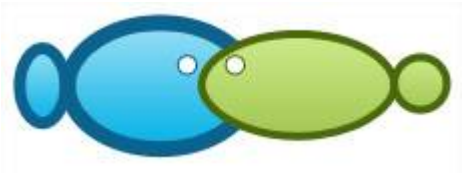

Estimated economic losses due to white spot syndrome virus (WSSV) disease in intensive vannamei shrimp culture business in Kendal Regency

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Abstract. White spot syndrome virus (WSSV) disease is one of the main problems in vannamei shrimp (*Litopenaeus vannamei*) culture which must be overcome. The disease emergence leads to a decrease in production and economic losses which further causes the cultivation to stop. On the other hand, if the vannamei shrimp culture is successful and not attacked by the disease, then the business yields profits and brings sustainable future. The aim of this study is to determine the amount of loss or profit obtained if the cultivated vannamei shrimp were infected with WSSV. Employing a descriptive design, data were obtained by means of structured interviews using a questionnaire set to farmers of intensive vannamei shrimp of 74 plots spread over four sub-districts in Kendal Regency. The results indicated that there were 36 ponds infected with WSSV with an estimated economic loss of Rp. 21,318,920,134 in 2022 equivalent to USD 1,421,261. The estimated production loss due to WSSV infection in 2022 was 1,702,821.15 kg with an estimated population loss of 5,609,293 vannamei shrimp over more than 400,663.8 m^2 or 40 ha infected area.
Key Words: loss, RC ratio, vannamei shrimp, viral disease, WSSV.

Introduction. The vannamei shrimp (*Litopenaeus vannamei*) culture business in Indonesia is growing rapidly and has become a priority program of the Ministry of Marine Affairs and Fisheries since it does not only create jobs but also increases farmers' income and generates foreign exchange. Intensive shrimp culture is a type of business that not only potentially breeds high profit and capital intensive, but also has a high risk of failure due to diseases. A viral disease that attacks vannamei shrimp results in significant losses, thus leading to a decrease in income and causing business discontinuation (KKP 2020). According to Rushton et al (2021), disease burden is identified as the amount of cost, time and energy lost due to the disease. In other words, it is the loss caused by the disease. The loss of vannamei shrimp production in the first white spot syndrome virus (WSSV) infection to attack shrimp ponds in the world has been reported by Bir et al (2017). Moreover, the disease infection attacking barramundi (*Lates calcarifer*) in the rearing culture in Mediterranean (Sánchez et al 2022), and in Malaysia (Nor et al 2019) caused significant economic losses. Other studies also reported the impacts of diseases attacking salmon (*Salmo salar*) (Abolofia et al 2017; Iversen et al 2020), catfish (*Ictalurus punctatus*) in East Mississippi America (Peterman & Posadas 2019), penaeid shrimp in Honduras, Central America (Valderrama & Engle 2004) resulting in production and revenue lost. However, there has not been any study conducted to measure the economic losses due to WSSV infection in vannamei shrimp in Indonesia. Therefore, this study aimed at calculating how much economic value, production and vannamei shrimp population was lost due to WSSV disease in vannamei shrimp culture in Kendal Regency, Central Java, Indonesia.

Material and Method. This research was conducted in May to December 2022 at the intensive vannamei shrimp culture in Kendal Regency, Central Java. Respondents of this study

were farmers of intensive vannamei shrimp culture in Kendal Regency, Central Java, Indonesia. The data collection methods used in this study were observation and structured interviews. Observations were conducted to 74 plots of intensive vannamei shrimp culture ponds in Kendal Regency. There were primary and secondary data employed in this study. Primary data were obtained by direct observation and structured interviews using questionnaires. The primary data was cross section data during May - December 2022 which included economic aspects, consisting of variable total fixed costs, production costs, prevention costs, revenue, yield, profitability and business efficiency (R/C ratio). The data were then analyzed which involved cost analysis consisting of fixed costs and variable costs. The fixed costs in this study consisted of depreciation costs and monthly labor costs. Meanwhile, the variable costs consisted of production costs and prevention costs. The production costs included costs for feed, seeds, electricity, fuel, and consumption, while the prevention costs consisted of lime, minerals, probiotics and drugs as reported by Wijayanto et al (2017). The formula of production costs is as follows:

$$TC = TFC + TVC$$

where: TC = total cost (Rp/production cycle);
TFC = total fixed cost (Rp/production cycle);
TVC = total variable cost (Rp/production cycle).

Revenue is calculated by multiplying product quantity by the price of the product. The obtained revenue is used to calculate the yield. The formula to calculate revenue is as follows (Sánchez et al 2022):

$$TR = P \times Q$$

where: TR = total revenue (Rp/production cycle);
P = vannamei shrimp price (Rp/production cycle);
Q = quantity of sold vannamei shrimp (kg).

Yield is calculated by reducing total revenue by total cost (Sánchez et al 2022). The formula to calculate yield is as follows:

$$Y = TR - TC$$

where: Y = yield (Rp/production cycle);
TR = total revenue (Rp/production cycle);
TC = total cost (Rp/production cycle).

According to Majer et al (2020), profitability is profit before interest and taxes divided by total costs multiplied by one hundred percent, which can be formulated as follows:

$$\text{Profitability} = \frac{\Pi}{TC} \times 100$$

where: Π = profits from vannamei shrip culture (Rp/production cycle);
TC = total expenditures for the vannamei shrimp culture (Rp/production cycle).

Criteria used to calculate profitability include:
- profitability > 0 means that the vannamei shrimp culture business gains profit;
- profitability = 0 means that the vannamei shrimp culture business is even;
- profitability < 0 means that the vannamei shrimp culture business does not yield profit.

Based on Wijayanto et al (2017), R/C ratio (revenue/cost ratio) is an analysis that can be used to measure the efficiency level of a company in achieving the feasibility level by using its minimum production factors. The formula to calculate R/C ratio is as follows:

$$R/C = TR/TC$$

where: R/C = revenue/cost ratio;
TR = total revenue;
TC = total cost.

Criteria used to calculate R/C Ratio are as follows:
- R/C ratio > 1 means that the business is profitable;
- R/C ratio = 1 means that the business is even;
- R/C ratio < 1 means that the business is losing.

Results and Discussion

White spot syndrome virus (WSSV) disease. White spot syndrome virus (WSSV) causes significant economic losses in vannamei shrimp culture businesses worldwide (Ganjoor

2015; Trang et al 2019a). WSSV is the main pathogen causing the plague of white spot disease (WSD) which causes a significant decrease in shrimp production (Manoppo et al 2010; Koesharyani et al 2019; Amelia et al 2021; Vaiyapuri et al 2021). This virus has a double-stranded rod-shaped viral DNA, is a member of the *Whispovirus* genus in the Nimaviridae family (Bir et al 2017). WSSV is the most dangerous virus and causes high mortality in penaeid shrimp, especially tiger shrimp (*Penaeus monodon*) and vannamei shrimp (Hidayani et al 2016). This is the main factor of harvest failure in shrimp culture business (Supono 2021). The initial detection of this virus was in China in 1992 which was reported by shrimp farmers (Jiang et al 2009; Walker & Mohan 2009), which then spread in Japan in 1993 (Walker & Mohan 2009). The WSSV was first identified in Bangladesh in 1994 (Debnath et al 2014). Moreover, it was first reported by shrimp farmers in Texas in November 1995. WSSV spread in Spain and Australia in 2000-2001. Recently, WSSV attacks ponds around the world (Lightner et al 1997).

Result of the research conducted in ponds in Kendal Regency, Central Java Indonesia shows that WSSV also infected vannamei shrimp in intensive culture located in five districts in Kendal Regency, Central Java Indonesia. They include Rowosari, Kangkung, Kaliwungu, Patebon and Kendal Districts. However, in Kendal District, researchers found it difficult to obtain data due to several reasons, including the facts that the farmers were not being open, the farmers did not keep records neatly, and the farmers did not want to be visited. Therefore, the data of the research were only obtained from four districts with a total sample of 74 pond plots. There were 36 vannamei shrimp ponds infected by WSSV in the area. WSSV is a deadly virus that causes crop failure (Ganjoor 2015).

Clinical symptoms due to WSSV infection. In Indonesia, the most dangerous viral disease attacking and causing a lot of harm to vaname shrimp farmers are WSSV, taura syndrome virus (TSV), infectious myonecrosis virus (IMNV), infectious hypodermal and hematopoietic necrosis virus (IHHNV) (Taukhid & Nur'aini 2010; Ganjoor 2015; Amelia et al 2021) and yellow head virus (YHV) (Ganjoor 2015; Amelia et al 2021). According to Ganjoor (2015), two viruses that are very deadly in shrimp are WSSV and TSV. Each of these virus attacks has different clinical symptoms. Amrillah et al (2015) reported that there are three levels of clinical symptoms due to WSSV virus including mild, moderate, and severe infections.

Figure 1 shows the vannamei shrimp infected with WSSV in Kendal Regency. Meanwhile, Figure 2 depicts the vannamei shrimp not infected with WSSV in Kendal Regency.

Figure 1. Vannamei shrimp infected by white spot syndrome virus (WSSV) in Kendal Regency.

Figure 2. Vannamei shrimp not infected by white spot syndrome virus (WSSV) in Kendal Regency.

Based on the interviews with pond technicians, clinical symptoms of shrimp infected with the WSSV included sticking to the walls of the pond, showing pink color, swimming in the water surface, decreasing appetite, having many white spots on the shell of the head.

These clinical symptoms are similar to those reported by Pradeep et al (2012) and Wiradana et al (2019) that shrimp infected with the WSSV have the main characteristics of the appearance of white spots on the carapace with a diameter of 0.5-2 mm, decrease appetite, be sluggish, and there is a change in color in the body of the shrimp.

These clinical symptoms were experienced by vannamei shrimp infected with WSSV at various ages, thereby resulting in many deaths. The most deaths found among vannamei shrimp infected with WSSV in Kendal Regency were at the age of 0-40 days in 11 plots, 40-80 days in 23 plots and over 80 days in one plot. In the rearing farming, shrimp at all ages and sizes are very sensitive to WSSV. The highest mortality rate is usually recorded in the culture period 1-2 months after stocking (Trang et al 2019a). This virus attack results in not only the production failure but also economic losses. This has a huge impact on the sustainability of the intensive vannamei shrimp culture business in Kendal Regency in the future.

The average loss of vannamei shrimp culture due to WSSV infection in Kendal Regency. Losses due to a viral disease that attacks vannamei shrimp in ponds in Kendal Regency were in the form of decrease in production, loss of vannamei shrimp populations, and reduction in income. The income decreased because many vaname shrimp infected with WSSV were dead. Economic losses were measured by calculating the profitability of each pond plot to obtain the average data per pond infected with WSSV and compared with ponds which were not infected with the disease. The data are presented in Table 1.

Table 1

Average per cycle in pond infected with WSSV in Kendal Regency

Parameter	*Average value*	
	Infected with WSSV	*Not infected with disease*
Plot area (m^2)	3,992.42	1,400
Stocking density (head m^{-2})	103	135
Stocking number (head $plot^{-1}$)	422,855	184,369
Shrimp age (day $plot^{-1}$)	49	110
Survival rate (%)	68.07	85.61
Mortality (%)	31.93	14.39
FCR	1.14	1,36
Average fixed cost (Rp $plot^{-1}$)	17,944,011	13,101,207
Average fixed cost (Rp $plot^{-1}$ m^{-2})	5,042	11,209
Average fixed cost (%)	16.91	11.76
Average production cost (Rp $plot^{-1}$)	78,701,030	96,426,391
Average production cost (Rp $plot^{-1}$ m^{-2})	21,543	72,225
Average production cost (%)	67.90	78.74
Average prevention cost (Rp $plot^{-1}$)	16,077,734	11,178,572
Average prevention cost (Rp $plot^{-1}$ m^{-2})	4,734	8,798
Average prevention cost (% total cost)	15.20	9.5
Average production (kg $plot^{-1}$)	1,451.61	2,594,09
Average production (kg $plot^{-1}$ m^{-2})	0.43	1.96
Average population death (head $plot^{-1}$)	164,707	27,277
Average population death (head $plot^{-1}$ m^{-2})	33	19
Average production loss (kg $plot^{-1}$)	899.95	627.45
Average production loss (kg $plot^{-1}$ m^{-2})	0.20	0.44
Average total expenditure (Rp $plot^{-1}$)	112,722,775	120,706,169
Average total expenditure (Rp $plot^{-1}$ m^{-2})	31,320	92,232
Average total yield (Rp $plot^{-1}$)	56,426,200	172,907,024
Average total yield (Rp $plot^{-1}$ m^{-2})	18,014	132,135
Profitability (Rp $plot^{-1}$)	-56,296,576	52,200,855
Profitability (Rp $plot^{-1}$ m^{-2})	-13,306	39,903
Profitability (%)	-50.79	42.60
R/C ratio	0.49	1.43
Total plot infected by WSSV in Kendal	36	-
Total plot not infected by WSSV in Kendal	-	16
Average loss in Kendal (Rp $plot^{-1}$)	Rp 108,497,431	

Table 1 shows the average area of ponds infected with WSSV covering an area of 3,992.42 m plot^{-1} with a total of 36 plots. While those that were not infected were 1400 m plot^{-1} with a total of 16 plots. The average stocking density of shrimp infected with WSSV was 103 individuals m^{-2} while those not infected with the disease had an average stocking density of 135 individuals m^{-2}. The average number of stockings of shrimp infected with WSSV was 422.855 individuals plot^{-1} while those that were not infected with the disease were 184,369 individuals plot^{-1}. Due to the WSSV infection, the average harvested age of vannamei shrimp was 49 days. Meanwhile, in the ponds not infected with WSSV, the average harvested age of vannamei shrimp was 110 days. Maximum profit is obtained when the age of the shrimp is at least 112 days per cycle (Wijayanto et al 2017). The average survival rate due to WSSV infection was 68.07%, the survival rate for shrimp that was not infected was 85.61%. The average mortality due to WSSV infection was 31.93%, while the mortality of those which were not infected was lower than those infected with WSSV, 14.39%. WSSV infection in vannamei shrimp is characterized by rapid death because WSSV infection can attack vannamei shrimp up to 100% within 7-10 days (Trang et al 2019a).

Feed costs contribute more than 50% of total expenditure (Asche & Oglend 2016). The average FCR due to WSSV infection is 1.14, lower than that not being infected at 1.36. The higher the FCR, the higher the costs incurred, similar to that reported by Iversen et al (2020). The amount of feed costs affects the amount of production costs and total expenses. The total feed cost in ponds that were not infected with WSSV was higher than those infected with WSSV. This was influenced by the length of time the shrimp were reared, the longer the age of the shrimp, the higher the FCR average. This was also influenced by the culture actions in which when the shrimp were infected, the feed was reduced.

The average fixed cost was Rp. 17,944,011 per plot. This fixed fee was affected by the different pond facilities owned by each farmer and the monthly labor costs. The average production cost due to WSSV infection was Rp. 78,701,030. The average production cost was influenced by the number of pond plots and the length of time the shrimp were reared. The longer the shrimp were reared, the greater the production cost was incurred during the production process. The average cost of prevention due to infection with WSSV was Rp. 16,077,734, which was higher than the average cost of prevention of those not infected with the disease. According to Iversen et al (2020), the prevalence and impact of diseases have large cost implications. The cost of this prevention is influenced by the presence or absence of disease infections that attack vannamei shrimp and is influenced by the length of time the shrimp are reared. In addition, it is also influenced by the actions performed by the farmers in making decisions when vannamei shrimp are attacked by diseases. Generally, the prevention costs are always presented before the shrimp are infected with disease. Thus, whether there is or there is no disease that infects vannamei shrimp, this prevention cost is always present. The average total expenditure due to WSSV infection was IDR 112,747,775 and the average yield from shrimp harvest due to WSSV infection was Rp. 56,426,200 per plot.

The average profitability of vannamei shrimp ponds due to WSSV infection was a loss of Rp. -56,296,576 while the average profitability of that not infected with the disease was Rp 52,200,855 per plot. This resulted in an average population loss due to WSSV infection of 164,707 vannamei shrimp/plot. Meanwhile, the average R/C ratio because of the WSSV infection was 0.49. This means that on the average the WSSV infected ponds suffered losses. According to Nguyen et al (2020), the cost greatly affects profits. The greater the costs incurred, the less the profit gained.

According to research result conducted by Iversen et al (2020), disease outbreaks have an important role in changing the production costs in salmon culture in 5 main producing countries, including Canada, Chilli, Faroe Islands, Norway, and Scotland. The estimated costs spent on disease prevention in shrimp culture around the world have reached USD 15 billion since the onset of the disease. The disease outbreak that occurred in Ecuador in 1999 resulted in a reduction in production of more than 60% with losses of more than USD 1 billion in 1998-2001 (Chakraborty & Ghosh 2014). Similar conditions

were also experienced in Peru and Panama, where shrimp production decreased by up to 90% with losses of USD 100 million and USD 70 million over a period of three years (Bir et al 2017). China experienced the highest production decline of 180 mt (metric tons) in 1992, followed by Thailand by 130 mt in 1994 and Taiwan by 100 mt in 1987. The lowest decline was reported in Mexico in 1994 with a loss of 1 mt. Meanwhile, the shrimp production in Indonesia decreased because of WSSV infection appearing for the first time in 1992 causing losses reaching approximately USD 1 billion (Israngkura & Sae-Hae 2002). The presence of a viral disease that attacks the brood and fry of vannamei shrimp in the shrimp culture industry spread across Asian countries was reported by Wiradana et al (2019).

Estimated total losses of vannamei shrimp culture due to WSSV infection in Kendal Regency. The data of estimated total loss caused by the WSSV infection to vannamei shrimp culture in ponds in Kendal Regency during the first and second cycles in 2022 are presented in Table 2.

Table 2

Estimated total loss cycle 1 and 2 due to WSSV infection to intensive vannamei shrimp culture in Kendal Regency in 2022

Parameter	*Cycle 1*	*Cycle 2*
Total area of productive ponds (m^2)	610,480	502,475
Total plot of productive ponds (plot)	248	196
Estimated WSSV infected percentage (%)	36	36
Estimated WSSV infected plot area (m^2)	219,772.8	180,891
Estimated population loss (head)	3,076,819	2,532,474
Estimated loss (Rp m^{-2})	53,209	53,209
Estimated loss (kg $plot^{-1}$ m^{-2})	1.53	1.53
Estimated total loss per cycle (kg)	934,034.4	768,786,75
Estimated total loss per cycle (Rp)	11,693,890,915	9,625,029,219

Note: 2 cultivation cycles are carried out per year.

Table 2 shows the total area of productive ponds in Kendal Regency in 2022 in cycle 1 by as large as 610,480 m^2 and cycle 2 of 502,475 m^2. The total plots of productive ponds in Kendal Regency in the cycle 1 were 248 plots and in the cycle 2 they decreased by 52 plots due to losses caused by the disease. Additionally, the selling price of vannamei shrimp fell. The estimated percentage of the total area of ponds infected with WSSV was 36%. The estimated area of the WSSV infected plots in cycle 1 and cycle 2 decreased by 38,881.8 m^2. It is assumed that the difference of the population loss in 2022 between cycles 1 and cycle 2 is 544,345 vannamei shrimp. Table 3 shows that the total estimated production lost due to WSSV infection in 2022 is 1,702,821.15 kg and the estimated total population lost due to WSSV infection is 5,609,293 vannamei shrimp. The estimated total loss due to WSSV infection in 2022 is IDR 21,318,920,134 equivalent to USD 1,421,261.34. WSSV is the most detrimental pathogen for shrimp culture (Escobedo-Bonilla et al 2008; Sánchez-Paz 2010). WSSV virus transmission can occur horizontally and vertically (Taukhid & Nur'aini 2010).

Table 3

Estimated total loss due to WSSV infection to intensive vannamei shrimp culture in Kendal Regency in 2022

Parameter	*(Cycle 1)+(Cycle 2)*	*Total*
Estimated total loss due to WSSV infection in 2022 (Rp)	(11,693,890,915)+(9,625,029,219)	21,318,920,134
Estimated total production loss due to WSSV infection in 2022 (kg)	(934,034.4)+(768,786,75)	1,702,821,15
Estimated total population loss due to WSSV infection in 2022 (head)	(3,076,819)+(2,532,474)	5,609,293

In shrimp culture in ponds, horizontal transmission of the virus can occur through pond water, cannibalism, and oral consumption. Meanwhile, vertical transmission occurs through the mother transmitting it to the larvae when they hatch, from plankton or wild animals. WSSV has high virulence and is very fast spreading or transmission. Besides, this virus can cause cumulative mortality up to 100% within 3 to 10 days (Lightner 2011).

Shrimp production in Indonesia experienced an increase for six years between 1985 and 1991. However, since then it decreased and reached a loss of USD 1 billion due to WSSV infection in 1992 (Bir et al 2017). Global losses due to this disease had previously exceeded USD 3 billion per year, impacting a global industry worth USD 19 billion per year (Millard et al 2021). Total economic losses due to viral diseases in shrimp culture in several Asian countries including Thailand, the Philippines, Vietnam, Indonesia, China, Taiwan, India, and Bangladesh and outside Asia such as Mexico, Ecuador, and the United States in 1994 amounted to USD 3.019 million, the production loss was 541 mt and a total loss percentage of 74% (Bir et al 2017). In the Philippines, shrimp production decreased from 1-1.5 tons per hectare to less than 200 kg per hectare due to WSSV disease in 2014. The production loss was 800 to 1300 kg per hectare or a loss percentage of 80% (Lowell 2020). In 2022, the estimated economic loss due to WSSV infection in intensive vannamei shrimp culture in Kendal Regency was Rp. 21,318,920,134, equivalent to USD 1,421,261.34. The estimated production loss was 1,702,821.15 kg and the population loss was 5,609,293 vaname shrimp with a WSSV infected plot area of more than 400,663.8 m^2 or 40 Ha.

Measures to handle viral disease in vannamei shrimp. The significant economic losses due to viral diseases including the WSSV in Kendal Regency often occur because of the environmental changes and high density so that the transmission is very fast (Trang et al 2019b). This is also due to significantly fluctuating weather that causes extreme temperature changes (Millard et al 2021; Nguyen et al 2021). The changes in water salinity can also reduce the shrimp's immune system (Amrillah et al 2015) that causes shrimp to experience stress. Stress due to high density (Sadhu et al 2015), drastic changes in temperature, pH, ammonia, nitrate, and dissolved oxygen cause the shrimp more susceptible to disease (Nor et al 2019). Changing water salinity causes metabolic changes that occur in the hemolymph during the infection process of this virus, causing a decrease in immune function and an increase in the susceptibility of shrimp to pathogens (Yoganandhan et al 2003). Increased activity in hemolymph metabolism in the early stages of WSSV infection takes place due to the mobilization of energy reserves towards the hepatopancreas and muscles, to meet energy needs to ward off infection. Decrease hemolymph metabolism was significant in infected shrimp under salinity stress. This can be described as the disorganization of the energy flow to support osmotic processes under the dual stress due to salinity and pathogenic stress. The metabolic response variable has a correlation with several immune variables. It can be explained that the poor metabolic response causes decreased immunity thereby increasing the amount of virus in infected shrimp (Wang et al 2008).

The process of WSSV infection mechanism initially occurs when the virus enters the vannamei shrimp's body through the intracytoplasm into the host cell. Then at higher levels of infection, the viral DNA enters to the host DNA and takes over the transcription and translation processes according to the viral DNA. At the transcription and translation stages, the WSSV gene expresses a non-structural protein called ICP11, which is considered important in WSSV infection (Amrillah et al 2015). Exposure to stress in shrimp can increase the risk of WSSV attack, because stress damages the vannamei shrimp's immune system (Doan et al 2009). As a result, when shrimp are under stress conditions, WSSV can reproduce rapidly and cause death in shrimp. The solution for controlling this viral disease for which there is no cure is prevention by providing special feed compositions with vitamins, immunostimulants, and vaccinations and cultivating in an environmentally friendly manner to prevent WSSV disease (Manoppo et al 2010; Haryanti et al 2014; Feng et al 2017; Rajkumar et al 2017). Up to recently, intensive vannamei shrimp farmers in Kendal Regency have taken precautions before the shrimp are attacked by disease, starting from the initial preparation of the pond by treating

water entering the sterile pond, buying shrimp seeds that are SPF (Specific Pathogen Free) certified, providing vitamins through feed, and maintaining water quality. However, so far, not all farmers do regular water quality measurements due to the limitations of the tools they have. Aquaculture waste has not been managed properly. The water is only resided without given wastewater treatment before being discharged into the river. This also causes pollution and is suspected of transmitting viral diseases to all aquatic ecosystems, both farmed animals and wild animals in rivers or seas around the culture site. Thus, the measure taken by the farmers if their shrimp are infected with WSSV is to harvest them immediately. The Ministry of Marine Affairs and Fisheries of the Republic of Indonesia has intensively socialized Good Fish/Shrimp Culture Methods to intensive vannamei shrimp farmers through the Department of Marine Affairs and Fisheries, Kendal Regency to be implemented, so that the intensive vannamei shrimp culture industry in Kendal Regency remains sustainable.

Conclusions. Economic losses in vannamei shrimp culture business infected with WSSV in Kendal Regency in 2022 amounted to Rp. 21,318,920,134 that is equivalent to USD 1,421,261.34. The estimated production loss due to WSSV infection in 2022 was 1,702,821.15 kg with an estimated population loss of 5,609,293 vannamei shrimp in a WSSV infected plot area of more than 400,663.8 m^2 or 40 ha. Vaname shrimp infected with a viral disease requires fast action. It is suggested that quarantine is preferably performed fast. Moreover, sterilization and biosecurity of both equipment and the environment should be carried out immediately. Additionally, it is importance to have insurance for intensive vannamei shrimp culture so that the business continues.

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