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Productivity of Vannamei Shrimp Cultivation (*Litopenaeus vannamei*) in Intensive Ponds in Tegal City, Central Java Province

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Abstract

The failure of tiger shrimp (*Penaeus monodon*) farming could make farmers stop their cultivation activities. As an alternative, vannamei shrimp cultivation gives hope for productive, profitable, and sustainable cultivation. The development of shrimp farming in Tegal City is carried out through simple methods, intensive technology, and the use of Busmetik technology or mini-scale shrimp farming on plastic ponds. The high demand in the shrimp market continues to encourage farmers to increase their productivity by increasing stocking density. The purpose of this study is to determine the performance of vannamei shrimp cultivation which is cultivated intensively including yields, survival rate (SR), feed conversion ratio (FCR), and shrimp growth in Tegal City, Central Java Province. The research was conducted from July to October 2019. The research method used was a case study with 16 plots of ponds, and the average area of the pond was 1000 m^2. Based on the results of the calculation, it can be seen that the average yield is 1,603 kg per pond with a stocking density of 100 fish/m^2, a survival rate (SR) is 85.6%, a feed conversion ratio (FCR) is 1.41 and the shrimp growth is 0.16 grams per day. Economically, based on the Benefit-Cost Ratio (B/C ratio) of 1.46, vannamei shrimp cultivation in Tegal City is profitable so that shrimp farming can be carried out sustainably.

INTRODUCTION

The coastal area of Tegal City has a coastline of about 7.5 km with a pond area of 488.8 hectares. The commodities that are maintained are the cultivation of milkfish, shrimp, crab and seaweed. The prospect of shrimp farming provides a good expectation for shrimp cultivators. However, this high potential of profit leads to a large amount of land clearing for shrimp farming activity and the increased production which has a lack of concern on the environment. Therefore, a development strategy is highly needed in the use of ponds for shrimp cultivation, including the utilization of land potential and the use of science and technology of cultivation in fisheries development (Susilowati *et al.*, 2014). Unsustainable development will provide temporary benefits and losses, which can result in the closure of the business.

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As of today, this huge potential has not been optimally utilized. Besides, the development of coastal areas for industrial, tourism, fishery, settlement, agriculture, and ports has caused changes in water quality, soil and the environment. The population growth, industrial growth, transportation and other sectors that utilize limited natural resources have also resulted in a shift in land use, which has a negative impact on the environment in the aspects of ecology, economy, and security (Surya *et al.*, 2020).

The current problem of developing shrimp farming in the coastal area of Tegal City is unstable shrimp production. The decrease in the environmental quality is caused by the management of cultivation waste that has not been maximally implemented, environmental pollution from household waste, tourism, and the development of port development. Therefore, the development of shrimp farming must be carried out in an integrated manner by utilizing the coastal lands of Tegal City.

The decline in production in the 3rd quarter of 2018 as well as the failure of the giant tiger shrimp harvest in the 1990s have made shrimp cultivators pay attention to not overly determine production targets. It is important to implement environmentally friendly technology in accordance with the conditions in the field. Besides, the adjustment to the existing waste management capabilities is also highly needed.

Shrimp farming in ponds must be sustainable so that the principles of shrimp farming can be implemented efficiently and effectively. The cultivation technology which is environmentally friendly is an alternative that can be used as a reference in conducting shrimp farming. The intensive and environmentally friendly technology of vannamei shrimp cultivation is expected to create sustainable shrimp farming. The narrow land area also makes it easy to control maintenance and to maintain good productivity.

The increasing demand for shrimp and quite high prices of shrimp have encouraged shrimp farmers or entrepreneurs to compete in order to increase the productivity of their shrimp ponds, either by increasing the use of technology or by increasing the density of their stockings. The increase in vannamei shrimp production is closely related to the increase in feed, which is one of the main production factors in aquaculture activities (Suantika *et al.*, 2018). As the largest component in aquaculture financing, feed management is critical to the success of the cultivation business, so it is necessary to conduct good feed management. Thus, the efficiency in the use of feeds in cultivation business activities can be reached (Yustianti *et al.*, 2013). Given the fact that the cost of feeds in the cultivation process can reach 60-70% of the total expenditure, it is necessary to reduce costs by using feeds efficiently (Mansyur *et al.*, 2011). Likewise, according to Budiardi *et al.* (2008), in intensive shrimp farming, feed is the largest variable cost of the total production cost of around 50-70%.

Vannamei shrimp can grow well at high stocking densities, namely 60-150 individuals/m^2 with a growth rate of 1-1.5 g/week (Briggs *et al.*, 2004). This is because the vannamei shrimp is able to use all the water space as a place to live so that the living space of the shrimp becomes wider. However, the high stocking density of shrimp, apart from giving an advantage of being able to provide high production income, also has a risk in terms of the quite high waste load, which is caused by the remaining nitrogen (N) and phosphorus (P) feeds in vannamei shrimp farming.

The problem will be even more complex if there is no good management of aquaculture waste. This situation is in accordance with the results of previous research which state that ecologically the fish cultivation in Tegal City has not implemented waste treatment in accordance with CBUB where cultivation waste is directly channeled to the disposal channel having a connection to the open sea (Mas'ud and Rouf, 2017). For this reason, the application of environmentally friendly technology needs to be done so that the results of cultivation production are well-maintained and sustainable.

At the present time, the cultivators in Tegal City are applying intensive technology with the use of a narrow land with an average pond area of 1000 m², a stocking density of 100 individuals/m², and the production target of 1.6 tons per pond/per plot or 16 tons per hectare. The optimal stocking density will result in maximum productivity and income so that the cultivation can be sustainable (Syah *et al*., 2017).

The application of environmentally friendly technology is expected to remain profitable and sustainable. The limited management of production waste and the environment close to settlements and tourism are challenges for farmers to be able to maintain their production.

This study aims to determine the performance of vannamei shrimp cultivation with intensive technology, including yield, survival rate (SR), feed conversion ratio (FCR), and shrimp growth. Meanwhile, the economic aspects analyzed from the cultivation business include profit/loss, Benefit-Cost Ratio (B/C ratio), Break-Even Point (BEP) and Payback Period (PP).

METHODOLOGY

Place and Time

The research was conducted from July 2019 to October 2019. The research site was in the vannamei shrimp ponds of Tegal City, which included the East Tegal District (2 ponds), West Tegal District (5 ponds) and Margadana District (9 ponds).

Research Design

Samples were taken from 16 units of ponds spreading across three districts in Tegal City, including East Tegal District, West Tegal District and Margadana District. The pond had an average area of 1000 m² with a stocking density of 100 individuals/m² in the coastal area of Tegal City, Central Java. The data of harvest yields included the amount of harvest, the amount of feed, the feed conversion ratio (FCR), the survival rate (SR), the shrimp growth, and sales data.

Work Procedures

The work procedures were carried out by collecting production data from each sample of vannamei shrimp ponds measuring 1000 m² with a density of 100 fish/m² in one cycle. Afterward, the data were analyzed with parameters including yields, survival rate (SR), feed conversion ratio (FCR), and shrimp growth, as well as financial aspects including profit/loss, Benefit Cost Ratio (B/C ratio), Break Even Point (BEP), and Payback Period (PP).

Data Analysis

This research used a case study method with a descriptive approach by observing and collecting data including yields, survival rate (SR), feed conversion ratio (FCR), and shrimp growth as well as financial aspects including profit/loss, Benefit Cost Ratio (B/C ratio), Break Even Point (BEP), and Payback Period (PP) (Supono, 2006; Farchan, 2006). Data collection was taken from the cultivation of vannamei shrimp in three districts in Tegal City, which obtained an average stocking density of 100 individuals/m², or 100 000 individuals per 1000 m² of pond area.

RESULTS AND DISCUSSION

Productivity

The data obtained show that the highest productivity is found in pond/plot 7 accounting for 1.905 tons, while the lowest productivity is in pond/plot 9 accounting for 1.295 tons. Meanwhile, the average productivity is 1.603 tons per pond or 16 tons per hectare. These yields show that the ponds in Tegal City are productive. This is following the Regulation of the Minister of Marine Affairs and Fisheries (Permen KP) No. 75 Year 2016 suggesting that the harvest is expected to be 10 tons to 15 tons/hectare for intensive ponds. These results also conforms with Syah *et al.* (2017) stating that the optimal stocking density will result in maximum productivity and income so that the cultivation can be sustainable.

The productivity which reaches an average of 1.603 tons per pond or 16.03 tons per hectare is possible because the depth of pond water is between 110 cm and 120 cm, so the water volume is higher. If the stocking density is 100 individuals/m^2, then the number that is stocked is 100,000 individuals/plot of pond. Another factor is the survival rate (SR) which is quite high at 85.6% (Supono, 2006). The quality assurance of shrimp seeds from the hatchery also affects the survival of the shrimp as the seeds are free from certain diseases or better known as SPF (specific pathogenic free), such as: WSSV (white spot syndrome virus), TSV (taura syndrome virus), IMNV (infectious mionecrosis virus), and EMS (early mortality syndrome).

Also, the amount of vannamei shrimp produced is closely related to the feed, which is a major factor in cultivation activities (Yi *et al*., 2018). Thus, good feed management is highly needed so that there is an efficient use of feed in cultivation business activities (Yustianti *et al*., 2013). Given the cost of using the feed in the cultivation process can reach 60-70% of the total expenditure, it is necessary to reduce costs by using feed efficiently (Mansyur *et al.*, 2011).

The decline in production in the previous year and the failure of the tiger shrimp harvest in the 1990s have made the vannamei shrimp cultivators more careful in choosing the technology. This is following Ahmad (2006) stating that the cultivation business that does not pay attention to sustainability and environmental carrying capacity is a trigger for the failure of cultivation businesses.

In addition to setting the stocking density to produce optimal production, other methods were carried out before spreading the shrimp seeds. In these methods, the water in the culture container was sterilized using 20 ppm chlorinelankton, the growth of shrimp was encouraged using TSP 10 ppm fertilizer to add element N to the pond waters for the shrimp growth, and the water quality monitoring was carried out periodically as needed. The measurement results show DO at around 5 - 6 ppm, the temperature of 26 - 30 ˚C, and salinity of 30 ppt. To maintain water quality, water changes of 5-10% or 500 -100 m3 per day were carried out. The management of pond water quality was carried out by reducing and adding water using a pump so that the water quality of the plots is maintained optimally. Feed management was carried out using the estimation method according to the recommendations or experiences from the past period (blind feeding) and using a feeding tray (Anco) sampling system. The use of this method can reduce the FCR to less than 1.8 (Farchan, 2016).

The regulation of the number of stocking densities by shrimp cultivators in Tegal City is currently in an average of 100 individuals/m^2. Using a narrow area of land with an average pond area of 1000 m^2 with a production target of 1.6 tons per plot or 16 tons per hectare. The shrimp cultivators are not interested in the very high density given the previous year's experience when they were suffering from a decline in production. The decline in production is thought to be due to stocking densities of more than 350 individuals/m^2. Meanwhile, waste management was not sufficiently available so it was not environmentally friendly.

Natural feed management was also carried out at the beginning of the maintenance in accordance with the Regulation of the Minister of Marine Affairs and Fisheries (Permen KP) No. 75/2016. Each pond was given 4 windmills as a source of dissolved oxygen and to even out the water quality of the media (Supono, 2006).

Table 1. Data of the harvest of vannamei shrimp.

Pond No.	Feed (kg)	Harvest (kg)	FCR	SR (%)	SIZE	AGD (gr/day)
1	1,857	1,550	1.2	93	60	0.15
2	2,555	1,597	1.6	87	54.4	0.16
3	2,312	1,713	1.35	86	50	0.18
4	2,230	1,670	1.3	91	55	0.16
5	2,356	1,651	1.43	92	56	0.16
6	1,921	1,413	1.36	87	61.5	0.14
7	2,667	1,905	1.4	81	42.5	0.19
8	1,910	1,435	1.33	85	59	0.15
9	2,201	1,295	1.7	82	63	0.14
10	1,621	1,351	1.2	89	65.8	0.13
11	2,130	1,716	1.24	82	48	0.18
12	3,015	1,675	1.8	76	45	0.18
13	2,561	1,507	1.7	80	53	0.17
14	1,955	1,527	1.28	75	49	0.18
15	2,300	1,862	1.23	93	50	0.18
16	2,695	1,785	1.5	91	50	0.18
Average	2,268	1,603	1.41	85.6	53.8	0.16

Survival rate (SR)

The highest survival rate (SR) is found in pond 1 and pond 15, standing at 93%. Meanwhile, the lowest survival rate (SR) is found in pond 14 at 75%. The death of shrimp is thought to be due to diseases, which causes shrimp mortality. Specifically, the suspicion of suffering from diseases is based on the physical characteristics as the shrimp is pale and has a white color in the muscles in the lower segment to the tail; the temporary suspicion is that they have IMN disease. This situation is in accordance with the opinion of Sukenda *et al.* (2011) who explain that IMNV disease causes death in vannamei shrimp with clinical symptoms of white muscles formed on the body segments occurring due to necrosis in muscle tissue. The highest SR) is found in pond 1 and pond 15 with an average survival rate (SR) of 85.6%.

Feed Conversion Ratio (FCR)

The lowest FCR is found in pond 1 and pond 10 of 1.2, while the highest FCR is found in pond 12 of 1.7. Meanwhile, the average FCR is 1.41. The difference in FCR, according to Lailiyah *et al.* (2018), is caused by a reduced appetite for shrimp due to the influence of disease and inaccurate estimation of the population calculation.

Shrimp Growth

The average shrimp yields are at an average of 1.603 kg with average size of 53.8 or an average weight of shrimp at harvest of 18.58 grams/individual. The average shrimp growth is 0.16 grams per day. The slowest growth of shrimp is found in pond 10 with 0.13 grams/day of shrimp growth per day. The highest shrimp growth is found in pond 7 with 0.19 grams/day. Differences in shrimp growth can be caused by stocking density and competition in the space of cultivation media (Lailiyah *et al.*, 2018). Meanwhile, according to Gunarto and Hendrajat (2008) shrimp grow quickly to a size of 20 grams with a growth rate of 3 grams per week at a density of 100 fish/m^2. Growth slows down after 20 g, which is 1 g per week but grows rapidly at low salinity.

Financial Analysis

Economic aspects need to be analyzed to determine the income of shrimp cultivators. The results of the financial analysis show that the lowest income for shrimp farming is Rp. 163,170,000, and the highest is Rp. 323,850,000. Out of profit from 16 ponds, the lowest profit is Rp. 12,881,900, and the highest is Rp. 158,602,300 (Table 2).

Table 2. Analysis of the economic aspects per pond, 2 cycles (1 year).

Pond	Investment Cost	Fixed Cost	Variable Cost	Total Cost	Income	R/L Analysis	B/C Ratio Analysis	PP	BEP Kg	BEP Price (IDR)
1	85,000,000	39,950,000	100,111,700	140,061,700	201,500,000	61,438,300	1.44	1.15	1,221,49	79,396,982
2	83,500,000	39,800,000	111,525,500	151,325,500	227,120,000	75,794,500	1.50	0.95	1,149,99	78,199,015
3	82,000,000	39,650,000	121,470,500	161,120,500	214,744,000	53,623,500	1.33	1.25	1,357,75	91,286,374
4	87,500,000	40,200,000	114,034,700	154,234,700	243,246,000	89,011,300	1.58	0.86	1,065,89	75,678,282
5	82,000,000	39,650,000	102,070,100	141,720,100	180,864,000	39,143,900	1.28	1.61	1,422,08	91,012,853
6	82,000,000	39,650,000	110,638,100	150,288,100	163,170,000	12,881,900	1.09	3.31	1,954,88	123,157,367
7	85,500,000	40,000,000	108,465,500	148,465,500	257,400,000	108,934,500	1.73	0.71	921,75	69,131,061
8	82,000,000	39,650,000	115,381,100	155,031,100	221,234,000	66,202,900	1.43	1.05	1,236,85	82,869,039
9	90,000,000	40,350,000	124,897,700	165,247,700	323,850,000	158,602,300	1.96	0.53	772,72	6,568,806
10	83,000,000	39,700,000	101,733,500	141,443,500	189,420,000	47,986,500	1.34	1.38	1,299,39	85,759,769
11	82,000,000	39,650,000	92,896,220	132,546,220	164,822,000	32,275,780	1.24	1.86	1,489,51	90,860,221
12	82,000,000	39,650,000	135,546,500	175,196,500	264,650,000	89,453,500	1.51	0.81	1,028,85	81,278,761
13	82,000,000	39,650,000	121,654,100	161,304,100	204,952,000	43,647,900	1.27	1.48	1,434,67	97,557,643
14	84,000,000	39,850,000	103,110,500	142,960,500	213,780,000	70,819,500	1.50	1.01	1,099,69	76,978,147
15	92,000,000	44,650,000	110,152,000	154,802,000	264,404,000	109,602,500	1.71	0.76	1,077,95	76,534,752
16	86,000,000	40,050,000	125,754,500	165,804,500	253,470,000	87,665,500	1.53	0.86	1,119,51	79,485,055
Average	1,350,500,000	642,100,000	1,799,442,220	2,441,542,220	3,588,626,000	1,218,776,516			19,652,96	1,344,866,127
Amount	84,406,250	40,131,250	112,465,139	152,596,389	224,289,125	71,692,736	1.46	1.22	1,228,31	84,054,133

To see the economic aspects of the ponds in Tegal City, the overall income (total of 16 ponds) is obtained as much as Rp. 3,588,626,000 or Rp. 224,289,125 per pond. The average monthly profit is Rp. 71,692,736 or equal to Rp. 5,974,395 per month. This income is above the minimum wage income in the Tegal City of Rp. 1,950,000. Meanwhile, the value of the benefit cost ratio (B/C ratio) is 1.46, so the business is declared feasible to do. The breakeven point of business (BEP) is obtained on the production or amount of shrimp harvested of 19,652.96 kg or 1,228.31 kg/pond and the BEP price of Rp. 1,344,866,126.59 or Rp. 84,054,133 per pond.

The return-on-investment costs of 1,22 means that the total payback period required for the fishpond in Tegal City is 1.22 years (Table 3.). The utilization of ponds in Tegal City, in general, can still be improved in terms of environmental management, especially in protecting the aquatic environment from being polluted by waste so that it can support the sustainability of shrimp farming.

Table 3. Analysis of economic aspects based on the calculation of a total of 16 ponds in Tegal City.

No	Economic Aspect	Amount (Rp)	Average (Rp)
1	Investment cost	1,350,500,000	84,406,250
2	Fixed cost	642,100,000	40,131,250
3	Variabel cost	1,799,442,220	112,465,139
4	Total cost	2,441,542,220	152,596,389
5	Income	3,588,626,000	224,289,125
6	R/L analysis	1,218,776,516	71,692,736
7	B/C Ratio analysis		1.46
8	BEP : a. Kg	19,652.96 kg	1,228.31 kg
	b. Price	1,344,866,126.59	84,054,133
9	PP (year)		1.22

Shrimp farming can financially improve the economic and environmental sustainability, so the use and the development of technology in shrimp farming needs to be done (Kuhn *et al*., 2010). The use of *Busmetik* technology or mini-scale shrimp farming on plastic ponds used by shrimp cultivators in Tegal City is one method which has been done, apart from setting the stocking density, to make the shrimp cultivation activities keep running in its production and the farmers' income keep maintained.

CONCLUSION

Shrimp farming production in Tegal City is classified as productive with an average production amount at harvest of 1,603 kg/pond. The average survival rate (SR) is 85.6%, feed conversion ratio (FCR) is 1.41. Intensive technology is carried out at a density of 100 individuals/m^2. The profit or average income of shrimp cultivators per year is Rp. 71,692,736 or Rp. 5,974,395 per month above the minimum income of Tegal city of Rp. 1,950,000.

The shrimp production will be maintained if the application of environmentally friendly technology refers to the environmental conditions, the production pays attention to the carrying capacity and the availability of facilities and infrastructure, and the shrimp density does not exceed 100 individuals/m^2. Moreover, it is essential to establish a pond waste treatment system and carry out environmental rehabilitation by expanding a green belt to support sustainable pond operations.

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