Productivity and profitability of rice-freshwater prawn culture in different stocking density of prawn

R R S P S Dewi1*, H Krettiawan1, F Anggraeni1, E Kusnendar1 and Kusdiarti1

1Center for Fisheries Research, Jl.Ragunan No. 20, 16431, Jakarta, Indonesia

*Corresponding author: sripudjisinarini@gmail.com

Abstract. Integrated farming of fish and rice is a form of rational use of limited land resources. The rice-fish culture has been developed in several countries, especially in Asian countries. This is because rice and fish are important commodities for Asian people. Rice-fish culture can provide almost three times the benefits compared to paddy fields that are only planted with rice alone. The system is environmentally friendly, low cost, low risk, and also provides a source of animal protein food for the community. Indonesia not only develops rice-fish culture but also rice-freshwater prawn culture. In 2014, the Fish Breeding Research Institute produced a strain of fast-growing giant prawn called GI Macro II (Genetic Improvement of Macrobrachium rosenbergii II). The use of GI Macro II giant prawns in the rice - prawn system is expected to increase the production of giant prawns. This research was conducted to determine the optimal density of giant prawns in the rice - prawn culture system. We hypothesize that using an optimal stocking density will increase the productivity of rice and giant prawns. This research was conducted in March-November 2016 in four locations in Pakem District, Sleman Regency, Yogyakarta Province, Indonesia. Trenches for giant prawns culture were made around the paddy fields to achieve a ratio of 20% of the paddy field. The size of the trenches was 1 m wide and a minimum depth of 50 cm, and the main trench with a width of 3-4 m which contained a harvest basin was made. Giant prawn seeds stocked have a total length of 5.8 ± 1.09 cm or weight of 2.2 ± 1.42 g. The depth of the puddle in the paddy field was less than 5 cm in the vegetative phase and more than 10 cm in the generative phase until harvesting. After 14 days of rice planting, giant prawn seeds were spread into prepared trenches. The treatment consisted of two levels of stocking density of giant prawns, 10 ind/m² and 15 ind/m². Density at 10 ind/m² yielded higher growth and survival (1.76 ± 0.39% BW/day & 62.53 ± 17.43%) and lower feed conversion ratio (1.04 ± 0.38) compared with density of 15 ind/m² (1.3 ± 0.20% BW/day; 46.3 ± 4.28%; and 1.66 ± 0.49%). Production of rice and prawns in an area of 1000 m² with a density of 10 ind/m² were 698 kg of rice and 112 kg of giant prawns. As for the stocking density of 15 ind/m², rice production was 795 kg and prawns were 107 kg. The benefit obtained from the stocking density of 10 ind/m² was IDR 5,037,000 with a B/C ratio of 1.7. As for the stocking density of 15 ind/m², the benefit obtained was IDR 3,942,000 with a B/C ratio of 1.1. Thus, stocking density of 10 ind/m² produces higher prawn production and higher profits than stocking density of 15 ind/m².

Keyword: integrated farming, production, density, Macrobrachium rosenbergii

1. Introduction

Rice-fish/prawn farming is the growing of rice and fish/prawn simultaneously in the same field [1]. In Indonesia, integrated farming of rice-fish/shrimp in rice fields is one of the farming systems that is
being developed. Rice and fish are the main components in global food security. Both are major carbohydrate sources and protein sources for public consumption. Rice-fish farming is an integrated approach to increase the economic benefits of rice fields and at the same time serves as the development of freshwater aquaculture. Integrated farming of rice-fish can play an important role in increasing food production. The rice-fish system is better than the monoculture system of rice cultivation, especially in terms of resource use, crop diversity, productivity, quantity, and quality of food products. Some researches showed that there is a mutually beneficial relationship between the growth of rice and fish that are kept in an integrated manner: fish reduce the attack of rice pests and rice provides a comfortable environment in the aquatic environment. A mutually beneficial relationship between rice and fish reduces the need for pesticide use in rice fields. Fish also control the growth of weeds by eating weed roots and stirring the soil around the rice plants. Fish feces are useful as organic fertilizer which provides essential nutrients needed for rice to flourish [2].

Integration between fish and rice cultivation increases diversification, intensification, and agricultural productivity [2]. Through the cultivation of two commodities, farmers can reduce the risk of loss if one of them fails to harvest. Fish is a source of protein, and through integration with rice, farmers can improve their food security. Fish also consume animals that transfer disease in humans, so that it can improve human health. Some fish species, such as common carp eat mosquito larvae and snails, which can spread disease. In addition, fish played an important role in controlling water weeds, algae and snails, and reducing the need for chemicals towards ecologically better agriculture. Fish farming in rice fields increases rice production. Even though with the rice-fish farming system, land to grow rice is reduced because it is used to make ditches, but rice production increases by 7-30%. Several studies have shown that the system of rice-fish farming provides higher profits compared to rice cultivation alone [1]. Integrated aquaculture can increase rice production by 8-15% plus fish production by around 260 kg/ha. Rice-fish culture can also increase profits by 64.4% and rice yield by 5% [2, 3].

Efforts to increase fish/shrimp productivity in rice fields can be done by using superior seeds that have fast-growing character and aquaculture technology improvement. In 2014, the Fish Breeding Research Institute produced a superior prawn strain named GI Macro II (Genetic Improvement of Macrobrachium rosenbergii II) produced from a selective breeding program. GI Macro II prawns do not require specific land to be cultivated. The use of superior seeds of GI Macro II prawns in the rice-prawn culture system is expected to be able to increase the production of prawns, considering that the production of prawns is still dominated by the fishing sector.

Prawns (M. rosenbergii) are aggressive and territorial animals, so it is suspected that it can not be cultivated in high density. Various attempts were made to increase the density of prawns, including through the use of shelter. In this study, the density of prawns was tested to determine the optimal density in the integrated farming of rice-prawns. Optimal stocking density can increase the productivity of giant prawns.

2. Materials and methods

2.1. Research time and location
This research was conducted in March-November 2016. The research was conducted in four locations, namely the Agriculture, Fisheries, and Forestry Counseling Center of Sleman Regency, and fish/prawn farmer groups in Sembung Village, Nglingi Village, and Samberembe Village, Yogyakarta Province.

2.2. Land preparation
The rice fields used are around 1000 m² in size. The water used is sourced from irrigation. Trenches for giant prawns are made around the rice fields (Figure 1A). The size of the trench was 1 m wide and minimum water depth was 50 cm, and a trench was also made in the middle with a width of 30-40 cm and a water depth of 30 cm (Figure 1). The total area of the trench is calculated at a ratio of 20% of the plot area. To increase the stocking density of prawns, a bamboo shelter is placed (Figure 1B).
Figure 1. Rice field preparation. A. The trench was around the rice field; B. Installation of shelters for giant prawns; C. Rice fields that had been planted with rice and ready to stock with prawns.

2.3. Experimental design
Before being stocked in rice fields, rice seeds that were around 15-20 days old were planted in the nursery first. Rice planting used a 3:1 row planting system (20 × 20 cm) with a column spacing of 40 cm. The depth of the puddle in the yard was less than 5 cm in the vegetative phase and more than 10 cm in the generative phase until harvesting. After 14 days of rice, juvenile prawns with a total length of 5.79 ± 1.09 cm or weight 2.19 ± 1.42 g were stocked into prepared trenches (Figure 1C). The treatment in this study were two levels of giant prawn stocking densities, namely 10 ind/m² and 15 ind/m².

2.4. Culture
Prawn were fed by commercial feed (protein 30%), three times a day. Sampling was done to determine growth and at the same time to calculate the adjustment of the amount of daily feed given once every 10 days. The amount of daily feed provided (FR = feeding rate) of 5% of the weight of all fish
(biomass) at the beginning of stocking then decreased to 4% to 3% in the third month. However, the amount of feed given were also adjusted to the level of fish appetite. In certain conditions (presence of disturbance, rain, weather changes, changes in water quality, etc.) causing prawn appetite to decrease, the amount of feed given must also be reduced. Sampling was done by randomly taking a few prawns.

2.5. Evaluation of productive performance

The parameters observed included prawn weight, total length, prawn biomass, specific growth rate, feed conversion ratio, survival rate, and economic benefits (Benefit-Cost Ratio, BCR). Biometrics (total length and weight) were performed at the beginning and the end of the experiment, intermediate biometrics were not performed to avoid stressing the prawns. At the end of the experiment the remaining prawns in all the experimental units were counted to determine the survival rate, additionally, prawns were weighed to evaluate the productive performance. The following production indexes were evaluated: final weight, total length, feed conversion rate, and specific growth rate. The feed conversion ratio was apparent and calculated based on the amount of feed supplied. The following equations were used:

Survival rate, SR (%) = (Nf / N) × 100

Specific growth rate, SGR (% d⁻¹) = 100 × [ln (Wf) - ln(Wi)] / ∆t

Feed conversion ratio, FCR = feed offered (kg)/Biomass (kg)

Benefit-cost ratio, B/C ratio = benefit / cost

where:
N = number of prawns stocked at the beginning of the experiment; Nf = number of living prawns at the end of the experiment; Bf = final biomass (g); Bi = initial biomass (g); Wf = final weight (g); Wi = initial weight (g); ∆t = duration of experimental period (days).

3. Results and discussion

The choice of shelter will determine the stocking density of giant prawns. The use of simple shelter in the form of coconut fronds, stocking density is only 1.5 - 6 fish / m² [4, 5]. However, the use of bamboo shelter in the form of an apartment frame can increase the stocking density of giant prawns to 10 ind/m². At density of 10 ind/m², prawns grow faster and utilize feed more efficiently. At a density of 15 ind/m², the survival of prawns is lower, presumably due to competition in fighting over territorial areas (Table 1). Freshwater prawn shows higher performance at lower stocking densities [6]. Several researchers also found increased mortality with increasing stocking density in the production of freshwater prawn [7-9] and marine shrimp [10, 11] in different farming systems. The increase in stocking density interferes with hierarchical competition and disputes for space and food, resulting in higher cannibalism [12].

The positive effect of the use of multilevel shelter is closely related to the characteristics of giant prawns as animals that live in the bottom of the water, so that the provision of shelter has an important role in expanding the living space of giant prawns and as a shelter from attacks by other giant prawns and predators [13]. Giving shelter indirectly can also increase the availability of natural food in the form of periphyton, and improve water quality because the shelter is able to trap suspended particles and break down organic matter. This causes a decrease in FCR in giant prawns reared in ponds equipped with shelters [14, 15]. The provision of shelter was also able to significantly increase the net production of giant prawns [16]. If a tiered shelter is installed in the pond, the giant prawn population will be spread at the bottom and the shelter (level I, II, and III). Overall the proportion of giant prawns at the bottom of the pond and multi-storey shelters is 18.3% and 81.7%. This condition shows that giant prawns prefer a multi-storey shelter as a shelter. The highest distribution of giant prawns is found at level I, then followed by level II, bottom of the pond, and level III. This fact shows that level I is the most preferred shelter layer by giant prawns. Giant prawns are classified as crustaceans who like the bottom of the water, but tend to take shelter when found shelter. This is the reason that ultimately causes giant prawns to prefer level I, the shelter layer which existence is closest to the bottom of the water. Conversely, level III which is farthest from the bottom of the water is less favored by giant prawns.
Table 1. Specific growth rate, survival rate, feed conversion ratio, rice and prawn production in integrated farming of rice – prawn with different stocking densities

| Parameter                              | Density (ind/m²) | 10      | 15      |
|----------------------------------------|------------------|---------|---------|
| SGR (% BW/day)                         |                  | 1.76 ± 0.39 | 1.30 ± 0.20 |
| SR (%)                                 |                  | 62.53 ± 17.43 | 46.33 ± 4.28 |
| FCR                                    |                  | 1.04 ± 0.38 | 1.66 ± 0.49 |
| Production of prawn (kg/1000 m²)       |                  | 112 ± 4 | 107 ± 2 |
| Production of rice (kg/1000 m²)        |                  | 698 ± 12 | 795 ± 14 |

Production of giant prawns reaching 112 kg/1000 m² (Table 1). Higher prawn production at a density of 10 ind/m² was followed by increased profits (Table 2). In the stocking density of 10 ind/m², the number of prawns reaching the size of 30-50 ind/kg was 66 kg compared to the stocking density of 15 ind/m² which is only 33 kg. The selling price of giant prawns measuring 30-50 ind/m² was IDR 70,000, while the lower size was only IDR 30,000-40,000/kg. Based on the analysis of the B/C ratio, the cultivation of rice-prawns at a density of 10 ind/m² of prawns is more profitable. At a stocking density of 15 ind/m², the use of higher numbers of prawns and the use of inefficient feed (high FCR) results in higher production costs. Paul et al. [8] and El-Sherif and Mervat [7] also stated that the use of feed was less efficient with the increase of stocking densities in prawn culture. Besides the high mortality and low growth rate in stocking densities of 15 ind/m², causing the production and size of prawns produced lower which affect the selling price and the amount of profits obtained. High mortality and FCR in raising high-density giant prawns are unprofitable, due to higher production costs (investment in purchasing shrimp seeds) and more spent on feed during maintenance [9].

Table 2. Economic analysis of integrated farming of rice-prawns at different stocking densities of prawns

| Parameter          | Density (ind/m²) | 10       | 15       |
|--------------------|------------------|----------|----------|
| Operational cost   |                  |          |          |
| Prawn              |                  |          |          |
| - Seed (IDR)       |                  | 1,500,000 | 2,250,000 |
| - Feed (IDR)       |                  | 1,083,000 | 1,083,000 |
| Sub total (IDR)    |                  | 2,583,000 | 3,333,000 |
| Rice               |                  |          |          |
| - Labour (IDR)     |                  | 840,000  | 840,000  |
| - Seed (IDR)       |                  | 10,000   | 10,000   |
| - Fertilizer (IDR) |                  | 152,500  | 152,500  |
| Sub total (IDR)    |                  | 1,002,500 | 1,002,500 |
| Total cost (IDR)   |                  | 3,585,500 | 4,335,500 |
| Revenue            |                  |          |          |
| - Prawn (IDR)      |                  | 6,481,500 | 5,700,000 |
| - Rice (IDR)       |                  | 3,141,000 | 3,577,500 |
| Total revenue (IDR)|                  | 9,622,500 | 9,277,500 |
| Margin             |                  |          |          |
| - Prawn (IDR)      |                  | 3,898,500 | 2,367,000 |
| - Rice (IDR)       |                  | 2,138,500 | 2,575,000 |
| Total margin/benefit (IDR) | | 6,037,000 | 4,942,000 |
| B/C ratio          |                  | 1.7      | 1.1      |
4. Conclusion
Rearing of *M. rosenbergii* juveniles in the rice-prawn integrated farming system have a better productive performance with the use of a stocking density of 10 ind/m². The use of feed was less efficient at density of 15 prawn/m². The high growth rate and survival of giant prawns at a density of 10 ind/m², followed by higher production and benefit.

References
[1] Saikia A K, Abujam S K, Das D N and Prasad B S 2015 Economics of paddy cum fish culture: A case study in Sivsagar, Assam. *International Journal of Fisheries and Aquatic Science* 2 198-203
[2] Rahman M A, Parvez M S and Marimuthu K 2016 Prospects, potentials, practices and benefits of integrated rice-fish farming in Bangladesh *International Journal of Biological, Ecological and Environmental Sciences* 5 46-49
[3] Parvez M S, Salekuzaman M, Hossain M E and Azam K 2012 Economics and productivity of rice cum freshwater prawn (*Macrobrachium rosenbergii*) in the gher farming system. *International Researchers* 1 39-49
[4] Suhendra T 2006 Meningkatkan produktivitas lahan sawah irigasi melalui usaha tani padi – udang galah GI MACRO sistem tumpangsari *Media Akuakultur* 1 119-124
[5] Ranjeet K and Kurup B M 2002 Heterogeneous individual growth of *Macrobrachium rosenbergii* male morphotype. *NAGA, The ICCLARM Quarterly* 25 13-18
[6] David F S, Cohen F P A and Valenti W C 2015 Intensification of the giant river prawn *Macrobrachium rosenbergii* hatchery production *Aquaculture Research* 47 3747-3752
[7] El-Sherif M S and Mervat A M 2009 Effect of rearing systems (mono- and poly-culture) on the performance of freshwater prawn (*M. rosenbergii*) juveniles *Journal of Fisheries and Aquatic Sciences* 4 117-128
[8] Paul P, Rahman M A, Hossain M M, Islam S, Mondal S and Haq M 2016 Effect of stocking density on the growth and production of freshwater prawn (*Macrobrachium rosenbergii*) *International Journal of Fisheries and Aquaculture Sciences* 6 77-86
[9] Negrini C, de Castro C S, Bittencourt-Guimarães A T, Frozza A, Ortiz-Kracizy R, Cupertino-Ballester E L 2017 Stocking density for freshwater prawn *Macrobrachium rosenbergii* (Decapoda, Palaemonidae) in biofloc system *Latin American Journal of Aquatic Research* 45 891-899
[10] Krummenauer D, Peixoto S, Cavalli R O, Poersch L and Wasielewsky Jr W 2011 Superintensive culture of white shrimp, *Litopenaeus vannamei*, in a biofloc technology system in southern Brazil at different stocking densities *Journal of World Aquaculture Society* 42 726-733
[11] Wasielewsky Jr W, Froes C, Fóes G, Krummenauer D, Lara G and Poersch L 2013 Nursery of *Litopenaeus vannamei* reared in a biofloc system: the effect of stocking densities and compensatory growth *Journal of Shellfish Research*. 32 799-806
[12] Moraes-Valenti P, Morais P A, Preto B L and Valenti W C 2010 Effect of density on population development in the Amazon River prawn *Macrobrachium amazonicum Aquatic Biology* 9 291-301
[13] Balasundaram C, Jeyachitra P and Balamurugan P 2004 Shelter preference in *Macrobrachium* spp. with reference to aquaculture *Acta Ethologica* 7 95-101
[14] Uddin M S, Farzana A, Fatema M K, Azim M E, Wahab M A and Verdegem M C J 2007 Technical evaluation of tilapia (*Oreochromis niloticus*) monoculture and tilapia–prawn (*Macrobrachium rosenbergii*) polyculture in earthen ponds with or without substrates for periphyton development *Aquaculture* 269 232-240
[15] Asaduzzaman M, Wahab M A, Verdegem M C J, Mondal M N and Azim M E 2009 Effects of stocking density of freshwater prawn *Macrobrachium rosenbergii* and addition of different levels of tilapia *Oreochromis niloticus* on production in C/N controlled periphyton based system *Aquaculture* 286 72-79
[16] Priyono S B, Sukardi and Harianja B S M 2011 Effects of shelter addition on behavior and growth of giant freshwater prawn (*Macrobrachium rosenbergii*) *Jurnal Perikanan Universitas Gadjah Mada* **13** 78-85