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# Effects of Artificial Substrate on Growth Performance, Survival and Production of Freshwater Prawn, *Macrobrachium rosenbergii* (de Man 1879) in Cages in Laguna de Bay, Philippines

**HANNIBAL M. CHAVEZ***

Bureau of Fisheries and Aquatic Resources Region IVA - Regional Fisheries Research and Development Center IVA, Bambang, Los Banos, Laguna 4030, Philippines

## Abstract

The effects of the number of artificial substrates on growth performance, survival and production of freshwater prawn, *Macrobrachium rosenbergii* (de Man 1879) were evaluated in cages in Laguna de Bay, Philippines. Juvenile prawns (1.97$\pm$0.27 g; 5.52$\pm$0.19 cm) were stocked in cages (L x W x D: 2 x 3 x 2 m or 12 $m^3$) at 20 pieces $m^{-3}$. Three treatments with three replicates each were used: $T_1$= without substrate; $T_2$ = with 6 pieces artificial substrates and $T_3$ = with 12 pieces artificial substrates. After 160 days, mean weights were 46.10 g, 45.57 g and 52.20 g in $T_1$, $T_2$ and $T_3$, respectively. The water quality parameters were favourable throughout the experimental period. Production was highly significant among treatments ($P<0.01$). Highest total production was recorded in $T_3$ (17.90 kg) and $T_2$ (16.40 kg) while $T_1$ has the lowest production (12 kg). Survival was significantly different among treatments ($P<0.05$). Highest survival was recorded in $T_3$ (85.83%) and $T_2$ (83.05%) and the lowest was observed in $T_1$ (63.19%). Survival and production were greatly influenced by the increased number of substrates. The higher the number of artificial substrates installed, the greater the survival and production of prawns.

## Introduction

Freshwater prawn *Macrobrachium rosenbergii* (de Man 1879) is a species commonly used in commercial farming. It is found in most inland freshwater areas like lakes, rivers, ponds, swamps, as well as estuarine areas (New 2002). Although predominant in various areas in the Philippines, it is not normally found in Laguna de Bay. The most abundant commercial species of crustacean in the lake is the small freshwater prawn, *Macrobrachium lanceifrons* (Dana 1852) (Cuvin-Aralar et al. 2007).

*Corresponding author. E-mail address: bfarrfrdc@yahoo.com

In the natural habitat, prawns spend much of their life in lotic and riverine environments (Raman 1967). These areas are characterised by water movement, high oxygen concentration and relatively complex benthic substrate (Cohen et al. 1981). The introduction and farming of *M. rosenbergii* as an aquaculture species in the lake, do not cause any possible threat to the biodiversity of Laguna de Bay (Cuvin-Aralar et al. 2007).Nevertheless, prawns cannot complete their life cycle in the lake and requires brackishwater for the larvae to survive.

Numerous studies have been conducted on the culture of freshwater prawn in ponds. Results showed that growth and survival were influenced by the farming system such as rice-fish integration system (Mohanty 2003), coconut garden channels (Ranjeet and Kurup 2011) and polyculture ponds (Rahman et al. 2012). Reports on various methods to increase per unit production of freshwater prawns ($kg \cdot ha^{-1}$) in ponds including increased size and stocking density have been published in several literatures. Studies of Tidwell et al. (1999; 2000) focused on the evaluation of the effects of substrate on pond production. The substrate serves as additional habitat of prawns, whether natural e.g. leaves, branches or artificial, such as PVC pipes and plastic nettings.

These also increase the surface area, provide shelter and increase the survival rate of prawns (Raanan et al. 1984). During the molting stage, prawns are vulnerable to cannibalism and tend to look for shelter during this period. Providing shelter for prawns reduce the frequency of aggressive interactions particularly in high stocking densities (Sandifer and Smith 1975). Some attempts have been made in the culture of prawns in cages particularly in Laguna de Bay. Previous studies reported the highest survival rate of 55.3% at 15 $pieces \cdot m^{-2}$ after 5 months culture in cages with shirred nets as shelter (Cuvin-Aralar et al. 2007). There are great opportunities to improve the survival and production through improved culture systems. This study attempted to evaluate the effects of varying number of artificial substrates on the growth, survival and production of freshwater prawns cultured in cages under the lake-based culture system.

## Materials and Methods

### *Cage preparation and stocking*

This study was conducted in Barangay Dalig, Cardona, Rizal, Laguna de Bay area. Nine units of fish cages (L x W x D: 2 x 3 x 2 m or 12 $m^3$) with mesh size no. 22 were used in the experiment. Freshwater prawn, *M. rosenbergii* post larvae were obtained from the BFAR-National Integrated Fisheries Development Center, Binloc, Dagupan City, Pangasinan. Prawn post larvae were held in the conditioning tank at the station for 1 month until they reached the juvenile stage and were ready for stocking. Three treatments with three replicates each were used, namely: Treatment 1 = without substrate; Treatment 2 = 6 pieces artificial substrates per cage (2 $m^{-3}$:1 substrate) and Treatment 3 = 12 pieces artificial substrates/cage (1$m^{-3}$:1 substrate). The cages and artificial substrates were installed a week prior to stocking.

Juvenile prawns were transported early in the morning to the experimental site in oxygenated plastic bag with plastic netting as substrate and acclimatised to the water conditions in the area for 1 h. Juvenile prawns with average weight of $1.97\pm0.27$ g and length of $5.52\pm0.19$ cm (tip of rostrum to telson) were hand-counted and stocked in cages at 20 pieces $m^{-3}$. Prawns were fed with commercial pellets (30% crude protein) at 5% body weight twice daily.The artificial substrates consisted of bundled dried tamarind twigs (20 pieces twigs per bunch = 1 piece artificial substrate) without leaves and almost uniform in diameter measuring 70 cm length (Fig. 1). Treatment 2 (6 pieces artificial substrates), were equally installed inside the cages in single layer and vertically suspended at the bottom of the cage flooring. Treatment 3 (12 pieces artificial substrates), were equally installed in two layers at 6 pieces per layer and suspended vertically at the bottom inside the cages. The artificial substrates were tied to the bamboo poles provided above the cages using monofilament nylon twine number 150 mm. The distance from the first and second layer substrates was 10 cm. The first layer artificial substrates touched the bottom of the cage flooring. The cages were provided with net cover to prevent the escape of prawns during wave action. The bottom of the cage net was provided with fine mesh net to serve as feeding tray.

### *Sampling of prawns*

Random sampling was conducted monthly at 10 prawn samples per treatment per cage. Prawn samples were individually weighed and measured to determine the growth and to adjust the feeding ration. During sampling, prawn samples collected per cage were placed separately in an aerated basin to avoid stress. Collection of prawn samples was done by hauling the bottom of the cage net to the surface and scooping the prawns gently. The artificial substrates were not removed during the sampling, instead these were moved slowly beside the corner of the cage without prawns. Sampled prawns were returned to their respective cages after sampling.

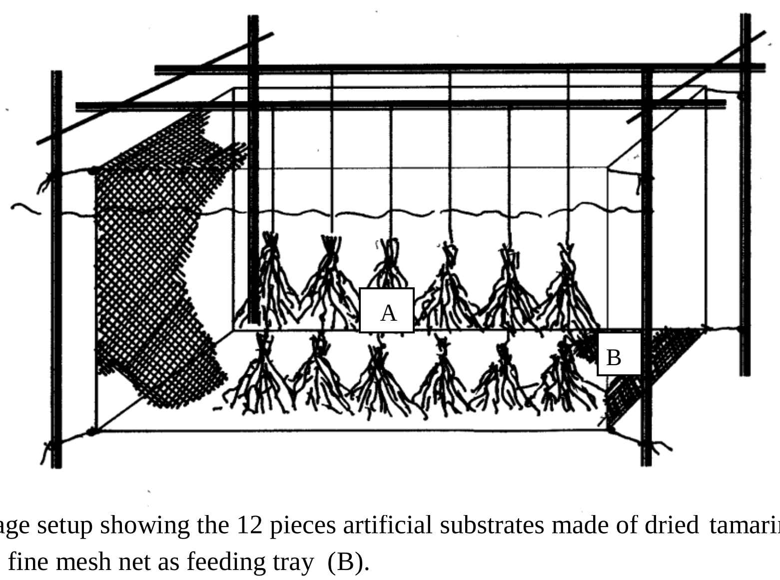


**Fig. 1**. Floating cage setup showing the 12 pieces artificial substrates made of dried tamarind twigs installed in 2 layers (A) and the fine mesh net as feeding tray (B).

### *Harvest*

After 160 days culture, prawns were ready for harvest. Prior to harvest, all of the artificial substrates were removed. Prawns were harvested by hauling the cage net to the surface and by scooping the prawns. Total weight and number of prawns per treatment per cage were recorded. Harvested prawns were sorted by morphotype and classified into blue-clawed male and female morphotypes: berried (egg carrying; BE), or open (previously egg carrying; OP). Smaller males become blue-clawed males at harvest. As presented in this study, BE and OP females were combined into a composite group of mature females termed reproductive females or RF (Tidwell et al. 2000).

### *Physico-chemical parameters*

The physico-chemical parameters such as water temperature, water depth, turbidity, pH, conductivity, dissolved oxygen and salinity were done in situ in each sampling site. The temperature was measured using a laboratory thermometer; turbidity using a Secchi disk; and pH using a pH meter (YSI, Model No. pH 10). The salinity measurements were done using a refractometer and dissolved oxygen was measured using a YSI handheld multi-parameter, Model No. 55/12ft (YSI Incorporated-Yellow Springs, Ohio, USA). Conductivity was measured using a Lamotte Tracer Pocketester.

### *Statistical analysis*

One-way analysis of variance (ANOVA, $P<0.05$, 0.01) was used to determine if significant differences existed in the mean growth, survival, feed conversion ratio and production ($kg \cdot m^{-3}$) among treatments. Scheffe Test was used to compare the significant differences between treatments. Analyses were carried out with SPSS 13.0 for Windows.

## Results

The results of water quality analysis were within tolerable range throughout the experimental period (Table 1). There was no significant differences ($P>0.05$) among the different water quality parameters measured.

The growth performance of prawns among treatments is shown in Fig. 2. The best growth was attained for prawns stocked in cages with 12 pieces artificial substrates with mean size of 52.20±2.52 g; 16.03±0.09 cm (tip of rostrum to telson) at harvest. This was followed by cages without substrate (46.10±4.51 g; 15.67±0.19 cm) and 6 pieces artificial substrates (45.57±4.68 g; 15.60±0.11 cm).

**Table 1.** Water quality parameters in the cage culture area.

| Parameter | Mean ± SD | Range |
|---|---|---|
| pH | 7.57±0.26 | 7.2-8.0 |
| Temperature $^0$C | 30.26±1.89 | 27.8-32.1 |
| Dissolved oxygen (mg·L-$^1$) | 5.24±1.10 | 5.12-7.0 |
| Total hardness (mg·L-$^1$) | 162.27±8.89 | 156.6-180 |
| Conductivity (mS·cm-$^1$) | 1352.87±236.63 | 1039.33 - 1706.33 |
| Total dissolve solids, NTU | 45.30±5.90 | 41.67-57 |
| Transparency (cm) | 37.67±3.34 | 35-41 |
| Salinity (ppt) | 1.36±1.52 | 1-4 |
| Water depth (m) | 2.35±0.52 | 2- 3.2 |

There were no significant differences (P>0.05) in the mean size of prawns among treatments. By the 4$^{th}$ month of culture, the cages and prawns were affected by the strong current and wave action due to bad weather conditions. This resulted in the damage of almost all of the second pair of walking legs or chelipeds of prawns used in capturing food but the chelipeds were able to regenerate after a month.

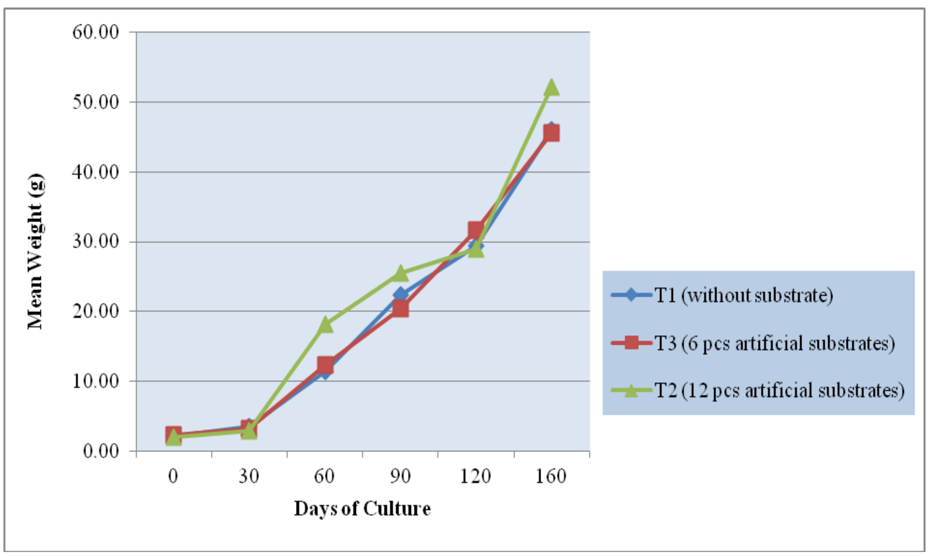


**Fig. 2.** Growth performance of freshwater prawn, *Macrobrachium rosenbergii* reared in cages at varying number of artificial substrates after 160 days culture period.

The specific growth rate (SGR) and the daily weight gain (DWG) did not differ significantly among treatments (P>0.05). SGR ranged from 1.97 (without substrate) to 2.07 (12 pieces artificial substrates) while DWG ranged from 0.27 to 0.31 g·day$^{-1}$ (Table 2).

**Table 2.** Growth performance of freshwater prawn, *Macrobrachium rosenbergii*, specific growth rate (SGR), and daily weight gain (DWG) reared in cages in Laguna de Bay after 160 days culture period (mean±SEM).

| Treatments | Initial Weight (g) SL (cm) | Final Weight (g) SL (cm) | SGR (% BW day-$^1$) | DWG (g day-$^1$) |
|---|---|---|---|---|
| without substrate | 1.97±0.12g 5.57±0.55cm | 46.10±0.66g 15.67±0.19cm | 1.97±0.05 | 0.28±0.05 |
| 6 pieces artificial substrates | 1.97±0.64g 5.47±0.45cm | 45.57±4.68g 15.60±0.11cm | 1.98±0.12 | 0.27±0.05 |
| 12 pieces artificial substrates | 1.97±0.38g 5.53±0.60cm | 52.20±2.52g 16.03±0.09cm | 2.06±0.09 | 0.31±0.03 |

SGR (% body weight.day$^{-1}$) = [(In final wt – initial wt) 100]/Δt, where In = natural log.
DWG = (final wt – initial wt)/Δt

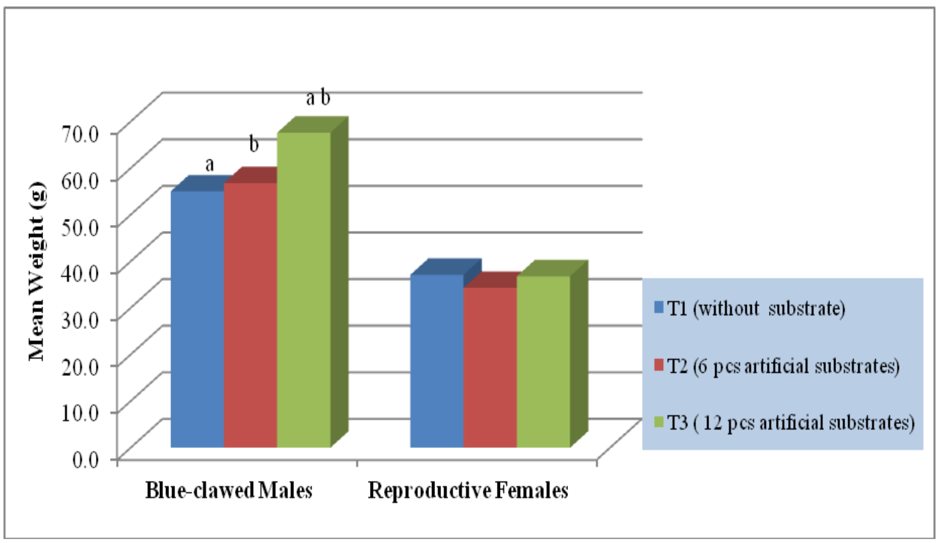


**Fig. 3.** Mean weight of blue-clawed male and reproductive female prawns. Values with different letters are significantly different at 5% level of significance (P<0.05).

The mean weight (67.6±2.91g) of blue-clawed males was significantly higher (P<0.05) in cages with 12 pieces artificial substrates (Fig. 3). This was followed by cages with 6 pieces artificial substrates (56.8±5.10 g) and without substrate (55.0±4.73 g). There were no significant differences in the mean weight of reproductive females among treatments (P>0.05). The percentage composition of female morphotypes: (BE and OP) classified as reproductive females were significantly higher (P<0.05) in cages with 6 pieces artificial substrate (86%), followed by cages without substrate (84%) and 81% in cages with 12 pieces artificial substrates. There was no significant difference (P>0.05) in the composition of blue-clawed males among treatments. Blue-clawed males comprised 19% in $T_3$, followed by $T_1$ with 16% and 15% in $T_2$ (Fig. 4).

Survival was significantly different among treatments (P<0.05). Highest survival was noted at 85.83% and 83.05% in cages with 12 and 6 pieces artificial substrates, respectively. Lowest survival was recorded in cages without substrate (63.19%). Feed conversion ratio (FCR) decreased with the increased amount of substrates. An FCR of 2.8, 3.0 and 3.1 were obtained for the 12 and 6 pieces artificial substrates and without substrate, respectively. Differences in production was highly significant among treatments (P<0.01). Highest production was obtained in cages with 12 pieces artificial substrates with the higher mean size and survival of prawns (Table 3).

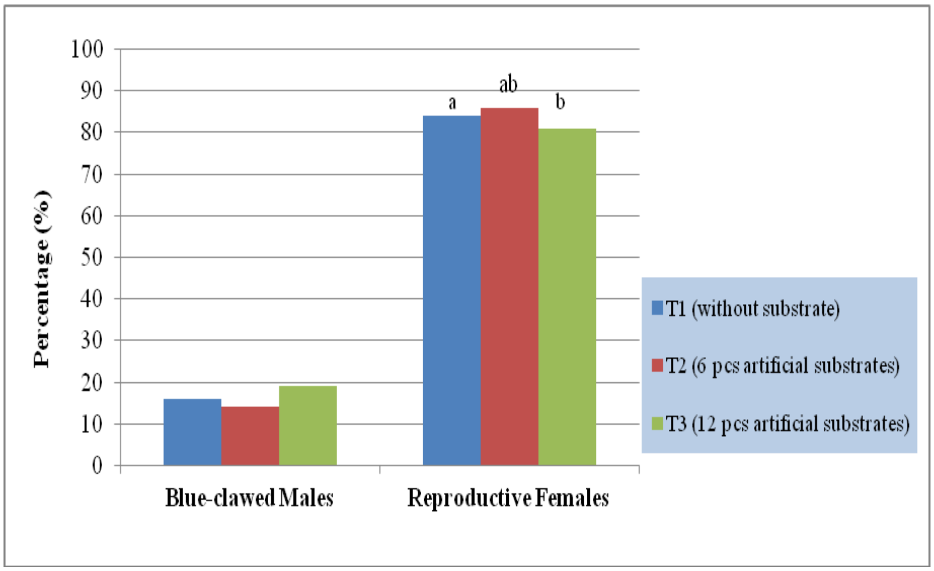


**Fig. 4.** Percentage of blue-clawed male and reproductive female prawns. Values with different letters are significantly different at 5% level of significance (P<0.05).

**Table 3.** Survival rate (%), feed conversion ratio (FCR), total yield (kg) and production rate ($kg \cdot m^{-3}$) of freshwater prawn, *Macrobrachium rosenbergii*, cultured in cages at Laguna de Bay after 160 days culture period (mean±SD).

| Treatments | Survival rate* (%) | FCR | Total yield** (kg) | Production Rate** ($kg\ m^{-3}$) |
|---|---|---|---|---|
| without substrate | 63.19±12.07$^{a}$ | 3.1±0.40 | 12$^{a}$ | 0.33±0.04$^{a}$ |
| 6 pieces artificial substrates | 83.05±2.77$^{ab}$ | 3.0±0.15 | 16.40$^{ab}$ | 0.46±0.04$^{ab}$ |
| 12 pieces artificial substrates | 85.83±4.69$^{a}$ | 2.8±0.32 | 17.90$^{a}$ | 0.50±0.01$^{a}$ |

Values having a different superscripts are significantly different (*P<0.05; **P<0.01)

## Discussion

Cage farming of freshwater prawn, *M. rosenbergii* in the lake utilising varying number of artificial substrates (dried tamarind twigs) was proven to be feasible and showed promising results. It is a viable technology, an alternative to pond culture and has the potential to improve aquaculture production in the fish farming communities in lakeshore areas. The culture of prawns in the lake with high rate of water exchange and natural food exhibited improved good growth and survival even in a limited surface area. Culture period was 160 days compared to pond culture (6 to 8 months) to achieve a marketable size prawn. Stocking of juvenile prawns is more advantageous and more tolerant to high pH and ammonia than post larvae even in tropical areas (New 2002). Installation of cages a week prior to stocking ensures a good colonisation of the natural food and periphyton on the nets and allows the prawns to acclimatise easily to the lake conditions.

Predators were removed inside the cages during the colonisation period and during sampling. The substrates used (made of dried tamarind twigs) are available in the area, is environmentally friendly and cheaper than PVC pipes. FCR in the lake-based cage culture was comparable to those reported for pond-based culture (2:1 to 3:1) of prawns (New 2002; Cuvin-Aralar et al. 2007). The mean weight of prawns at harvest (52.20 g) with a survival rate of 85.83% after 160 days culture at 20 pieces $m^{-3}$ with 12 pieces artificial substrates was higher than those reported by Ranjeet and Kurup (2002) for 8 months culture in polders, with lower stocking density (6 prawns $m^{-2}$; the mean weight at harvest is 36.7 g with a survival rate of 23%). On the other hand, Tuli et al. (2014) attained the mean weight of 56.48 g and survival rate of 63.12 % with lower stocking density (19,760 prawns $ha^{-1}$) using bamboo-mats as substrates for 6 months culture in ponds.

Aside from these, the stocking density of 20 pieces per $m^{-3}$ and growth rates of prawns at harvest were considerably better than those studies reported by Ranjeet and Kurup (2011) in the farming of *M. rosenbergii* in the coconut garden channels with a lower stocking density of 25,000 $ha^{-1}$ with a mean weight of 55.48 g at harvest. Results similar to the stocking density of 25,000 $ha^{-1}$ utilising all-male *M. rosenbergii* in the polyculture ponds was much lower at harvest with a mean weight of 43.57 g (Rahman et al. 2012). Although very low stocking densities of prawns have been used at 5,000, 10,000, 15,000 $ha^{-1}$, it has attained a higher mean weights of 101.65 g, 87.7 g and 69.11 g, respectively, but this entails longer culture period of 8 months (Ranjeet and Kurup 2011). Extending the culture period of prawns in the lake will also result in higher weight gains of prawns. The effects of artificial substrate on the survival and production were evident in the study. The significant increase in production could be explained by the consistent increase in the average weight and survival as the number of artificial substrate was increased in $T_2$ and $T_3$. This was also observed by Tidwell et al. (2000) with the increased amount of substrate. The increased amount of artificial substrate reduced the agonistic behavior and stress to prawns reared in cages which resulted in improved survival and production.

Moreover, it also provides shelter to protect the prawns during molting when they were more vulnerable to predation from other aggressive prawns. The more they were protected with the increased number of artificial substrates wherein they can hide, the more prawns survived and they were able to feed themselves properly. Reduction in agonistic interactions between prawns has been shown to reduce stress, improve growth, and feed conversion efficiency (Karplus et al. 1992). Studies on prawns have illustrated that artificial substrates could increase growth and survival (Tidwell et al.1998). As reported by Tidwell and Bratvold (2005) the potential function of substrate include physical separation of animals, increased production of natural foods, and even improved water quality through the actions of attached periphyton. The effectiveness, quality and physical characteristics of the materials used as substrate could have a major impact, as this maybe a result of increase surface area for the growth and production of periphyton and increased production of the natural food. However, the lifespan of the dried tamarind twigs as artificial substrate has not yet been evaluated. As justified with the result of this study, it was evident that the presence and number of artificial substrates have improved the total production and average weight of prawns reared in cages.

## Conclusion

Freshwater prawn farming in the lake is a viable technology since the culture period is relatively shorter than in pond culture to achieve marketable size, in addition to higher stocking density as traditionally used in ponds. The use of juvenile prawns as initial stock with higher amount of artificial substrates resulted in increased total production, mean weight and survival in the lake-based culture system.

Further studies on the refinement of the technology particularly on mesh size, the type of net, feed, substrates, and stocking density should be done to improve the growth, survival and production of freshwater prawn. Also, there is a need to conduct verification studies on the commercialisation of this freshwater prawn farming technology in a lake-based culture system as justified by the results of this study.

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