DOI: http://dx.doi.org/10.15578/iaj.20.1.2025.87-95 *Indonesian Aquaculture Journal, 20 (1), 2025, 87-95*

Available online at: http://ejournal-balitbang.kkp.go.id/index.php/iaj

A REVIEW OF THE DEVELOPMENT PACIFIC WHITE SHRIMP (*Litopenaeus vannamei*) FARMING IN INDONESIA

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(Received: May 8, 2024; Final revision: May 16, 2025; Accepted: May 16, 2025)

ABSTRACT

Pacific white shrimp (Litopenaeus vannamei) cultivation in Indonesia has been carried out since the early 2000s with satisfactory results. This shrimp is able to replace the previously cultivated black tiger (Penaeus monodon), which experienced cultivation failure due to disease attacks. The pond construction used includes an earthen pond, a lining pond, and a concrete pond, which are equipped with paddlewheels as a source of dissolved oxygen. Pacific white shrimp are mostly cultivated using semi-intensive, intensive, and super-intensive systems, depending on technological input and stocking density. Semi-intensive stocking density is around 50 PL/m^2, intensive 100 PL/m^2, and super-intensive 500 PL/m^2, with productivity of 10 tons/ha, 15 tons/ha, and 42 tons/ha, respectively. There are two types of harvests carried out by farmers in Indonesia, namely partial harvests and total harvests. The main aim of partial harvest is to reduce excessive shrimp biomass, as indicated by a decrease in dissolved oxygen content. Problems that often arise during the cultivation process are disease attacks such as white spots and infectious myonecrosis (IMN) caused by viruses, White Feces Syndrome (WFS) and Acute Hepatopancreatic Necrosis Disease (AHPND) caused by Vibrio parahaemolitycus and Enterocytozoon hepatopenaei (EHP). To increase the productivity of whiteleg shrimp cultivation, the advice given is to minimize disease attacks, namely by installing several biosecurity devices, such as bird scaring devices (BSD), crab protection devices (CPD), and water filtration. In addition, the application of a recirculation aquaculture system, biofloc technology, aquamimicry and whiteleg shrimp cultivation at low salinity (inland) can be an alternative cultivation in the future.

KEYWORDS: Aquamimicry; biosecurity; infectious myonecrosis; inland; white spot

INTRODUCTION

Shrimp are among the most widely cultivated aquatic species by farmers in Indonesia, primarily due to their high economic value and strong global market demand (Kopot & Taw, 2004). Initially, farmers cultivated black tiger shrimp (*Penaeus monodon*), which is a tropical aquatic shrimp. Black tigers have fast growth, but their survival rate is low. (Anwar, 2003). This species inhabits the bottom of water bodies, which limits its stocking density and increases susceptibility to bacterial infections. By the end of 1999, many farmers experienced significant losses in black tigers cultivation due to outbreaks of white spot disease (Supono, 2006). To replace black tiger shrimp, the Indonesian government brought in white shrimp, often called Pacific white shrimp (*Litopenaeus vannamei*). This shrimp is native to the Pacific coast of Mexico and Central and South America (Rosenberry, 2002), is considered more resistant to disease attacks, and has high productivity (Sugama *et al.*, 2006). This review discusses the development of Pacific white shrimp aquaculture in Indonesia, focusing on its history, pond construction, cultivation systems, production, inland shrimp culture, freshwater Pacific white shrimp, problems, and economic analysis, with the hoped that this review can help shrimp farmers, researchers, policy makers and academics for proper understanding in order to develop whiteleg shrimp farming in Indonesia.

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HISTORY

Shrimp cultivation was carried out by Indonesian farmers before 1980 using traditional systems, particularly along the North Coast of Java and the East

Coast of Lampung (Supono, 2006). The species initially cultivated was black tiger shrimp (*Penaeus monodon*), which is native to Indonesian waters (Taw *et al.*, 2002). At that time, shrimp post-larvae (PL) were sourced from the wild, with a stocking density of 2–5 PL/m² and a productivity of approximately 300 kg/ha (Hariati *et al.*, 1998). Intensification of shrimp farming practices began in the 1990s, incorporating the use of paddlewheels, commercial feed, chemical inputs, and higher stocking densities (30–40 PL/m²), with productivity reaching 6 tons/ha (Supono, 2015). However, black tiger shrimp farming began to experience widespread failures due to disease outbreaks, primarily caused by viruses and Vibrio spp. The main viral pathogens included white spot syndrome virus (WSSV) (Supono, 2006) and monodon baculovirus (MBV) (Nash *et al.*, 1988), while *Vibrio*-related diseases such as white feces syndrome also contributed to losses (Limsuwan, 2010).

Pacific white shrimp were first introduced to Indonesia in 1999, specifically in East Java and Bali (Sugama *et al.*, 2006). Initial trials yielded 10-15 tons/ha with a survival rate of 80–90%, a feed conversion ratio of 1.0–1.2, and an average size of 14.9–17.8 g over a 92–96 day culture period (Sugama, 2000). In Lampung, commercial cultivation of Pacific white shrimp began in the early 2000s (Kopot & Taw, 2004). By 2004, farmers in Tulang Bawang, Lampung, reported FCRs of 1.4, survival rates above 80%, and stocking densities of 100 PL/m² (Supono, 2006). Pacific white shrimp demonstrate high adaptability to a wide range of water temperature (Rosenberry, 2002) and salinities (Wyban & Sweeny, 1991; Davis *et al.*, 2002; Jayasankar *et al.*, 2009; Roy *et al.*, 2010). They also tolerate high stocking densities of up to 400 PL/m² (Sugama *et al.*, 2006), exhibit low FCRs (Briggs *et al.*, 2004), require lower dietary protein than *P. monodon* (Taw *et al.*, 2002), and are well accepted by global markets. Moreover, *L. vannamei* broodstock can be domesticated (Wyban, 2007; Sugama *et al.*, 2006; Lightner, 2011), and their seeds are specific pathogen-free (Sugama *et al.*, 2006), enabling better adaptation to pond conditions and improved health status.

POND CONSTRUCTION

Shrimp ponds used for cultivating Pacific white shrimp in Indonesia typically range from 1000 to 5000 m² and include earthen ponds (Taw *et al.*, 2002; Kopot & Taw, 2004), concrete ponds (Taw, 2005; Kilawati *et al.*, 2020), and, most commonly, fully or partially lined ponds (Taw *et al.*, 2002). Linings are made of high-density polyethylene (HDPE) (Valentine *et al.*, 2023) or plastic mulch (Supono, 2021). These pond are equipped with paddlewheels to supply dissolved oxygen, with the number of units adjusted based on the shrimp biomass. One 1 HP paddlewheel can support approximately 400–500 kg of shrimp (Taw & Setyo, 2014; Boyd *et al.*, 2018). According to Kopot & Taw (2004), in an earthen pond, a 1 HP paddlewheel can support 430 kg of shrimp biomass, and in a semi-lined pond, it can support 560 kg. To reduce the risk of disease, several biosecurity measures are implemented, including bird scaring devices (BSD), crab protection devices (CPD), and water filtration, were installed (Taw *et al.*, 2002, Delphino *et al.*, 2022).

Figure 1. Paddle wheel aerators in operations.

Figure 2. Crab protection device installed around the pond.

CULTURE SYSTEM

Intensification of the cultivation system remains the primary strategy for increasing pond productivity, particularly given the high density tolerance of Pacific white shrimp (Briggs *et al.*, 2004). Shrimp stocking density is influenced by water quality and the carrying capacity of the pond, which is greatly influenced by the number of paddlewheels in the pond. Pacific white shrimp in Indonesia are mostly cultivated using an intensive system with a stocking density of around 100 PL/m^2 (Supono, 2015). Ponds with high environmental quality and advanced technological support may adopt super-intensive systems with stocking densities exceeding 150 PL/m^2. In West Nusa Tenggara, for example, a stocking density of 250 PL/m^2 is practiced (Pratiwi *et al.*, 2022). In contrast, in areas with suboptimal environmental conditions, such as East Lampung, farmers apply semi-intensive methods with stocking densities of 50–70 PL/m² (Supono, 2021). Traditional-scale cultivation is less common. Hendrajat *et al.* (2007) reported that the traditional plus system in Maros, South Sulawesi, applied a stocking density of only 8 PL/m^2. Currently, the common vaname shrimp farming systems in Indonesia are semi-intensive, intensive, and super-intensive systems, depending on the technology input and stocking density. These systems maintain low, medium, high, and very high stocking densities, respectively. Optimal stocking density can provide many benefits including growth, survival, higher productivity as well as improving overall health status and reducing stress conditions in an aquaculture system. Higher stocking densities will increase total ammonia, nitrate and total phosphorus (Arambul-Muñoz *et al.*, 2019).

Several regions have also adopted the recirculating aquaculture system (RAS), such as in Tulang Bawang, Lampung Province, through the company PT. CP Bahari (Taw, 2005) and Gresik, East Java (Suantika *et al.*, 2018a). Prior to entering the culture ponds, sea water is sterilized from pathogens (viruses, bacteria) and predators (fish, snakes) using 30–40 mg/L chlorine. Waste water from cultivation ponds is channeled to a treatment pond consisting of a settling pond, a biological filter pond, and a reconditioning pond before being returned to the cultivation pond. The advantage of RAS is its ability to minimize pathogens such as viruses, bacteria, and fungi (Kenedy *et al.*, 2016; Suantika *et al.*, 2018b). Additionally, the use of ozonation at optimal doses has been shown to control the abundance of *Vibrio parahaemolyticus* in culture ponds (Pumkaew *et al.*, 2021). However, the system may not always function effectively due to limitations in the capacity of the treatment ponds to purify the wastewater adequately.

The biofloc (heterotroph) system has been implemented by Pacific white shrimp farmers in Indonesia since 2010. Although the system presents some challenges, it offers considerable potential to enhance production (Supono, 2019). The advantages of the biofloc system are faster growth, a low feed conversion ratio, and increased nonspecific immunity (Effendy *et al.*, 2016). However, its primary drawbacks are the high demands for carbon sources and electrical energy (Ma'in *et al.*, 2013). The application of the biofloc system is also applied in the nursery phase, where it has demonstrated the ability to maintain survival rates of up to 90% (Witoko *et al.*, 2023).

The aquamimicry system has been tested by farmers in several regions of Indonesia. Aquamimicry is a combined system of autotroph and heterotroph systems where there is a balance between bacteria, zooplankton, and phytoplankton that imitates estuary conditions (Romano, 2017; Cho & Yigit, 2022). Zooplankton, especially copepods as live food (Khanjani *et al.*, 2022), stimulated their growth by adding fermented rice bran to the pond (Subramanian *et al.*, 2023). Often referred to as a synbiotic system, this system does not require the addition of chemicals so it is a completely organic shrimp cultivation (Catalani *et al.*, 2023). Aquamimicry has been implemented in Indonesia, although performance data on shrimp cultivated under this system have yet to be published.

INLAND SHRIMP CULTURE

Pacific white shrimp can live well in a wide range of salinities, so they can be cultivated in both high and low salinities, although the best growth occurs at salinities of 10–15 ppt (Wyban & Sweeny, 1991; Davis *et al.*, 2002). Several regions in Indonesia have developed Pacific white shrimp cultivation in locations far from the coast using low-salinity water (inland). Farmers in Pasir Sakti District, East Lampung, have cultivated Pacific white shrimp using low salinity by utilizing groundwater as a water source. Pacific white shrimp reared in a 2000 m^2 pond with a density of 70 PL/m^2 produced 2005 kg, a survival rate of 85%, and a weight of 24.5 g for 100 days of rearing (Supono *et al.*, 2022). Ariadi *et al.* (2019) also reported that low-salinity shrimp cultivation in Probolinggo, East Java, was successful and very profitable. The main problem in cultivating low-salinity shrimp is mass death, especially during molting, which is caused by low macromineral content (Boyd, 2015).

FRESHWATER PACIFIC WHITE SHRIMP

Pacific white shrimp, as a euryhaline species, can survive in freshwater environments with salinity as low as 0 ppt (Araneda *et al.*, 2008). The innovation of cultivating Pacific white shrimp using fresh water has been carried out by several farmers in Palas District, Lampung (Supono *et al.*, 2023), Surabaya (Kusyairi *et al.*, 2019), and Lamongan (Mas'ud & Wahyudi, 2018), with notably successful results. Pacific white shrimp reared in freshwater ponds in Palas District have a productivity of 1.5 kg/m^2 (15 tons/ha), a survival rate of 82%, and a daily growth rate of 0.22g/day (Supono *et al.*, 2023). The advantages of freshwater cultivation include reduced prevalence of viral and bacterial diseases and the possibility of using cultivation waste as fertilizer in agriculture. However, the primary limitation is the lack of macrominerals in freshwater (Suguna, 2020), which are essential for metabolism, molting, and osmoregulation (Davis *et al.*, 2005). Therefore, mineral supplementation in ponds is necessary.

PROBLEMS

The failure of Pacific white shrimp cultivation in Indonesia is attributed to several factors, including disease outbreaks (Rafiqie, 2014; Hakim *et al.*, 2018; Suryana *et al.*, 2023), low mineral availability (Suguna, 2020), and a low survival rate (Pratama *et al.*, 2017). Based on research by Supono (2006), there are several causes of failure in shrimp cultivation in Tulang Bawang Regency, Lampung Province, namely: The main problem with Pacific white shrimp cultivation is disease attacks, both caused by viruses and bacteria. Diseases that attack ponds in Indonesia and are caused by viruses are white spot (Taw *et al.*, 2002; Sugama *et al.*, 2006; Kusuma *et al.*, 2020; Akbar *et al.*, 2022) and infectious myonecrosis (Sugama *et al.*, 2006; Nur'aini *et al.*, 2007, Taukhid & Nur'aini, 2008; Koesharyani *et al.*, 2019). Diseases caused by bacteria, especially *Vibrio parahaemolyticus*, include white feces syndrome (WFS), which occurs in Lampung Province (Supono *et al.*, 2019), Aceh (Arisa *et al.*, 2021), and East Java (Sumini & Kusdawarti, 2020), as well as acute hepatopancreatic necrosis disease (AHPND) found in Banten (Saputra *et al.*, 2023) and Bangkalan (Suryana *et al.*, 2023). Recent studies have linked WFS to the parasite *Enterocytozoon hepatopenaei* (EHP) (Nirea *et al.*, 2025)

HARVEST TYPE

There are two types of harvests carried out by farmers in Indonesia, namely partial harvests and total harvests (Pratama *et al.*, 2017). The main aim of partial harvest is to reduce excessive shrimp biomass, as indicated by a decrease in dissolved oxygen content. According to Da Silveira *et al.* (2022), partial harvest can increase survival rate, shrimp productivity, and pond water quality. A partial harvest can be used as an effort to fulfill local markets in small quantities (Chamberlain *et al.*, 2002). The first partial harvest is carried out when the shrimp reach a weight of 10 g, while the second is carried out when the shrimp reach a weight of 15–17 g (Supono, 2021). For farmers with limited capital, a partial harvest is very helpful to increase capital until the final harvest. The total or final harvest is carried out at a rearing age of 100–120 days, depending on the condition of the shrimp. Shrimp harvesting is carried out using cash net (partial harvest) and seine net (total harvest).

PRODUCTION

Initially, Pacific white shrimp were reared intensively at a density of 100 PL/m^2 with a productivity of 15 tons/ha, a survival rate of 84%, and a feed conversion rate of 1.4 (Supono, 2006), then increased to 500 PL/m^2 with a productivity of 42 tons/ha and a survival rate of 80% (Lailiyah *et al.*, 2018). However, for certain areas with poor environmental quality, such as East Lampung, this shrimp is cultivated using a semi-intensive system with a stocking density of 50 PL/m^2 and a productivity of 10 tons/ha and a survival rate of 85–93% (Supono, 2021). In the study conducted by Pratama *et al.* (2017), *L. vannamei* was cultivated semi-intensively with a stocking density of 66 PL/m^2 and a pond area of 1000 m^2, producing 1050 kg, a survival rate of 92.5%, and a feed conversion ratio of 1.3. A trial of cultivating Pacific white shrimp using a recirculating aquaculture system combined with zero water exchange in Gresik, East Java, with a stocking density of 500 PL/m^2 resulted in a productivity of 4.2 kg/m2 or 42 tons/ha for 84 days of rearing (Suantika *et al.*, 2018a). The application of the biofloc system in Pacific white shrimp cultivation at BBPAP Jepara resulted in a survival rate of 86–92%, a specific growth rate of 15.6%, and a feed conversion ratio of 1.3 (Mai'in *et al.*, 2013). Taw & Setio (2014) reported that the biofloc system implemented in Bali was able to overcome disease attacks caused by viruses and produce stable harvests of around 45–55 tons/ha.

ECONOMIC ANALYSIS

Pacific white shrimp cultivation is the most profitable business in aquaculture in Indonesia; even the revenue-cost (R/C) ratio can reach 1.71 (Wafi *et al.*, 2021). Meanwhile, according to Ariadi *et al.* (2019), the revenue-cost ratio for cultivating Pacific white shrimp at low salinity reaches 1.35. Feed is the largest component of operational costs (51%), followed by workers (22%), and seeds (13%) (Supono, 2021). Errors in feed management greatly affect the profits obtained by farmers. The efficiency of feed use in shrimp cultivation can be seen from the feed conversion ratio (FCR) value, which is the ratio of feed used divided by the shrimp biomass produced. A lower FCR shows that the feed used is more efficient. The ideal feed conversion ratio for Pacific white shrimp is 1.4–1.5 (Supono, 2015; Boyd *et al*., 2018). Variables for analyzing business financial feasibility in this article includes Break Event Point (BEP) analysis on the basis of sales and units, as well as the internal rate of return (IRR). The break-even point is the level of production at which total costs and total revenues are equal so that no profit is earned and no loss occurs. The break-even point can also be defined as the point where net profit is zero. Selling prices, fixed costs, or operational costs will not be fixed constantly, resulting in a change in the break-even point. Therefore, these things must be calculated periodically to reflect changes in costs and prices and to maintain profitability. The break-even price can be compared to the cost of production of a single unit of production. Profit is generated when break-even price is higher than the cost of production. Break-even production and break-even price offer additional insights into the overall feasibility of farming. Break-even production and breakeven selling price were calculated as follows (Gammanpila, 2015) :

Break even production = (Fixed cost + Annuity of investment) / (Farm-gate price per unit – Variable cost per unit production).

Break even sales price = Fixed cost per unit production + Variable cost per unit production.

Internal Rate of Return (IRR) is the level of net investment profit based on net present value (NPV) analysis and applicable interest rates. The IRR value is recognized as feasible and profitable if it is greater than the bank interest rate, and recognized as unfeasible if it is lower than the bank interest rate. IRR analysis is used as a form of evaluating the performance of investment value in a business. The IRR value can be calculated using the formula (Wafi *et al*., 2021):

$$\text{Internal Rate of Return (IRR)} = i' + \frac{NPV'}{NPV' - NPV''}(i'' - i')$$

Note: IRR = internal rate of return; i' = interest rates that produce a positive NPV; i" = interest rates that produce negative NPV; NPV' = NPV at the interest rate i'; NPV" = NPV at the interest rate i"

We need to explain that the economic data presented, including internal rate of return (IRR) data in this study, is data from field studies and projections modeled on a land area of 10 Ha with each pond area of 2000 m^2 (50 ponds) which are intensively cultivated (Table 1). In the analysis of the feasibility of

Table 1. Feasibility analysis of Pacific white shrimp farming (10 ha)

Remark	Price (IDR)	Number	Total Value (IDR)
Capital expenditure			
1. Land lease	15,000,000/ha/year	10 ha, 10 years	1,500,000,000
2. Pond construction	25,000,000/pond	50 ponds	1,250,000,000
3. Feed warehouse	20,000,000/unit	5 units	100,000,000
4. Guard house	20,000,000/unit	5 units	100,000,000
5. Paddlewheel 1 HP	5,000,000/unit	200 units	1,000,000,000
6. Pump 8"	6,000,000/unit	20 units	120,000,000
7. Genset 25 KVA	50,000,000/unit	10 units	500,000,000
8. Electrical installation	50,000,000	-	50,000,000
Total			4,870,000,000
Operational expenditure			
1. Fry	50/PL	10,000,000 PL	500,000,000
2. Feed	17,000	225,000 kg	3,825,000,000
3. Chemicals	2.500.000/pond	50 ponds	125,000,000
4. Fuel	15.000.000/pond	50 ponds	750,000,000
5. Electricity (PLN)	20,000,000/month	4 months	80,000,000
6. workers	8,000,000/person	20 persons	160,000,000
7. Incentive	1,500/kg	150,000 kg	225,000,000
8. Depreciation			310,750,000
9. Others	2,000,000/pond	50 ponds	100,000,000
			6,075,750,000
Revenue			
Partial harvest 1 (10 g)	50,000/kg	20,000 kg	1,000,000,000
Partial harvest 2 (15 g)	65,000/kg	30,000 kg	1,950,000,000
Final harvest (25 g)	75,000/kg	100,000 kg	7,500,000,000
Total harvest value			10,450,000,000
BEP (volume/kg)			10,656
BEP (value/IDR)			742,375,836
IRR (%)			66

this vaname shrimp cultivation business, environmental change factors, market fluctuations and risk factors were not taken into consideration.

Table 1 explains the feasibility analysis for cultivating Pacific white shrimp on an area of 10 ha with each pond size of 2000 m^2 (50 ponds), which is cultivated intensively.

The BEP analysis value based on volumes and sales in this business analysis produces 10,656 kg/cycle and Rp. 742,375,836,-/cycle. This means that the company will gain business profits if it is able to produce more than 10,656 kg of shrimp or is able to provide total value receipts of more than Rp. 742,375,836,-. BEP or production break-even point, is a technique that can be used by companies to determine production and sales volumes so that the company does not experience production losses. The Internal Rate of Return (IRR) values for intensively managed Pacific white shrimp cultivation (66%) are greater than the current bank interest rate of 12% per year. This shows that intensive cultivation of Pacific white shrimp is very profitable (Wafi *et al*., 2021).

CONCLUSION

Vannamei shrimp (*L. vannamei*) was introduced to Indonesia in late 1999 and began to be commercially cultivated in 2000. Vannamei shrimp has high productivity and is an alternative for farmers after experiencing failure in cultivating tiger shrimp (*P. monodon*). Several cultivation systems that have been used to cultivate vannamei shrimp, ranging from traditional to super intensive, are recirculation aquaculture, biofloc, and aquamimicry (synbiotic) systems. Vannamei shrimp productivity can reach 42 tons/ha (super intensive) and has been successfully cultivated in low salinity and fresh water. Based on economic analysis, vannamei shrimp cultivation in Indonesia is very profitable, despite the threat of disease attacks caused by viruses and *vibrio* as the main obstacle in vannamei shrimp cultivation. The recommendation given to increase shrimp production is to try to minimize disease attacks by installing several biosecurity devices, such as bird scaring devices (BSD), crab protection devices (CPD), and water filtration. In addition, the application of recirculation aquaculture systems, biofloc technology, aquamimicry and vannamei shrimp cultivation at low salinity (land) can be an alternative cultivation and this is a need for future research so that vannamei shrimp cultivation technology can be sustainable and support the national food security program in Indonesia.

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