Current status of technical and economic analysis of inland shrimp culture in Lampung Province, Indonesia

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Abstract. The culture of Pacific white shrimp (*Penaeus vannamei*) in Indonesia has rapidly grown since it was first introduced in 2000. One of the advantages of this shrimp type is its ability to live in low salinity locations far from the coast. This study aims to analyze Pacific white shrimp cultivation at low salinity in Lampung Province, Indonesia. This species, often called the inland shrimp culture, is an alternative to overcome problems associated with water degradation and the spread of diseases. Since 2016, studies have been carried out on the Pacific white shrimp cultivation using low salinity in Lampung Province, especially in East Lampung Regency. The cultivation was carried out in small ponds, ranging between 1000 and 2000 m^2 and managed semi-intensively, with the application of biosecurity. Seed stocking density ranged from 50 to 70 post-larvae m^{-2} with the partial and final harvest types used for cultivation. The result showed that the diseases that often attack Pacific white shrimp include white spot virus syndrome, infectious myonecrosis, white feces syndrome, and vibriosis. Pond productivity reached 10-13 tons ha^{-1}, and based on performance, the average shrimp weight was 21.5-24.5 g, feed conversion ratio (FCR) 1.3-1.5, and survival rate (SR) 5-93%. Furthermore, the economic analysis showed that Pacific white shrimp's cultivation with low salinity was very beneficial with a benefit cost (B/C) ratio of 0.8.

Key Words: *Penaeus vannamei*, Pacific white shrimp, low salinity, white feces syndrome.

Introduction. White shrimp is also known as Pacific white shrimp (*Penaeus vannamei*); it is an euryhaline species that grows adequately in salinity of 2-40 ppt (Wyban & Sweeney 1991; Roy et al 2007). According to Briggs et al (2004), this shrimp species has several advantages over others, such as rapid growth and high survival rates at high stocking densities, low feed conversion ratio (FCR) and resistance to disease attacks. Furthermore, Lightner (2011) stated that the Pacific white shrimp can be domesticated, therefore, its adaptation to the pond environment is very good with a low level of cannibalism. Its health status is specific pathogen-free, with the ability to suppress diseases during attacks (Briggs et al 2004; Wyban 2007). As a euryhaline species, Pacific white shrimp is cultivated far from the coast (inland) with an increase in productivity in areas capable of maintaining the sustainability of coastal ecosystems such as mangrove forests and estuaries (Davis et al 2002; Jayasankar et al 2009; Roy et al 2010).

Since the cultivation of Pacific white shrimp in Indonesia in early 2000, there has been a rapid growth in production to 15,000 kg ha^{-1} (Supono 2015), thereby listing the country as one of the major with auspicious results. However, the increase in shrimp culture has led to the emergence of some problems associated with shrimp cultivation in Indonesia, such as the spread of disease and limited lands for cultivation. Some diseases that pose a threat to farmers include white spot virus syndrome (WSSV), infectious myonecrosis virus (IMNV), and white feces syndrome (WFS), thereby, leading to the closure of several ponds. These diseases are the main causes of failure in shrimp culture (Limsuwan 2010; Lightner 2011). Various studies have been carried out to overcome these problems, which still experience failure. Lampung is one of the shrimp producing areas in Indonesia, which started cultivation using low salinity (inland shrimp farming).

This farming method was used due to the outbreaks of disease and water quality degradation to pond layout. Therefore, this study aims to evaluate the application of Pacific white shrimp cultivation with low salinity, technical and economic review, as well as future development prospects in Lampung Province, Indonesia.

Material and Method. The study was conducted in Lampung Province, Indonesia and it was based on primary and secondary data. Primary data was collected through observasion of two ponds (pond size of 1000 m^2 and 2000 m^2) for shrimp performance and personal interviews to farmers for other information. Secondary data was collected from journal publications and government authority (KKP). Data regarding pond construction, problems, economic status, and future prospects were also analyzed.

Results and Discussion

Shrimp culture in Lampung. Lampung Province, which covers a coastal length of 1,050 km and ponds areas of 38,505 ha (KKP 2020), has enormous potential in marine aquaculture, including shrimp. Before the 2000s, farmers cultivated local black tiger shrimp (*Penaeus monodon*). However, due to disease and low-quality seed, the majority of farmers failed and switched to the Pacific white shrimp. Table 1 shows the Pacific white shrimp's ability to increase pond productivity twice that of the black tiger.

Table 1

Performance of shrimp culture in Lampung Province (Supono 2015)

Species	*Density (PL's m^{-2})*	*FCR*	*SR (%)*	*ABW (g)*	*Harvest (kg ha^{-1})*	*ADG (g day^{-1})*
P vannamei	102	1.46	83	17.6	15,006	0.14
P. monodon	51	2.18	54	23.1	6,294	0.17

FCR = feed conversion ratio; SR = survival rate; ADG = average daily growth; ABW = average body weight;

Inland shrimp culture. The decrease in the number of lands used for cultivation around the coast and the spread of diseases due to viruses and bacteria encouraged farmers to participate in the shrimp farming activities with low salinity. According to Dayma et al (2015), the use of aquaculture media with low salinity is expected to reduce the malignancy of viruses responsible for them. Lampung Province, which is one of the main producers of shrimp in Indonesia, has become a pioneer in the development of low salinity culture, especially in the East Lampung Regency, as shown in Figure 1.

Figure 1. Inland shrimp culture area in Lampung Province.

The area has an overall 8,775 ha of brackishwater aquaculture in the Pasir Sakti and Labuhan Maringgai Districts. Presently, the areas intensively, semi-intensively, and traditionally managed by ponds are 1,190 ha, 970 ha, and 3,800 ha, respectively, while the rest have not been utilized. Pacific white shrimp cultivation was only conducted in 2016 after farmers' experienced failure in black tiger cultivation. Aquaculture activities are carried out using low salinity with a decline in water quality and the spread of diseases like WSSV. Furthermore, the decrease in water quality and disease outbreaks encouraged farmers to cultivate Pacific white shrimp with a semi-intensive system and maximum stocking density of 70 PL's m^{-2}. Brigss et al (2004) stated that Pacific white shrimp have stronger endurance than other shrimp species.

Pond construction. Shrimp pond construction is similar to the other ponds types. However, it comprises some additional equipment, such as freshwater or low salinity installations, which are channeled through rivers and groundwater. According to Priyono et al (2019), groundwater is very important in supporting this culture, in terms of quality and quantity. The pond size is made of a square of an area of 1,000-2,000 m^2 and a depth of 1.5-2.0 m. The bottom of the pond, such as the embankment and feeding areas are coated with plastic mulch, high/low-density polyethylene (semi-lined pond) according to its basic texture conditions. However, the bottoms of some ponds are coated with plastic throughout (full-lined pond) (Figure 2). Installation of biosecurity equipment such as bird scaring devices (BSD) and crab protection devices (CPD) is carried out before replenishing water to prevent crabs and birds.

Furthermore, the freshwater used to reduce salinity comes from groundwater with a depth of approximately 80 m. The pond is also equipped with 2-4 units of paddlewheel aerators driven by a generator or current from the State Electricity Company (PLN). The number of paddlewheels depends on the density of stocking and planned harvest targets. As a reference, every 1 unit of paddlewheel (1 HP) is capable of sustaining a maximum of 500 kg shrimp biomass (Boyd 2020).

Semi-lined pond Full-lined pond

Figure 2. Type of lined pond.

Biosecurity. Saha (2011) stated that it is essential to protect Crustacea from contracting diseases due to their low immunity rate, which is one of the biggest failures in its cultivation. Semi-intensive low salinity shrimp culture in Lampung Province has implemented biosecurity to minimize disease attacks. The application of biosecurity is divided into the first and second lines of defense (Lightner 2003). The first line includes the installation of barriers for birds and crabs, equipment and water sterilization, quarantine, zero water exchange, and the use of specific pathogen-free (SPF) seeds. At the same time, the second line of defense is the application of immune-stimulants through the feed.

Pond preparation. The filling of water into the pond is carried out at the highest tide time with a salinity of 10-15 ppt for 2-3 days using a 6-inch pump covered with a 1000-micron filter bag. A filter bag is used to prevent the entry of wild fish and shrimp into the pond, which tends to have an average depth of 1.2 m. Water preparation is carried out for 15-20 days, including sterilization, liming, fertilizing, and application of probiotics. The liming process was carried out using dolomite ($CaMg(CO_3)_2$) at a concentration of 100 mg L^{-1}.

Meanwhile, the fertilizers used to stimulate the growth of phytoplankton were urea (nitrogen source) and TSP (phosphorus source) at concentrations of 10 mg L^{-1} and 1 mg L^{-1}, respectively. Rice bran fermentation was also applied to increase the growth of zooplankton and heterotrophic bacteria, while ponds that are ready for stocking are marked by the growth of plankton with 70 cm water transparency. The addition of water is carried out at the time of cultivation using groundwater to slowly decrease the salinity from 0-4 ppt at the end of cultivation. Water loss is caused by seepage and evaporation.

Seed stockings. Seeds are obtained from shrimp hatchery units in South Lampung with PL between the ages of 8 and 10 days. The shrimp seeds used are free from pathogens and have passed the stress test, which was carried out using 100 mg L^{-1} formalin solution, with salinity stress tests of 5 ppt. The seeds are considered good, assuming the survival rate SR reaches 95%, with stocking carried out in the afternoon to avoid stress due to temperature changes (Figure 3). The stocking density at an average of 50-70 PL's m^{-2} is dependent on the pond supporting equipment, especially the availability of paddlewheels.

Figure 3. Seed stocking.

Feeding management. The blind and demand feeding programs are the two types of methods applied to the pond. The blind feeding program is given in the first month, while the demand feeding diagram is used in the second month until harvest. A commercial feed with an average protein content of 30% is used on the shrimps. Protein requirements in Pacific white shrimp feed range between 30 and 40% (Venero et al 2007), while Kureshy & Davis (2002) stated that it is between 30 and 35%. The frequency of feeding 4 times per day is 07.00, 11.00, 15.00, and 20.00, with the amount of feed dependent on the biomass present in the pond and shrimp size (Carvajal-Valdes et al 2012). The feeding rate is influenced by shrimp size.

Probiotics. Probiotics are applied by farmers to reduce the ammonia concentrations in water. Its application also aims to suppress the growth of pathogens such as *Vibrio* and contain several types of microorganisms, including *Bacillus, Nitrosomonas,* and *Nitrobacter*. *Bacillus* plays a role in decomposing organic matter and ammonia, while *Nitrosomonas* and *Nitrobacter* are chemoautotrophic bacteria that decompose ammonia (Musyoka 2016). In addition to improving water quality, farmers use probiotics as a feed mixture (feed probiotics) to improve digestibility, immunity, and shrimp growth.

Disease. Several diseases, such as WSSV, IMNV, and WFS, and vibriosis have attacked Pacific white shrimp in Lampung Province, as shown in Figure 4. WSSV disease causes sporadic death within a short period, as opposed to the IMNV, which is slow. The WFS is characterized by a decrease in appetite, followed by shrimp dung that floats on the water surface. According to Limsuwan (2010), this disease is caused by several types of *Vibrio*, such as *V. parahaemolyticus*, *V. vulnificus*, and *V. alginolyticus*. *Vibrio* exceeds the safe limit for shrimp above 10^5 CFU mL^{-1}, and it is found in the digestive tract (Supono et al

2019). Shrimp with infectious myonecrosis virus slowly experience decreased appetite until it dies. Their mortality rate is usually between 40 and 70%, with an increase in feed conversion ratio. Transmission of IMNV occurs through cannibalism, pond water, and vertical transmission from broodstock. Prevention of IMNV is carried out using SPF (specific pathogen-free) seeds and applying biosecurity to aquaculture facilities.

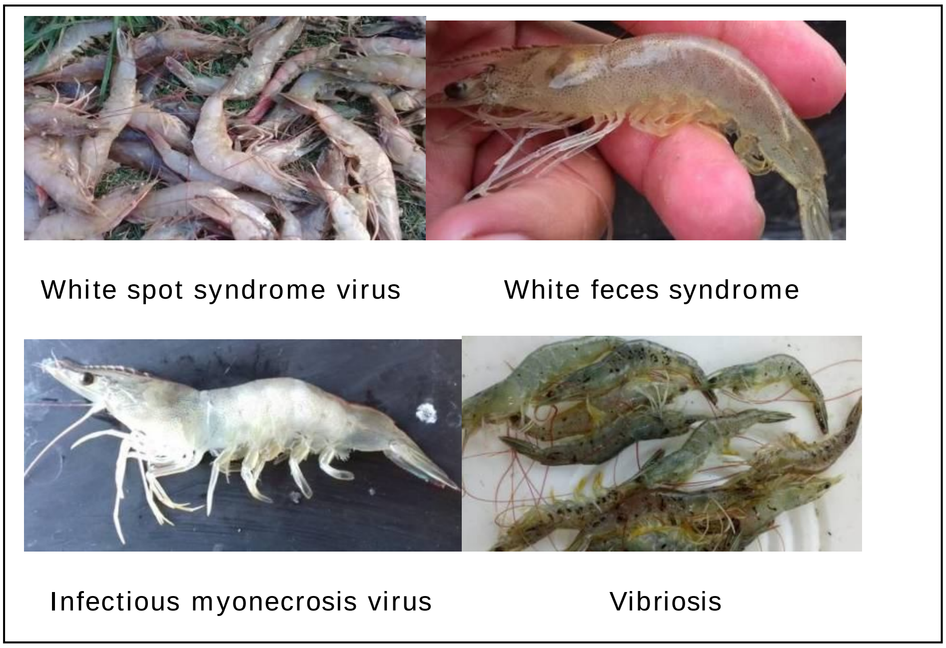

Figure 4. Diseases found in East Lampung.

Shrimp health management is carried out through prevention and treatment. Disease prevention is carried out by applying biosecurity, probiotic applications, and water quality management. Herbal ingredients such as ketapang (*Terminalia catappa*) and mangrove (*Rhizophora apiculata*) leaf extracts are widely used to treat WFS and reduce the population of *Vibrio* in pond water (Supono et al 2019).

Harvest type. There are two types of shrimp harvests carried out by farmers in Lampung Province using cash net from pond embankments, namely: partial and total harvests (Pratama et al 2017). The main purpose of partial harvesting is to reduce the population and increase shrimp growth. Furthermore, the excess shrimp biomass in ponds is indicated by a decrease in dissolved oxygen content of less than 4 mg L^{-1}, especially in the morning. The first and second partial harvests are carried out at the age of 60 and 75 days with shrimp weight of approximately 10 g and 15 g, respectively. In addition, their initially population are 20% and 30%, with the total harvest conducted at the end of the cultivation age of 110-120 days with shrimp weight of 25-30 g.

Shrimp performance. Pacific white shrimp growth at low salinity based on observations with pond sizes of 1000 m^2 and 2000 m^2 showed very good performance. At the maintenance age of 100 days, the pond size of 2000 m^2 had a shrimp weight of 24.5 g, while that of 1000 m^2, at 114 days (at harvest) was 21 g as shown in Figure 5. The slow growth of shrimp in ponds 1000 m^2 is due to a higher survival rate of 93% compared to 2000 m^2 at 85%. The shrimp grow at the lower density than at the higher density (Appelbaum et al 2002).

Semi-intensive shrimp farming in East Lampung Regency was able to increase pond productivity and farmer income. Previously, farmers only traditionally cultivated black tiger prawns with a productivity rate of 300-500 kg per hectare. However, after using the semi-intensive system, Pacific shrimp cultivation increased productivity by 10-13 tons per hectare with a feed conversion ratio of 1.3-1.5. Table 2 shows the Pacific white shrimp ponds' performance with a pond size of 1000 m^2 and 2000 m^2. Pacific white shrimp performance is better than that of black tiger, both in terms of growth and survival rate (Supono 2015).

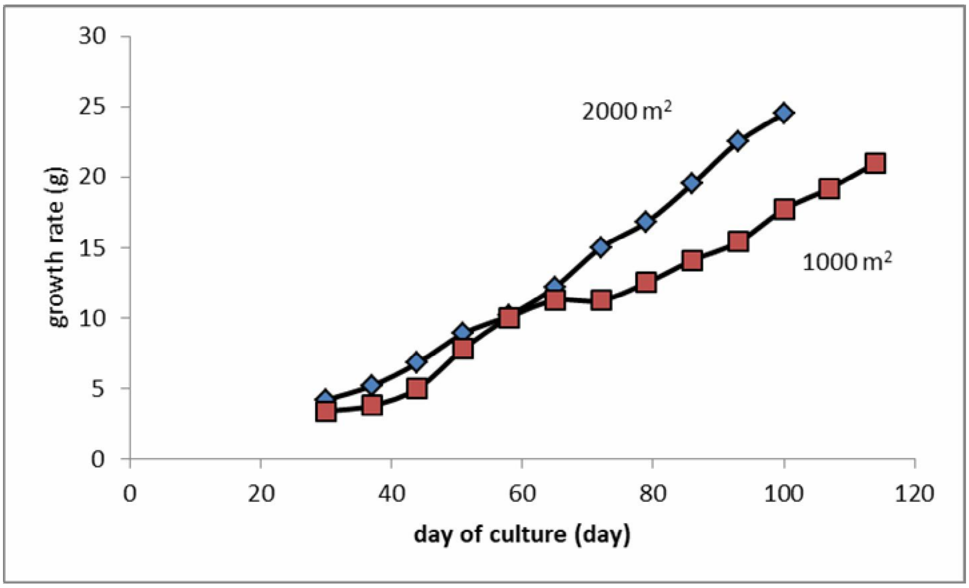

Figure 5. The growth of Pacific white shrimp.

Table 2

Performance of Pacific white shrimp cultured at low salinity

No	*Variable*	*Pond size*	
		2,000 m^2	*1,000 m^2*
1	Initial stocking	140,000 PL's	70,000 PL's
2	Stocking density (PL's m^{-2})	70	70
4	Survival rate (SR)	85%	93%
5	Partial harvest I (size 97)	310 kg (30,097 PL's m^{-2})	145 kg
6	Partial harvest II (size 76)	515 kg (39,313 PL's m^{-2})	130 kg
7	Final harvest (size 42)	1,180 kg	1,050 kg
8	Total harvest	2,005 kg	1,325 kg
9	FCR	1.5	1.3

Other problems. Besides diseases, farmers face several other problems during the cultivation process, such as the die-off plankton, which occurs, causing a drastic decrease in dissolved oxygen, especially at night. They also experienced high rainfall at the end of the year, which causes a decrease in pond water temperature and shrimp appetite. In some ponds, shrimps experienced slow growth and low survival rates, due to unknown reasons. There was also an increase in the water intake channel, thereby hindering its entry to the pond, especially during the initial cycle. Survival rate is influenced by the presence of disease and condition of the shrimp. Stress can cause a decrease in shrimp immunity and can even lead to death. The presence of disease, as well as shrimp conditions are influenced by environmental conditions (Duraiappah et al 2000).

Economic analysis. The yield on the pond with size 2000 m^2 observed 2005 kg with a selling value of IDR 159,204,000 and a production cost of IDR 86,830,000. Therefore, the production cost per kilogram was around IDR 43,300, and profitable, as shown in Table 3. One of the factors driving the increase in profit (benefit cost ratio) is the partial harvest, which is carried out twice during the cycle to improve the capital efficiency, which is indicated from the value of the benefit-cost at 0.83. Partial strongly covers the operational costs of farmers with small capital (Yu et al 2009).

Table 3

Economic analysis of Pacific white shrimp culture in East Lampung

No	*Remark*	*Number*	*Price (IDR)*	*Total value (IDR)*
	Production cost			
1	Fry	120,000	45	5,400,000
2	Feed	3,025	14,000	42,350,000
3	Chemicals			1,000,000
4	Fuel	2,600	5,800	15,080,000
5	Worker	4	1,500,000	6,000,000
6	Incentive	2,000	1,000	2,000,000
7	Others			5,000,000
8	Depreciation			10,000,000
	Total cost (1)			86,830,000
	Harvest value			
	Partial harvest I	310 kg		13,350,000
	Partial harvest II	515 kg		21,500,000
	Final harvest	1,180 kg		124,354,000
	Total harvest value (2)			159,204,000
	Benefit (2-1)			72,374,000
	B/C ratio			0.83
	R/C ratio			1.83

B/C ratio = benefit cost ratio; R/C ratio = revenue cost ratio.

There are two sources of energy used by farmers in East Lampung Regency to move the paddlewheel and lights, namely the generator set (Genset) using diesel fuel oil and current from the State Electricity Company (PLN). Data analysis showed that the use of electricity from PLN with 8% of the total cost is more efficient than Genset (15%). Meanwhile, the feed component contributed to the highest production cost (51%), followed by labor (21-22%). The composition of production costs is shown in Table 4.

Table 4

The composition of the production costs of pacific white shrimp cultivation

No	*Cost component*	*PLN*		*Genset*	
		Value (IDR)	*Percentage*	*Value (IDR)*	*Percentage*
1	Fuel	360,140	1	12,630,000	14.7
2	Electricity (PLN)	4,875,740	7	-	-
3	Seed	8,800,000	13	7,600,000	8.8
4	Feed	34,350,000	51	43,670,000	50.7
5	Workers	15,117,000	22	17,702,000	20.6
6	Others	920,000	1	1,910,000	2.2
7	Chemicals	3,150,000	5	2,600,000	3.0
	Total	67,572,880	100	86,112,000	100

Future prospects. Shrimp farming activities produce social and economic impacts on the surrounding community. Those conducted by the community in East Lampung Regency have the ability to drive the economy and improve the welfare of farmers and other people that directly participate in the business. Many professions have emerged from the development of inland Pacific shrimp farming activities, such as feeder, harvest servicers, pond, and electric technicians, buyers, sorters, and sellers of chemicals and feed. Based on economic analysis, Pacific white shrimp cultivation using low salinity (inland) has an excellent prospect to be developed in East Lampung Regency. The potential of untapped land also supports this.

Conclusions. The cultivation of pacific white shrimp with low salinity (inland shrimp culture) has developed well in Lampung Province. The growth and survival rate of acquired Pacific white shrimp is very good as well as very profitable economically. Inland shrimp culture can be a solution for developing shrimp culture for critical areas and far from the coast.

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