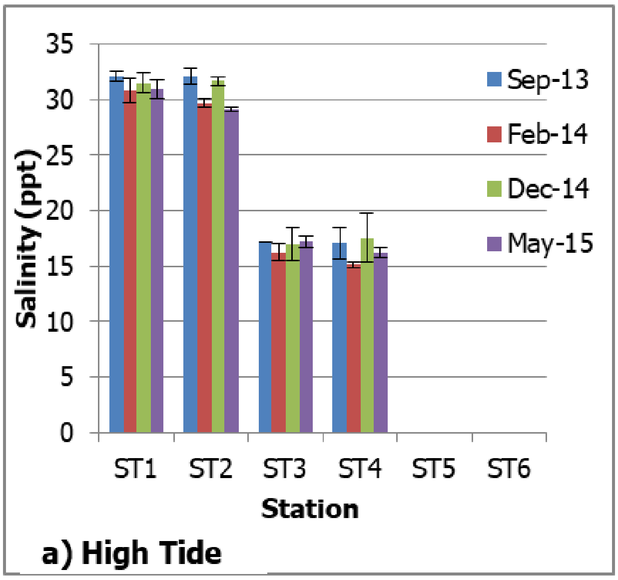


(b)

Fig 2. (a) The total number of prawns at the three main regions of the Petagas River. (b) The composition of PL, juvenile and adult freshwater prawn caught at three main regions of the Petagas River.

In-situ Parameter of Petagas River

The range of water salinity over the entire study period at Petagas River was between 0 ppt to 32.98 ppt. No significant difference in salinity was found between months ($p>0.05$). Further analyses showed that the salinities in both high and low tides were statistically different between stations (Mann-Whitney *U*-test; $p<0.05$) except for (ST1 and ST2), (ST3 and ST4) and (ST5 and ST6) (Mann-Whitney *U*-test; $p>0.05$) (Figure 3a and 3b).



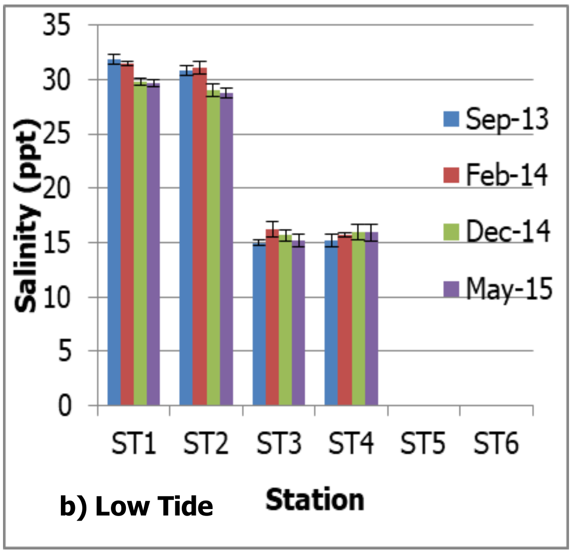


Fig 3.: a) Salinity in ppt at stations along Petagas River during high tide; and b) Salinity in ppt at stations along Petagas River during low tide

The mean of salinities at ST1 to ST6 were 31.32±0.60, 30.65±1.44, 16.89±0.44, 16.49±1.06, 0.00±0.0 and 0.00±0.0 ppt respectively. The stations were categorized into three main regions which were downstream, midstream and upstream according to their range of salinity. The mean of salinities of the regions were 31.28±1.50, 16.79±1.60 and

0.00±0.0 ppt accordingly. Henceforth, throughout this study, the stations were categorized into three regions i.e downstream, midstream and upstream. The mean values of environmental variables are shown in Table 3. The DO varied from 4.56 mg/L (ST1) at downstream station to 7.21 mg/L (ST6) at upstream station. The water pH and temperature of Petagas River were ranging between 6.04 (ST6) to 7.74 (ST1) and 25.83 °C to 28.74 °C respectively between stations.

Tab. 3: Water Parameters at different sampling stations in Petagas River

Para-meter	Salinity (ppt)			Dissolved oxygen (mg/L)			pH			Temperature (°C)		
Station	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
ST1	31.32 ±0.60	30.78	32.08	4.67 ±0.08	4.56	4.76	7.64 ±0.12	7.49	7.74	27.68 ±1.15*	25.90	28.26
ST2	30.65 ±1.44	29.16	32.09	4.73 ±0.10*	4.66	4.88	6.77 ±0.32	6.44	7.21	27.55 ±0.95	26.15	28.14
ST3	16.89 ±0.44	16.26	17.19	4.78 ±0.06	4.72	4.84	6.61 ±0.24	6.27	6.81	27.55 ±1.09*	25.95	28.34
ST4	16.49 ±1.06	15.13	17.54	5.34 ±0.35	4.86	5.62	6.43 ±0.11	6.30	6.54	27.45 ±1.09	25.84	28.15
ST5	0.00 ±0.0	0.00	0.00	5.52 ±0.46	4.93	6.06	6.22 ±0.08*	6.12	6.31	27.71 ±1.33	25.83	28.74
ST6	0.00 ±0.0	0.00	0.00	5.98 ±0.94	5.16	7.21	6.11 ±0.14	6.04	6.32	27.70 ±1.17*	25.96	28.40

* indicates significant difference between stations ($p<0.05$)

Relationship between Distribution of Macrobrachium spp. and In-Situ Parameters

The distribution of PL increased with increasing salinities and pH. There was a strong correlation between the distribution of PL with salinity (R^2=0.95) and PL with pH (R^2=0.51) (Figure 4 and Figure 5) However, there were opposite trends observed between the distribution of juvenile and adult against both salinities and pH. Their distribution decreased with increasing salinities. The trend showed an inversely strong and positive correlation between the distribution of juvenile (R^2=0.98) and adult (R^2=0.921) with salinity (Figure 4). The same trend can be observed between the distribution of juvenile (R^2=0.62) and adult (R^2=0.61) with pH (Figure 5).

The distribution of juvenile and adult freshwater prawns increased with increasing dissolved oxygen (DO). There was a strong correlation between the distribution of juvenile with DO (R^2=0.85) and adult with DO (R^2=0.86). However, opposite trend was observed for distribution of PL with DO with R^2=0.81. This result showed that distribution of PL decreased with decreasing DO (Figure 6). However, the relationship between distributions of all life stages of freshwater prawns PL, juvenile and adult with temperature were weak with R^2 value 0.39, 0.38 and 0.47 respectively (Figure 7).

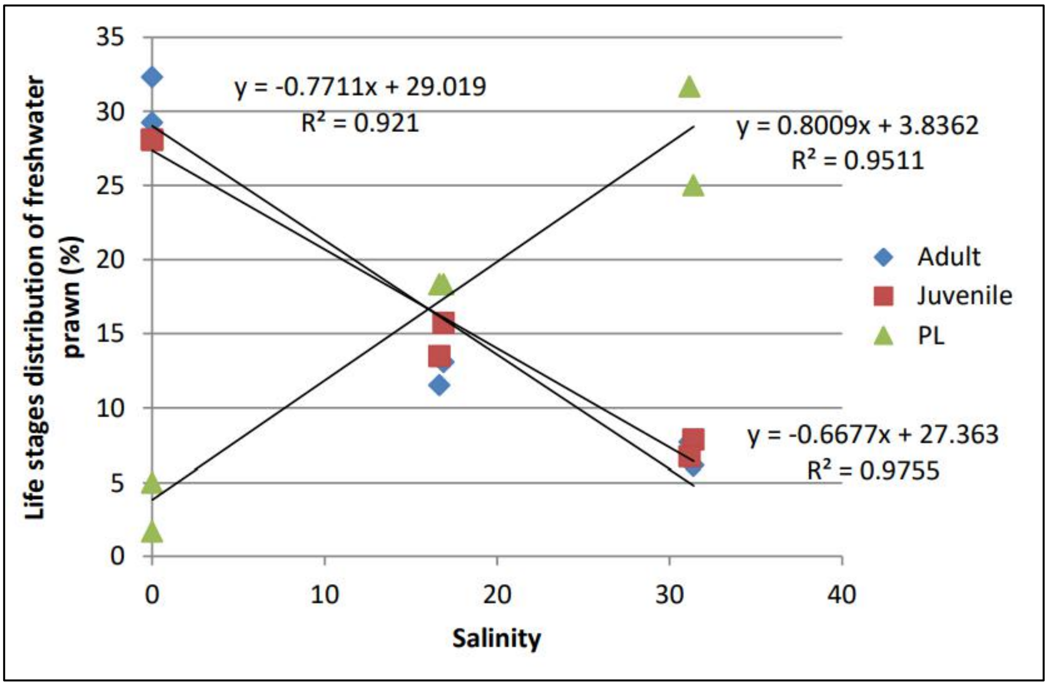


Fig 4 : Correlation of life stages of freshwater prawns, Macrobrachium spp. and salinity along the Petagas River.

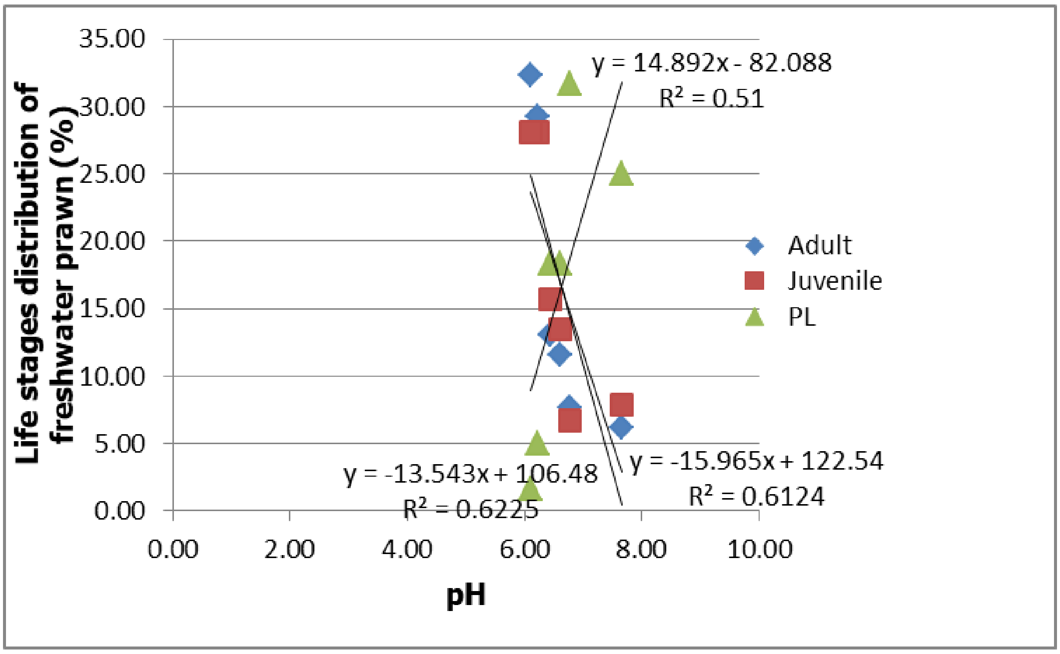


Fig 5:Correlation of life stages of freshwater prawns, Macrobrachium spp. and pH along the Petagas River.

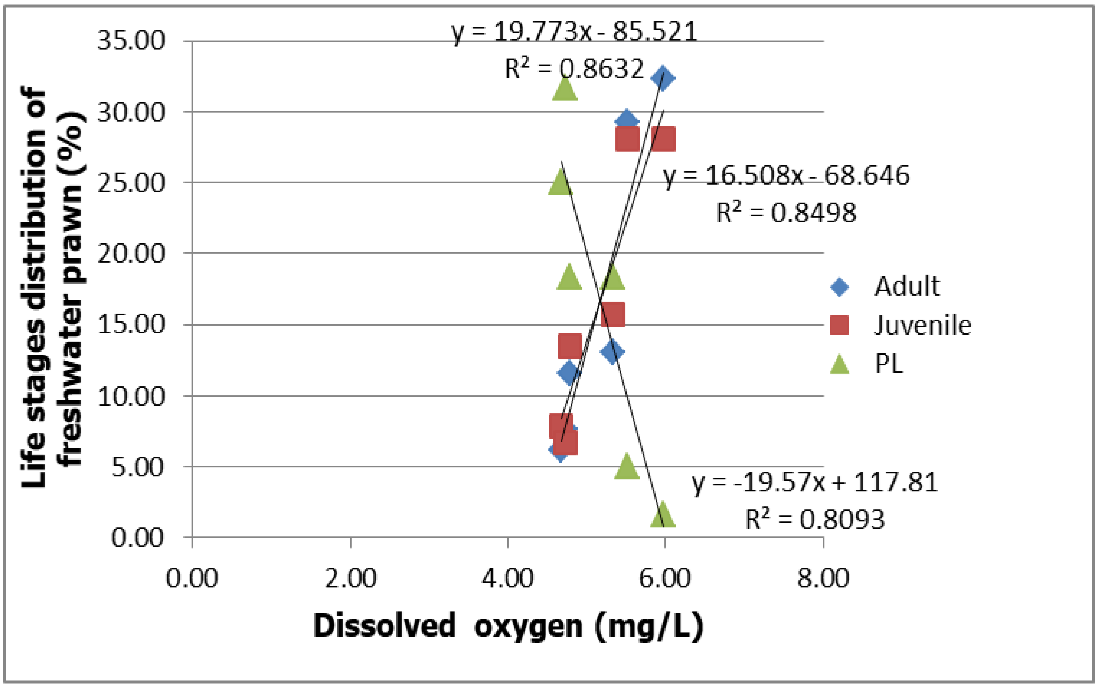


Fig 6: Correlation of life stages of freshwater prawns, Macrobrachium spp. and dissolved oxygen (DO) along the Petagas River.

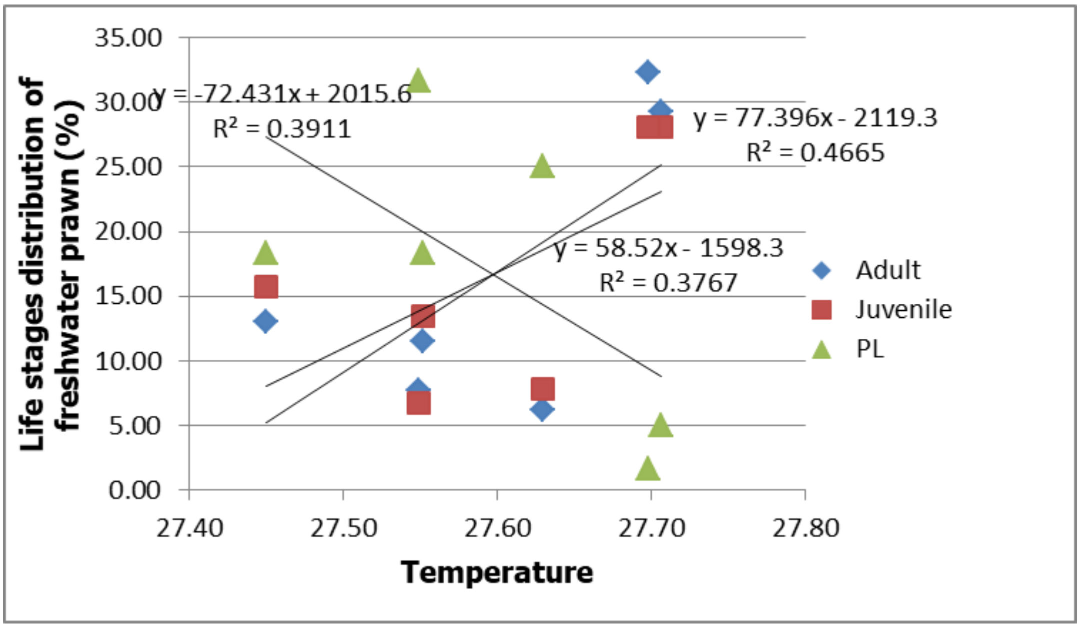


Fig 7: Correlation of life stages of freshwater prawns, Macrobrachium spp. and temperature along the Petagas River.

Trend of Catch per Unit Effort (CPUE) of Freshwater Prawns following Stocking Programme

The cumulative stocking of juvenile freshwater prawn in September 2013, February 2014, December 2014 and May 2015 were 21,000, 24,000, 27,300 and 37,300 individuals respectively (Table 1). The values of CPUE of different life stages of freshwater prawn were determined throughout the stocking programme. The mean values of CPUE of PL, juvenile and adult were 0.50, 0.74 and 5.42 prawn trap^{-1}day^{-1} respectively. The CPUE of PL from September 2013, February 2014, December 2014 and May 2015 were 0.30, 0.30, 0.63 and 0.77 trap^{-1} day^{-1} respectively. Meanwhile, the CPUE of juvenile and adult from the same time periods were 0.50, 0.53, 0.63 and 1.3 trap^{-1} day^{-1} and 4.06, 5.5, 5.89 and 6.22 trap^{-1} day^{-1} respectively. The result showed that the CPUE of PL, juvenile and adult were positively correlated with the increase of stocking juvenile following stocking programme with R^2=0.89, R^2=0.73 and R^2=0.87 accordingly (Figure 8).

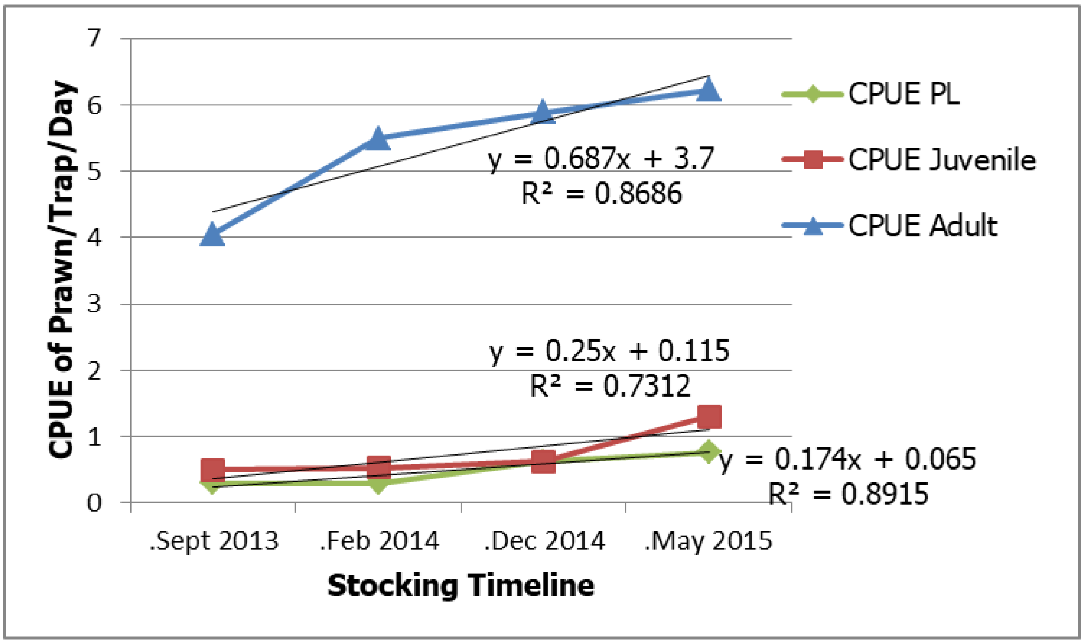


Fig 8 : Correlation in CPUE of different life stages of freshwater prawn, Macrobrachium spp. following stocking timeline in Petagas River.

IV. DISCUSSION

Distribution and Abundance of Genus Macrobrachium

The freshwater prawn is widely distributed along the Petagas River suggest that the species has great adaptation ability (Araújo and Valenti, 2007; Odinetz- Collart, 1991). Throughout their life cycle, the freshwater prawn is exposed to a wide range of salinities from 0–18 ppt (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003). The gravid females migrate from upstream river to estuary where eggs hatch and larvae developed (Ismael and New, 2000).

The abundance of PL was found to be highest at the downstream region (30.99±1.02 ppt) of Petagas River as compared to mid-stream and upstream region of the river. The relationship of PL distribution in Petagas River was also directly correlated with salinity as the distribution increased with increasing salinity. This present study supports the previous study carried out in three rivers of Paikgacha, Bangladesh where number of *M. rosenbergii* PL increasing as the salinities increased along the river (Khair *et al*., 2000). Sandifer *et al*. (1975) also proved that tolerance of PL *M. rosenbergii* to gradual and rapid increases in salinity around 25 ppt to 30 ppt. However, the PL of genus *Macrobrachium* was found to be absence in study carried out by Arshad *et al.* (2011) in the estuary of Sungai Pulai, Johor. This suggests that not every river existed as habitat of *Macrobrachium* spp.

In laboratory condition, survival rate of PL stages increased as the salinity increasing. Zafar *et al*. (2015) found that survival rate of *M. rosenbergii* PL was 34.42% in high salinity (12 ppt) compared to low salinity (8 ppt) with 20% survival rate. Willführ-Nast *et al*. (1993) reported higher survival rates of *M. rosenbergii* at 14 to 25 ppt compared to less than 14 ppt. Previous study in laboratory condition reported that PL of *M. rosenbergii* can tolerate salinity. These results show that saline salinity is better for larval to post larval stages then post larvae converted slowly and gradually on 0 ppt (Zafar *et al.*, 2015). Larval studies of *Macrobrachium* sp. showed that larvae require saltwater for growth development and survival, whereas molting process occurs in fresh and saltwater (Dugan, 1971; Dugan *et al*., 1975; Zafar *et al*., 2015). Therefore, it is clear that *Macrobrachium* prawns require conditions of constant saline water for successful development beyond stages VII and VIII until metamorphosis into PL (Ling and Merican, 1961; Uno and Kwon, 1969; Takano, 1987; Nandlal and Pickering, 2006).

According to Bauer and Delahoussaye (2008), the larvae undergo metamorphosis into PL and tend to be a benthic organism. At this stage, they migrate upstream towards freshwater to grow into juvenile prawn and finally becoming mature adult (Kriengkrai, 2006; John, 2009). During this time, juveniles may delay swimming upstream when hindered by stronger currents. The pattern is similar with results reported by Ling (1969) where the newly settled juveniles migrated from the estuary to the upstream region of river for their next phase of their life cycle. In *M. rosenbergii* from Southeast Asia, the juveniles began to swim upstream on 14th day after settlement (Ling, 1969). The present study showed that the juvenile size at the upstream region of Petagas River was larger (22.5±0.41 mm TL) than juvenile at the downstream region (18.2±0.28 mm TL), indicating the juveniles are growing as they migrate upstream of the river towards less saline water. The present result is supported by study from Atchafalaya River, Lousiana, USA, where the comparison between the carapace length of *Macrobrachium* sp. juveniles from upstream region and downstream region of the river showed significant different in sizes (Bauer and Delahoussaye, 2008).

Correlation between Abundance of Macrobrachium spp. with Water Parameters

The present study showed that PL of freshwater prawn increased with increasing pH value. This is in agreement with previous study showed survival rate of PL was higher at pH 6 than 5 in laboratory condition (Chen and Chen, 2003) while in wild, PL of was found highest at pH 8.0-8.5 (n>80) compared to lower pH 7.2-7.9 (n<80) at river in Bangladesh (Khair *et al*., 2000). Despite of some low and high pH values, it probably did not affect the distribution of PL in wild environment of Petagas River because the present study is in agreement with previous studies where pH ranging from 7.0-8.5 is known to be optimum for growth of *M. rosenbergii* (New, 1995; Khair *et al*., 2000, Chen and Chen, 2003 and Kawamura *et al*., 2015).

Negative correlation was found as PL distribution decreased with increasing DO. Low DO adversely affects the behaviour and normal physiology of crustaceans, such as the survival, respiration and circulation, feeding, metabolism, growth, and molting of penaeid shrimps (Cheng *et al*., 2003). In contrast with previous study carried out in laboratory condition, PL of *M. rosenbergii* were found to tolerate at more than 5 mg/L i.e 7.5 mg/L (Tidwell *et al*., 1998), 7.7± 0.1 mg/l (Tidwell *et al*., 2003) and 8.3 ± 0.2 mg/l (Tidwell *et al*., 2004). However, in most crustaceans including *M. rosenbergii*, a specific adaptive mechanism has developed, including behavioral and physiological responses, to cope with fluctuations in DO of the medium or even to hypoxic conditions (Johnson and Uglow, 1987; Charmantier *et al*., 1994; Morris and Butler, 1996; Chen and Kou, 1998). The correlation between distribution of PL and temperature of Petagas River was weak and had no significant difference with stations (p>0.05). The temperature was within the acceptable ranges 25.83 °C to 28.74 °C (Narejo *et al*., 2010; Abdul *et al*., 2014).

There were strong inversely positive correlations between the distribution of juvenile and adult freshwater prawn with salinity in Petagas River with R^2 value 0.98 and 0.95 respectively. Nina-Maryam and Anton (2015) reported the same trend of higher abundance of juvenile distribution (118.4 individuals/m^2) at the same river with salinity of 0 ppt while lower (2.6 individuals/m^2) at higher salinity. This finding is also in agreement with the previous study where the distribution and abundance of juveniles and adults freshwater prawn were highest (n>80 per sampling period) at low salinity ranging from 0 to 19 ppt (George, 1969; Ling, 1969; Khair *et al*., 2000; Montoya, 2003; De Silva and Funge-Smith, 2005).

In laboratory condition, previous studies showed that survival rate of juvenile and sub-adult of *M. rosenbergii* varied between 91% (at 0 ppt) and 78% (at 20 ppt) as the prawns grew and survived satisfactorily at 0–15 ppt salinities while decreasing as salinity increased, implying that the species can survive at wide salinity range (Limpadanai and Tansakul, 1980; Cheng *et al*., 2003; Chand *et al*., 2015). Results of this study also indicated juveniles and adult of *M. rosenbergii* occur naturally in estuarine areas of Petagas River are thus adapted to an environment in which salinity levels vary constantly and it supports that the species exhibits a wide tolerance to abrupt changes in salinity (George, 1969; Ling 1969; Chand *et al*., 2015).In contrast, the juvenile and adult of freshwater prawn, *M. rosenbergii* were found at range of salinity 2.1 to 8.7 ppt in Pumba River (John, 2009). These variations and differences of different life stages distribution may occur because of different environmental conditions such as local vegetation and food availability at the area and geographical locations. For example, the presence of adult individuals of *M. acanthurus* and *M. carcinus* were mainly found in coastal area (Mejía-Ortíz *et al*., 2001) while the absence in migration of adult *M. nipponense* from upstream to downstream was observed in study by Mashiko (1990). In the present study, besides can tolerate with wide range salinities, the environmental factors such as geographical and availability of vegetation in the mid-stream and upstream region of Petagas River contributed to the distribution and abundance of the juveniles and adult prawn compared to downstream region.

The distribution of juveniles and adult prawns were found to be negatively correlated with pH in the present study, where number of juveniles and adult decreased with increasing pH. In contrast, Khair *et al*. (2000) found that at lower pH, lesser number of juveniles (n<80; pH 7.0-7.9) and adult (n<80; pH 7-8-7.9) were caught while more juveniles (n>80; pH 7.8-8.1) and adult (n>80; pH 7.1-8.5) of *M. rosenbergii* and a greater number of juveniles and adult (n>80; pH 8.0-8.5) were caught at higher pH. The survival rate of juveniles *M. rosenbergii* also was found increasing at higher pH compared to lower with pH 8.2 (100%) 7.4 (88.9%) 6.2 (94.4%) and 5.6 (94.4%) respectively (Kawamura *et al*., 2015). Out of all, despite of some low and high pH values, it probably did not affect the distribution of juveniles and adults in wild environment of Petagas River because the present study is in agreement with previous studies where pH ranging from 7.0-8.5 is known to be optimum for growth of *M. rosenbergii* (New, 1995; Khair *et al*., 2000, Chen and Chen, 2003 and Kawamura *et al*., 2015).

The DO in the present study was found ranging within the acceptable ranges between 4.16 mg/L to 7.21 mg/L. The distribution of juvenile and adult freshwater prawns was found increased with increasing DO. Low DO adversely affects the behaviors and normal physiology of crustaceans, such as the survival, respiration and circulation, feeding, metabolism, growth, and molting of penaeid shrimps (Cheng *et al*., 2003). This trend was obviously opposite with distribution of life stages of prawns with salinity. This is because DO is strongly influenced by combination of physical, chemical and biological characteristics of the river (Quinn *et al*., 2005; Williams *et al*., 2000) including anthropogenic influences such as domestic areas, industry and agriculture (Jarvie *et al*., 1998). Downstream region of Petagas River is crowded with housing areas and industries. These factors may alter the concentration of DO at the downstream compared to upstream region, thus lower concentration of DO was found at downstream region.

In similarity, Chen and Kou (1998) reported that the juveniles and adult freshwater prawn *M. rosenbergii* can tolerate the exposure to 3.38 and 4.45 mg/L DO. Cheng *et al*. (2003) reported that *M. rosenbergii* could tolerate under 2.75 and 1.75 mg/L DO however with optimum survival at >5 mg/L. Generally different life stages of *M. rosenbergii* are mainly affected by wide range of salinity thus, presence of PL, juveniles and adults in Petagas River may vary at different DO concentration. Moreover, the distribution of juvenile and adult may not be affected much by DO since most crustaceans and *M. rosenbergii* experiences specific adaptive mechanism to DO (Johnson and Uglow, 1987; Charmantier *et al*., 1994; Morris and Butler, 1996; Chen and Kou, 1998).

Trend of CPUE following Stocking Programme

Comparison between the CPUE of all life stages of freshwater prawn in Petagas River before and after the stocking programme cannot be made since there was no initial sampling was done before the stocking programme thus, comparison was made based on the stocking timeline. The present study reported that the CPUE of all life stages of freshwater prawn increases with the progress of the stocking programme. There was a strong correlation between the CPUE of the three life stages of freshwater prawn i.e PL, juvenile and adult stages observed in this study, (R^2=0.89, R^2=0.73 and R^2=0.87 respectively) which could be concluded that the *Macrobrachium* spp. in Petagas River reproduces in the Petagas River and this promotes continuous recruitment (Silva *et al*. (2006). The result corroborates the previous studies found that an increase in CPUE of *Macrobrachium* spp. PL and juveniles in the same river (Mariam-Syarmilah and Anton, 2016; Nina-Maryam and Anton, 2015; Aqilah-Musfirah and Anton, 2014).

The success of the stock enhancement programme was proven affected by the size of water body of the river (Choonhapran *et al*., 2003; De Silva and Funge-Smith, 2005). In the present study, although the total number of released juveniles was lower compared to previous studies, however the value is still considered sufficient by comparing the number of juveniles released per area of the rivers. The Petagas River covering 3.16 km^2 with a total number of released juveniles of *M. rosenbergii* was approximately 13,200 juveniles/ km^2. Choonhapran *et al*. (2003) reported a stock enhancement in Pak Phanang River, Thailand covering 422 km^2 with a total number of released juveniles of *M. rosenbergii* was approximately 165,000 juveniles/ km^2. Another stock enhancement of *M. rosenbergii* in *Sungai Perak* reported the total number of released juveniles was 132 juveniles/ km^2. It is clear that in order to determine the success of the stock enhancement programme, the total amount of released juveniles alone does not matter, but the area of the rivers or reservoirs need to be considered too.

The main goal of stock enhancement is to build a larger population of the organism to support the local landings on a sustainable basis by releasing the cultured organisms into the river, sea and lakes to conserve, enhance, or restore the fisheries resources (Mustafa, 2003; Bell *et al*., 2006; Lorenzen, 2008). Therefore, based on the result of the present study, the positive recruitment of CPUE of various life stages of freshwater prawn, *Macrobrachium* spp. in

Petagas River have indicated improvement in its population. The established *Macrobrachium* spp. and increase in its CPUE at the end of the stocking programme also proven that the releasing species started to establish in its population showing a positive sign of stock enhancement programme. Maidin *et al*. 2017 has proven that there were close genetic distances between the broodstock prawns in hatchery involved in the stocking programme and the sample prawns in the same river which reflects the success of the establishment of the prawn in the river. Choonhapran *et al*. (2003) has also reported that there will be in increased production of target species as the stocking programme increases.

A study by Silva *et al*. (2006) found that of *Macrobrachium* spp. did not show variations in the modes or mean length of the prawn caught throughout the year because due to continuous reproduction, which helps the continuous recruitments in the population over time. This pattern also can be seen in *M. amazonicum* juveniles (Sousa *et al*., 2013) and *M. jelskii* (Lima *et al*., 2006) at Amazon estuaries in Brazil. In contrast, the results differed from Bialetzki *et al*. (1997) where the *M. amazonicum* in the state of Paraná, southern Brazil showed recruitment occurred in rainy season only but not throughout the year. The recruitment patterns and CPUE of the stocking species may vary in different species, localities and geographies. It may also be affected by other factors including temperature (Shoji *et al*., 2011) conductivity, clarity, habitat complexity, river flow and species behaviour patterns (Dutterer *et al*., 2012; Bayley and Austen, 2002; Reynolds, 1996; Hilborn and Walters, 1992).

V. CONCLUSION

The finding suggests that the distribution and abundance of *Macrobrachium* spp. varies along Petagas River as its life stages tend to adapt and survive in a wide range of salinity, pH, DO and temperature like other undisturbed river in previous studies. The CPUE of PL, juvenile and adult prawns were positively correlated with the increased stocking juvenile following stocking programme. In the present study, the population *Macrobrachium* spp. has started to establish and showed positive sign of natural recruitment following the stocking programme. It showed that *Macrobrachium* spp. is able to live and adapt in the Petagas River. This study offers suggestive evidence for stock enhancement to be carried out more by fisheries managers in Petagas River as increasing numbers of juveniles released will improve the natural recruitment of the stocking species. Continued study is needed to explore the whole Petagas River area to better characterize the *Macrobrachium* spp. distribution and abundance in the river ecosystem and evaluate the effectiveness of the stock enhancement programme practices. Study on long term genetic impacts on stocking species following stock enhancement also would be one of the mechanisms in assessing the stocking programme. In Petagas River, it is expected that the recruitment rate of the enhanced stock would then significantly increase after years of stocking programme. If successful, the re-establishment of a self-sustained prawn population could serve as an indicator of a healthy environment, at least for the Petagas ecosystem. This study will provide baseline information on the stock enhancement programme in Malaysia as to the best knowledge of this study, this is the first record of stock enhancement programme of target species *Macrobrachium* spp. in Sabah.

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