การเลี้ยงกุ้งก้ามกราม (*Macrobrachium rosengergii* De Man) แบบผสมผสานในนาข้าวอินทรีย์:ผลกระทบต่อผลผลิตข้าวและระบบนิเวศนาข้าว

Integrated Culture of Giant Freshwater Prawn (*Macrobrachium rosengergii* De Man) in Organic Rice Field: Impact on Rice Production and Rice Field Ecosystem

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Abstract

Rice production, giant freshwater prawns (*Macrobrachium rosengergii* De Man) production, and rice field environment were studied in experimental scale, in organic rice area zone in Surin Province, Thailand. Total 3 treatments with 3 replicates were conducted in experimental plots; Prawn only (T1), Rice-prawn (T2) and Rice only (T3) plots. After four months of the study period under the controlled organic rice protocol, rice field with prawn (T2) produced significantly higher paddy yield (240.50±27.58 kg/plot) than Rice only plot (T3) (186.00±14.14 kg/plot). The calculated difference of paddy yields between these two treatments was 29.30%. The prawn yield from the prawn only (T1) plot (75.34± 6.45 kg/plot) was higher than the prawn yield of the integrated prawn-rice plot (T2) (39.51± 9.15 kg/plot). The average population numbers of phytoplankton were 308.14, 298.76 and 245.00 individuals/m^3 found in T2, T1 and T3, respectively. The highest zooplankton abundance were found in the plot with the absence of prawns (T3) 298.76 individuals/m^3, while 225.00 individuals/m^3 and 130.01 individuals/m^3 were observed in (T1) and T2 plots respectively. The presence of prawn resulted in a significant (P<0.05) reduction of diversity indices of benthic fauna, in term of Shannon-Wiener index which was 1.58±0.21 with Evenness of 0.60 for T3 plot, and 1.38±0.16 with Evenness of 0.52 for T2, both of which were significantly higher (P<0.05) than those of 0.93 with Evenness of 0.35 for T1 plots, respectively. These results suggest that the treatments with prawn could be recommended for dissemination to rural farmers considering higher yields and economic benefits.

Keywords: Giant Freshwater Prawn, Organic Rice field, Rice field Ecosystem

Introduction

Rice is grown in 113 countries worldwide in a wide range of ecological conditions and water regimes. The cultivation of most rice crops in irrigated, rainfed and deep water systems offers a suitable environment for fish and other aquatic organisms. Over 90% of the world's rice, equivalent to approximately 134 million hectares, is grown under these flooded conditions providing not only home to a wide range of aquatic organisms, but also offering opportunity for their enhancement and culture (Halwart and Gupta, 2004).

Rice fields are rich in detritus and it forms the major food component in the diets for a number of fish to breed and to live in. Although the methods of rice /fish culture and the innovations made have been widely described (Janssen, *et al.,* 1988., Naravut, 1987, and Halwart and Gupta, 2004), in the ideal situation, rice and fish are harvested and marketed at the same time. Therefore, in the practice of concurrent rice-fish culture this is generally impossible since most fish species require more than 4 months to grow to marketable sizes.

The giant freshwater prawn (*Macrobrachium rosenbergii*) has been reported as a suitable species to grow together with rice in many Asian countries such as China (Halwart and Gupta, 2004), Vietnam (Thanh, 2001) and Thailand (Janssen *et al.,* 1988). Freshwater prawn is high commercial value, and is cultured in various water bodies such as pond, garden ditch, rice field, river. In Vietnam, freshwater prawn has been chosen as the most promising species to farm in rice fields (Phuong, 2006). In Thailand, Ngamsnae and Sudkotha (2008) reported the feasibility of giant freshwater prawn for controlling of golden apple snail population in non-organic rice farming system.

However, there is very limited information on culturing aquatic animals in organic rice farming environment. The objective of the present study was to investigate the impacts of giant freshwater prawn culture in organic rice-field on rice yields and some ecological aspects. To achieve this objective, biota, water quality, and rice yield were investigated in the organic rice-prawn and organic rice-only plots in experimental rice fields. The effects of prawn on biodiversity in the organic rice-field ecosystem were also discussed.

Research Methods

Study area and farm selection

A field experiment was conducted under the Development of appropriate technology for organic aquaculture project at Rajamangala University of Technology, Isan Surin Campus, Surin, Thailand (Figure 1). The agro-hydrological conditions of the study areas are favorable for organic rice farming, in which rice production is dominated and categorized according to IRRI (1993) as rainfed lowland rice ecosystem. The district of Phrasat represents two different rice producing practices in Surin province, conventional (using chemical inputs) rice farming and certified organic rice farming practices.

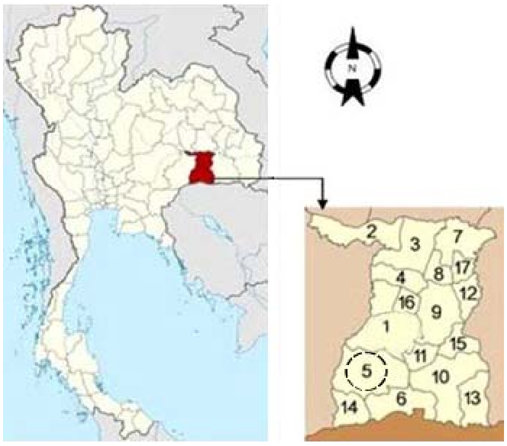
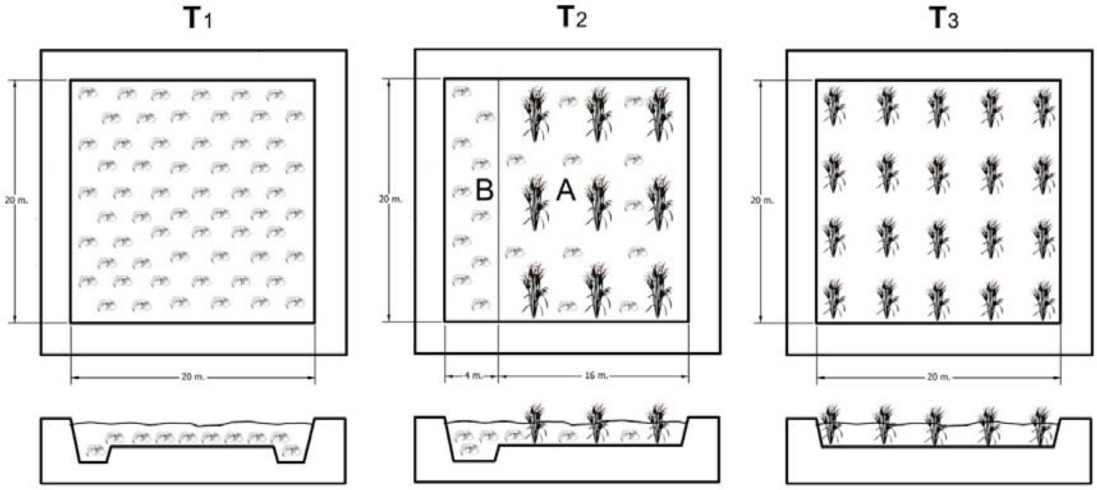


Figure 1. Map of Thailand highlighting Surin Province and Phrasat District (No. 5).

Farm design

Three collaborative organic rice farmers were selected for conducting three types of experimental plots; Prawn only (T1), Rice-prawn (T2) and Rice only (T3) plots. Experimental trials were conducted in wet season from July (rice seeded) to November 2013 (prawn, rice harvested). The integrated rice-prawn fields consisted of a 20 m × 20 m plot per treatment with three replications (Figure 2). On the dike surrounding the rice plots fences of screen nets (height 1.0 m) were installed to protect the prawns from escaping away and natural predators. According to Halwarth, (1998), recommended that 20–30% of total area should be provided for prawns, a trench of 4 m × 20 m and 0.8 m depth was built in the rice-field plot with stocked the prawn. The purpose of the trenches is to provide a place for prawns in case of water in the field dries up or is not deep enough. It also serves to facilitate prawn harvest at the end of the rice season.



A= Rice planting area B= Prawn trench

Figure 2. Design of the experimental plots; Prawn only plot (T1); rice-prawn Plot (T2) and Rice only (T3).

Farm preparation

Organic rice planting methods were conducted, complying with Surin Province Standard for Organic Agriculture Protocol (S.O.A, 2004).

Rice

The plots were ploughed two times before the transplanting of rice, after base dressing. Rice seedlings (Thai jasmine rice KDML 105) were transplanted in Rice-prawn (T2) and Rice only (T3) plots at 25 days after seeding. Rice was transplanted at a spacing of 25 cm between the rows and 20 cm within the rows, with two to three seedlings per hill. Water was supplied to maintain a water level of 25–30 cm in the plots. No pesticides were applied during the experimental period. Other characteristics of experimental organic rice-prawn farms were shown in Table 1.

The gross paddy yield at harvest of every rice field was determined by cutting all the rice plant plots. After threshing, cleaning and sun-drying, the total seed weight, and the moisture content of each sample was measured. The grain weight for each plot was adjusted to 14% moisture and weighted

Table 1. Characteristics of experimental organic rice-prawn farms.

Description	T1	T2	T3
Farm size (m^2)	400	400	400
Depth (of ditch from paddy surface) (m)	1.3	1.3	1.3
Water depth (above rice paddy surface) (m)	0.3	0.3	0.3
Source of prawn seed	DOF Seed center	DOF Seed center	-
Size of seed (length;cm)	2.50	2.50	-
Size of seed (weight;g)	3.50	3.50	-
Stocking density (prawn/m^2)	10	3	-
Prawn culture season	Jul-Sep	Jul-Sep	-
Rice culture season	-	Jul-Nov	Jul-Nov
Feeding rate* (%BW/day)	5	5	-

* Farm-made feed, from organic ingredients

Experimental procedure

Prawn

Post larvae of 45 days old *M. rosenbergii* were obtained from the hatchery of the Kalasin Fisheries Station of Thailand Department of Fisheries (DOF), nursed and acclimatized in organic environment of earthen ponds for one and half months. Before stocking of the prawns, the 15 days-transplanted rice field plots were treated with 15 ppm Derris root (5% rotenone) to eradicate wild fish. Afterwards, the water quality parameters were tested and the juvenile prawns (2-3 cm.) were stocked at density of 10 juvenile/m^2 for T1 and T3 juvenile/m^2 for T2 plots. These stocking rates were designed according to the recommendation of Janssen *et al*. (1988). By counting and bulk weighing the required number of prawn per plot, the average body weight (W_0) was calculated and recorded. Supplementing feeds were organically formulated and fed at 5% body weight 2 times per day. Feeding rates were monthly adjusted according to the growth of prawn.

Prawns were harvested 120 days after stocking by seining the drained trench, and caught productions (yields) of prawns in all treatments at the end of the study were measured. Growth performances of prawn were determined as followings:

1) Survival rate (%) = (No of prawn harvested/No of prawn released) x 100

2) Specific Growth Rate (SGR %/day) = [(Ln Final wet wt. - Ln Initial wet wt.)/days] ×100

3) Daily weight gain; DWG (g/day) = (Final wet weight-Initial wet weight)/days

4) Percentage weight gain; PWG (%) = [(Final wet wt.-Initial wet wt.)/Initial wet wt.)] ×100

Note: wt. = weight (g)

Water Quality

Dissolved oxygen, water temperature, Turbidity and pH were measured twice a week in the trench (30 cm below the water surface) and the rice-field, both in the morning (6:00-7:00) and afternoon (14:00-15:00), by using YSI Model 57 oxygen meter. Total ammonia and un-ionized ammonia in water samples collected from each plot at approximately 13:00 hours were determined by spectrophotometric methods (APHA, 1992) on a weekly basis. A Secchi disc was used to determine transparency (Boyd, 1982).

Plankton

Water from the experimental plots was sampled randomly with a 20µm mesh plankton net at 60-70 days after transplanting (DAT), a volume of 10-liter was collected. After mixing, a sub-sample of 50 ml was preserved with Lugol's iodine for determination of phytoplankton. A known volume of the remaining of the water sample was filtrated through a 55 µm mesh and the zooplankton concentrated in 200 ml, preserved with 10% formalin. Organisms from one sample of each plot were identified and counted under a stereomicroscope in the laboratory.

Benthic fauna

Benthic invertebrates were sampled at 15, 45, 80 and 115 DAT using 15×15 cm^2 (about 0.225 m^2) Ekman grab. Three soil samples were taken randomly from each plot and fixed in 10% formalin solution and then washed through a 420 µm sieve. Benthic organisms from one sample of each plot were identified and counted under a stereomicroscope in the laboratory. To estimate the community diversity of terrestrial arthropods, zooplankton, and benthic invertebrates, the Shannon-Wiener diversity index (H') was calculated (Krebs, 1989).

$$H' = -\sum_{i=1}^{S} pi \cdot \ln pi$$

Where; S is number of taxonomic categories and *pi* is the proportion of the i^{th} taxonomic category in the total specimens in the plot.

Species Evenness of benthic invertebrates can be calculated from *H´* by first have to calculate the maximum possible diversity (H'_{max}), given the number of species *S*. The formula for H'_{max} is:

$$H'_{max} = \ln(S)$$

And the formula for evenness is:

$$E = \frac{H'}{H'_{\max}}$$

Statistical Analysis

Data on water quality parameters were analyzed by averaging the measurements over time for the experimental period and were subjected to ANOVA. Comparisons between two treatments such as prawn (production, growth, survival etc.) and rice yields were analyzed using T-test. All significance testing was done at the 0.05 level. Proportional data for diversity and evenness of benthic fauna were converted to arcsine values prior to perform one-way ANOVA analysis.

Results and Discussions

Water quality of experimental plots

The values of water quality parameters of experimental plots of three different treatments are in Table 2. Water quality of all experimental plots is in the suitable range for the good growth of prawn. Mean water temperature in paddy fields did not differ significantly among the prawn-only (T1), rice-prawn (T2) and rice-only plots (T3). The mean values of pH in all treatments were not significantly different, although there was slightly increased pH in the prawn-only plot. The mean concentration of DO in the paddy fields did not differ significantly between the rice-prawn and rice-only plots. Water temperature, pH, and DO showed approximately equal values among the prawn-only, rice-prawn, and rice only plots, because the water supply were from the same irrigation water into each plot after the inlet gate of each plot was opened.

Table 2. Water quality parameters in the rice field (means, minimum, maximum and ANOVA significant level : ns (not significant, * (*P*<0.05)).

Parameter	T1			T2			T3			ANOVA[1]
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	p-value
pH	6.8	7.2	7.0±0.2	6.6	6.8	6.7±0.1	6.4	6.9	6.7±0.4	ns
Dissolved Oxygen (ppm)	4.1	4.5	4.3±0.2	4.1	4.9	4.5±0.6	3.9	4.9	4.4±0.7	ns
Total Ammonia (ppm)	0.10	0.92	0.51±0.41	0.07	0.88	0.48±0.41	0.20	0.69	0.45±0.25	ns
Un-ionized ammonia	0.01	0.06	0.03±0.00	0.01	0.05	0.03±0.01	0.01	0.04	0.02±0.00	ns
Nitrite – Nitrogen (ppm)	0.01	0.11	0.06±0.05	0.01	0.07	0.04±0.03	0.01	0.05	0.03±0.02	ns
Temperature (°C)	24.3	30.2	27.3±2.9	25.0	30.2	27.6±3.7	24.1	29.9	27.0±2.9	ns
Turbidity (NTU)	152.0	185.0	168.5±23.3	119.0	179.0	149.0±42.4	65.0	120.0	92.5±27.5	*
Transparency (cm)	16.8	20.5	18.6±2.6	16.8	20.8	18.8±2.8	20.9	31.1	26.0±5.1	*

[1]Comparison of treatment means

Although the mean value of NO_2–N concentration in the prawn-only plots (T1) (0.06±0.05 ppm) was higher than that in the rice-prawn (T2) (0.04±0.03 ppm) and in the rice-only (T3) (0.03±0.02 ppm) plots, the differences were not statistically significant. Similarly trend was found in the mean values of unionized ammonia (NH_3) concentrations of which were; 0.03.0±0.00, 0.03±0.01, and 0.02±0.00 ppm for T1, T2, and T3, respectively. There were neither significant differences in unionized ammonia (NH_3) nor total ammonia concentrations among all these experimental plots.

During the study period, the significantly highest (P<0.05) mean turbidity value was recorded 168.5±23.3 NTU in the prawn-only plots (T1), followed by 149.0±42.4 NTU in T2 and the lowest (92.5±27.5 NTU) was recorded in T3. The high turbidity of water in prawn-only farm was due to the suspension of clay particles, which were resulted from bottom feeding behavior of prawns. In contrast to turbidity, the higher water turbidity resulted in less transparency. The highest mean transparency value was 26.0±5.1 cm in the rice-only plots (T3). The significantly (P<0.05) lower values of water transparency (18.6±2.6 and 18.8±2.8cm) were observed in both T1 and T2.

The main factors affecting the aquatic animals in the rice field are the water level, temperature, dissolved oxygen (DO) and unionized ammonia (NH_3) (Halwart and Gupta, 2004; Naqvi *et al.*, 2007). Although DO values in this study varied from 4.1 to 4.9 ppm, but no response to these low DO levels observed by the prawns. Unionized ammonia in all treatments were lower than 0.03 ppm and, this concentration is considered less than the critical level for giant freshwater shrimp, which reported 0.1 ppm (Naqvi *et al,* 2007; Boyd, 1987).

Rice and prawn yields

The mean final weight, final length, survival rate, specific growth rate (SGR), daily weight gain (DWG), percentage weight gain (PWG) and the mean production of prawn and rice of different treatments are shown in Table 3. The culture period of prawn in the treatments was 120 days.

Table 3. Rice yield and prawn growth performance at different treatments (Mean±SD), values with the same superscript in a row are not significantly different at the 0.05 level.

Parameter	T1	T2	T3
Rice			
Rice yield (kg/plot)	-	240.50±27.58[a]	186.00±14.14[b]
Prawns			
Prawn yield (kg/plot)	*75.34±6.45[a]	*39.51±9.15[b]	-
Initial weight (g)	3.52±0.43	3.50±0.44	-
Final weight (g)	26.08±7.05	34.18±6.73	-
Initial length (cm)	2.56±0.13	2.62±0.14	-
Final length (cm)	14.08±2.14	16.18±1.86	-
Daily weight gain; DWG (g/day)	0.188±0.010[a]	0.256±0.039[b]	-
Percentage weight gain; PWG (%)	640.91±11.36[a]	876.57±9.84[b]	-
Specific growth rate; SGR (%/day)	1.67±0.02[a]	1.90±0.04[b]	-
Survival rate (%)	52.00±9.61	60.00±10.64	-

*Stocking density: 10 prawns/m^2 for T1, 3 prawns/m^2 for T2

Prawn yield

Comparison of prawn growth performances between the prawn-only (T1) and rice-prawn (T2) treatments, the rice-prawn plot showed higher mean values for all parameters than the prawn-only plots (Table3). The differences were statistically significant ($p<0.05$) for daily weight gain (0.188 ± 0.010 and 0.256 ± 0.039 (g/day), and percentage weight gain (640.91 ±11.36 and 876.57 ± 9.84%) and specific growth rate (1.67 ± 0.02 and 1.90 ± 0.04%/day) for T1 and T2 respectively. Other growth parameters of both treatments such as average final weights (26.08 ± 7.05 and 34.18 ± 6.73 g, average final length (14.08 ± 2.14 and 16.18 ± 1.86 cm) and survival rates of prawns (52.00 ± 9.61and 60.00 ± 10.64%) were also increased in the integrated rice-prawn. The total prawn yield was higher for prawn-only plot (75.34±6.45kg/plot) than that for rice-prawn (39.51± 9.15 kg/plot). This due to the fact that the density of prawns stocked in such plot was 10 prawns/m^2, whereas 3 prawns/m^2 was stocked in rice-prawn plots. This difference in stocking rate could have a positive effect on growth, and thus also higher survival rate of prawns. As mentioned earlier, the prawn stocking rates of this study were complied with the suggestion of Janssen *et al*. (1988).

For the growth of prawn itself, the overall better performances of treatment 2, integration of rice and prawns was observed. Although the harvest sizes in terms of final weight and final lengths of prawns in these two treatments were not significantly different, the results apparently show that prawns grow well in the rice field and are comparable to data from Gurerro *et al.,* (1982) who concluded from experiments with *Macrobrachium rosenbergii* that rice plants are beneficial for prawn growth and survival rate by providing additional shelter and increasing surface areas. A similar finding was found in another crustacean by Chien and Avault (1980), who reported that crayfish (*Procambus clarkii)* production in rice fields was significantly higher than in the control ponds.

Rice yield

The rice-prawn plots showed higher mean values of rice yield (240.50 ± 27.58 kg/plot) than the rice-only plots (186.00±14.14 kg/plot), and the difference was statistically significant (P<0.05). Rice yield increased by 29.30% when prawns were stocked in the paddy field. The rice yield of rice-prawn plots, calculated in term of production per rai (1,600 m^2) is 481.0 kg/rai, which more than the yield of rice without prawns (370 kg/rai) in the local neighboring areas reported by Losirikul and Kanjana (2006). This higher rice production in the experimental plots was also explained by Cruz, (1994) that prawns in rice fields had profound impacts on the availability of nutrients in the water and soil which increases the yield of rice grain and at the same time provides an additional yield of prawn from the same land. It is evident that introduction of prawn in rice fields improves the yield of rice grain; these increments may be associated with the presence of prawn in rice fields, which reduces the incidence of weeds and harmful pests upon them. These findings agree with the findings of Amin and Salauddin (2008) as well as, Kurup and Ranjeet (2002) who also obtained significant difference in the yield of rice grain and straw between the treatments with and without prawns in rice fish culture in Bangladesh and India.

Plankton:

The effects of rice and prawn presence on phytoplankton and zooplankton abundance in the experimental treatments are presented in Tables 4.

The prawn-only (T1) plot: The phytoplankton populations were dominated by 25 taxa consisting of Chlorophyta (14), Chromophyta (5), Cyanophyta (4), and Pyrrophyta (2), respectively with abundance of 298.76individuals/m^3. Zooplankton abundances were dominated by 9 taxa respectively of Arthropoda (4), Protozoa (3) and Rotifera (2), with abundance of 258.76 individuals/m^3.

Table 4. Phytoplankton and zooplankton abundance (total number/m^3) in three treatments over the 4-month experimental period.

Parameter	T1			T2			T3		
	No.×10^3.m^{-3}	%	No.of Taxa	No.×10^3.m^{-3}	%	No.of Taxa	No.×10^3.m^{-3}	%	No.of Taxa
Phytoplankton									
Chlorophyta	143.75	48.12	14	221.88	72.01	23	182.5	74.49	18
Cyanophyta	96.25	32.22	4	10.00	3.25	4	11.25	4.59	2
Chromophyta	29.38	9.83	5	49.38	16.03	6	51.25	20.92	7
Pyrrhophyta	29.38	9.83	2	26.88	8.72	1	0	0	-
Total	**298.76**	**100**	**25**	**308.14**	**100**	**34**	**245.00**	**100**	**27**
Zooplankton									
Arthropoda	151.88	48.55	4	41.88	32.21	5	125.63	67.5	5
Protozoa	11.88	25.36	3	14.38	11.06	2	65.63	5.28	1
Rotifera	61.25	26.09	2	61.25	47.11	8	67.50	27.22	6
Nematoda	0	0	-	12.50	9.61	1	0	0	-
Total	**225.01**	**100**	**9**	**130.01**	**100**	**16**	**258.76**	**100**	**12**

The rice-prawn (T2) plots: The phytoplankton populations were dominated by 34 taxa consisting of Chlorophyta (23), Chromophyta (6), Cyanophyta (4), and Pyrrophyta (1), respectively with abundance of 308.14individuals/m^3. Zooplankton abundances were dominated by 16 taxa respectively of Arthropoda (5), Protozoa (2) and Rotifera (8) and Nenatoda (1), with abundance of130.01individuals/m^3.

The rice-only plots (T3): The phytoplankton populations were dominated by 27 taxa consisting of Chlorophyta (18), Chromophyta (7) and Cyanophyta (2), respectively with abundance of 245.00 individuals/m^3. Zooplankton abundances were dominated by 12 taxa respectively of Arthropoda (5), Protozoa (1) and Rotifera (6), with abundance of 225.01 individuals/m^3.

The phytoplankton species identified in the prawn-only (T1) plots were dominated by Cyanophyta (*Anabaena* sp.*),* Chlorophyta *(Closterdium* sp.), Pyrrophyta (*Ceratium* sp.) and Chromophyta (*Dinobryon* sp.) respectively, while species of zooplankton abundance was dominated by Arthropoda (Cyclopoid copepod). In the integrated prawn-rice plot (T2), the most abundant phytoplankton species was Chlorophyta (*Staurastrum* sp.), followed by Pyrrhophyta (*Ceratium* sp.), Chromophyta (*Dinobryon* sp.) and Cyanophyta (*Spirulina* sp.), respectively. For zooplankton the dominant species was Rotifera (*Brachionus* sp.). Phytoplankton species in the rice plot without prawn (T3), respectively dominated by Chlorophyta *(Staurastrum* sp.), Chromophyta (*Mallomonas* sp.) and Cyanophyta (*Anabaena* sp.), while species of zooplankton abundance was dominated by nauplius larva of Arthropoda.

In the present study, the highest density of phytoplankton (308.14 individuals/m^3) was found in the prawn-rice (T2) plot, followed by 298.76 individuals/m^3 and 245.00 individuals/m^3 in prawn-only (T1) plot and rice-only plots (T3) respectively. On the contrary, zooplankton density was lowest (130.01individuals/m^3) in the rice plot with the presence of prawn (T2), and then increased to be 225.01 individuals/m^3in prawn-only plots (T1) and followed by 258.76 individuals/m^3 in rice without prawn plot (T3), respectively. The capability of giant freshwater prawn to feed on zooplankton was evidenced by a reduction in zooplankton density in plots with presence of prawn (T1 and T2). Thus prawn feeds on the various prey items including zooplankton in the paddy field and subsequently defecate the excrements. Therefore, the increase in density of phytoplankton in the plots resulted from excretion of unutilized food nutrients by the prawn.

Benthic Fauna:

Benthic invertebrates collected at 15, 45, 80 and 115 days after transplanting (DAT), (in July, August, September and October is presented in Table 5.

The prawn-only (T1) plot: Nine families of 6 classes of benthic invertebrate populations were found, consisting of Insecta (6 families), Oligochaeta (2 families) and Gastropoda (1 family). The fauna abundance ranged 801-4,666 individuals/m^3. Biodiversity for these benthic invertebrates in term of Shannon-Wiener index was 0.93±0.23 with Evenness was 0.35.

The rice-prawn (T2) plots: Similarly to T1 plot, 9 families belonging to 6 classes of benthic invertebrate populations were found, consisting of Insecta (5 families), Oligochaeta (2 families), Gastropoda (1family) and Pelecypoda (1family). The fauna abundance ranged 1,378-2,800 individuals/m^3. Biodiversity for these benthic invertebrates in term of Shannon-Wiener index was 1.38±0.29with Evenness was 0.52.

The rice-only plots (T3): Benthic invertebrate species diversity of benthic invertebrates in this plot was higher than the rice-prawn and the prawn-only plots. Ten families belonging to 6 classes of benthic invertebrate populations were found, consisting of Insecta (6 families), Oligochaeta (2 families), Gastropoda (1 family) and Pelecypoda (1 family). The fauna abundance ranged 1,112-3,112 individuals/m^3. Biodiversity for these benthic invertebrates in term of Shannon-Wiener index was 1.58±0.21with Evenness was 0.60, which were significantly higher ($P<0.05$) than those of T1 and T2 plots.

Table 5. Class in species number of benthic fauna abundance (number/m^3) and diversity index of different treatments in 4-month experimental period. Means of diversity index (H') with the same superscript letters in a row are not significantly different (*p*<0.05) among treatments.

Parameter	T1				T2				T3			
	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct
Class Insecta												
1.Caenidae	0	0	0	0	178	45	45	0	178	0	0	0
2.Ceratopogonidae	0	222	89	356	89	133	622	756	222	267	489	534
3.Chironomidae	222	489	44	1,333	578	710	444	1,244	311	445	356	711
4.Corethrindae	45	45	0	0	0	0	0	0	0	45	45	0
5.Baetidae	0	0	0	0	0	0	0	89	0	0	0	89
6.Hydroptilidae	0	45	0	0	0	0	0	0	0	0	0	0
7.Libelulidae	0	44	0	0	0	0	0	0	0	0	0	0
8.Lestidae	0	0	0	0	44	89	0	0	89	0	0	0
9.Nuecoridae	178	0	0	0	0	0	0	0	0	0	0	0
Class Gastropoda												
10.Viviparidae	0	178	89	133	45	267	267	311	133	178	178	889
Class Oligochaeta												
11.Tubificidae	356	1,600	4,222	0	311	89	89	356	445	133	44	711
12.Naididae	0	0	0	0	0	222	0	0	0	222	0	0
13.Lumbriculidae	0	133	222	0	0	0	0	0	0	0	0	0
Class Pelecypoda												
14.Corbiculidae	0	0	0	0	133	45	0	44	0	89	0	178
Total indi.m^{-2}	801	2,756	4,666	1,822	1,378	1,600	1,467	2,800	1,378	1,379	1,112	3,112
Diversity Index (H^1)	1.21	1.35	0.43	0.74	1.59	1.39	1.31	1.22	1.66	1.76	1.28	1.60
Mean Diversity	0.93 ± 0.23^{b}				1.38 ± 0.29^{ab}				1.58 ± 0.21^{a}			
Mean Evenness (E)	0.35				0.52				0.60			
Total no.taxa	9				9				10			

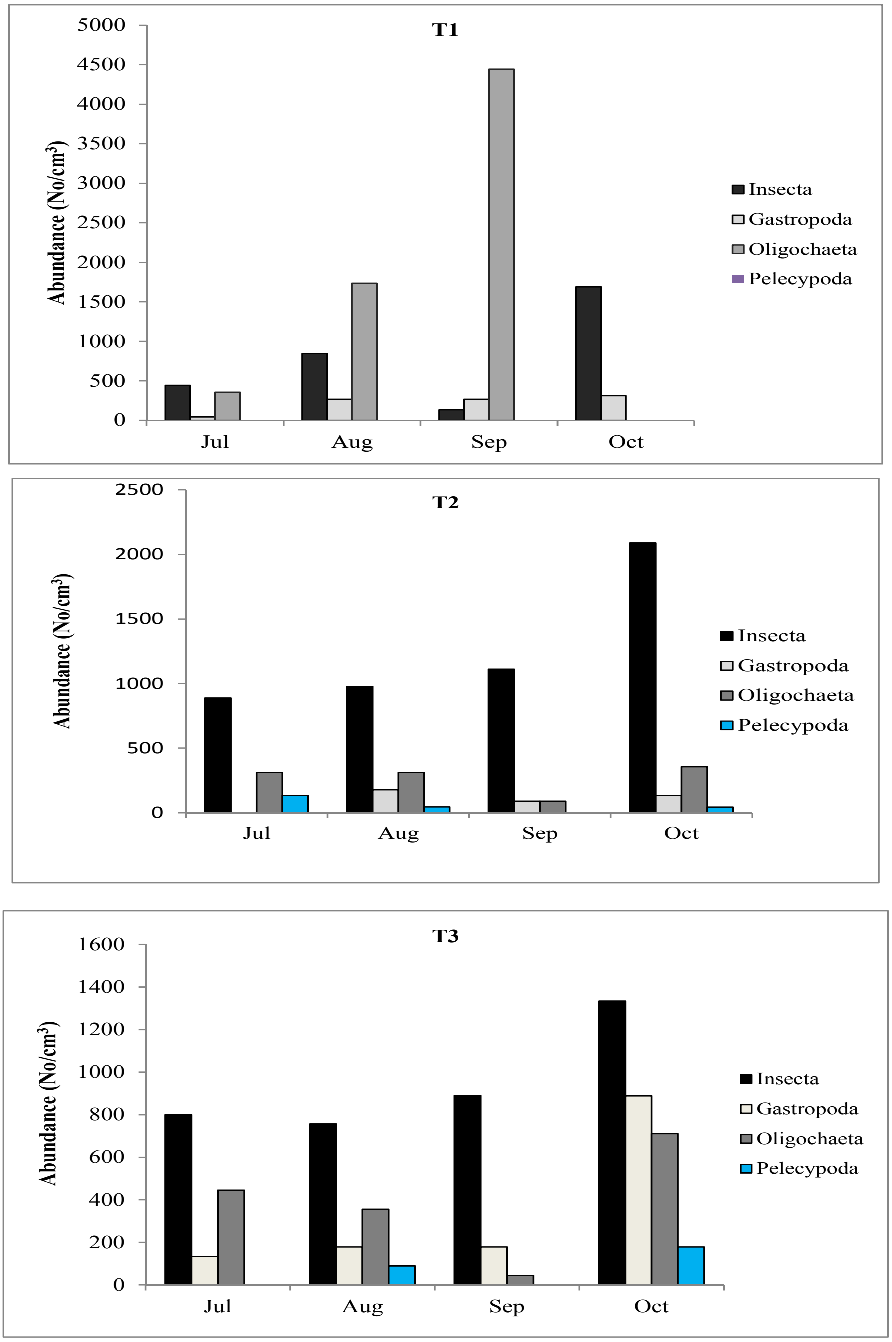


Figure 3. Monthly benthic fauna abundance (number/m^3) of different treatments in 4-month experimental period.

In the present study, among the treatments, the significantly highest diversity index of benthic invertebrates (Shannon-Wiener index and Evenness) were recorded in T3 (rice only treatment) and the lower values of the same were obtained in the plots with the presence of prawn treatments (T1 and T2) indicating higher feeding preference of prawn on zoobenthos. These results suggest that biodiversity of benthic invertebrates was influenced by prawn within the rice field and was decreased by their predation. It is interesting that no two-shell mollusk (Pelecypoda) was found in the prawn-only (T1) plots during four months of the study. The major groups of benthic fauna recorded during the present study were Tubificidae) and chironomidae (Figure 3). The dominance of these groups of macrobenthos in rice field has been reported earlier by Phrommi (2012) and Petchsuth *et al., (*2013) in the rice field and deep water rice field ecosystem, respectively. The possible reason for the occurrence of these groups of benthic fauna might be due to the favorable organic ecological condition provided in the rice field for their growth and development.

Conclusion

According to the findings of present study, it may be concluded that the introduction of giant freshwater prawn in organic rice fields has profound impacts on the ability of the rice field ecosystem which efficiently increases the yield of rice yield and at the same time provides an additional yield of prawn from the same land, and socioeconomic condition and nutritional status of farmers accordingly could be improved. However, it is essential to set up a trench in the rice plot to provide a place for prawns and to facilitate prawn harvest at the end of the rice season.

In Surin Province, the organic rice crop is certified complying with standard for organic Agriculture Protocol (S.O.A, 2004). This organic integration of rice-prawn approach could bring significant advantages with respect to economic returns and obvious environmental and social impacts.

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