Economic impact due to infectious myonecrosis virus (IMNV) disease in intensive vannamei shrimp aquaculture in Kendal Regency

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Abstract. Infectious myonecrosis (IMN) is a viral disease that attacks vannamei shrimp in intensive aquaculture in Kendal Regency. This virus often appears in every cycle of vannamei shrimp aquaculture, resulting in a decrease in yields and production due to shrimp death caused by infectious myonecrosis virus (IMNV). The purpose of this study is to determine the amount of the economic loss due to IMNV on intensive vannamei shrimp aquaculture in Kendal Regency. Employing a descriptive design, the data of this research were obtained from interviews and direct surveys to the locations of intensive vannamei shrimp aquaculture in Kendal Regency as many as 74 plots spread over four districts in Kendal Regency. The results showed that the pond area affected by IMNV was 467,441.1 m^2 equivalent to 46.7 ha. The total number of vannamei shrimp deaths due to IMNV infection in 2022 in Kendal Regency was 8,881,381 heads with a mortality rate of 29.86%. The amount of lost production due to IMNV was 257,092.6 kg or 257 tonnes. The profits from intensive vannamei shrimp farming infected with IMNV in Kendal Regency were smaller as compared to those obtained from healthy aquaculture plots. Therefore, in other words the profit reduced to Rp. 372,341,359 per hectare, equivalent to USD 24,822.76 per hectare.
Key Words: loss, profit, shrimp, viral disease.

Introduction. One of the fisheries commodities in Indonesia that provides the largest foreign exchange value is shrimp. This is evidenced by data on the export value of fishery products, shrimp is the highest export commodity both in terms of volume and value in 2020 with a volume of 239,282,011 kilograms and a value of USD 2,040,184,255. In the period of 2016-2020, shrimp experienced an average increase in export volume of 8.70% (DGSCMFP 2021). From the description above, it shows that high-value shrimp commodities continue to be developed with sustainable shrimp aquaculture. One type of shrimp that contributes the highest foreign exchange is vannamei shrimp (*Litopenaeus vannamei*) (DGSCMFP 2021). Vannamei shrimp are widely cultivated in the coastal areas of Central Java, one of which has been intensively cultivated in Kendal Regency.

Kendal Regency is one of the regencies in Central Java which has great potential in the field of fisheries, especially vannamei shrimp aquaculture. The total production of vannamei shrimp in Kendal Regency in 2018 was 8,609.11 tons worth approximately Rp 602 billion and in 2019 decreased to 7,829.13 tons worth approximately Rp 501 billion (BPS Kendal Regency 2020). The data show that production of vannamei shrimp in Kendal Regency decreased in 2019. One of the reasons for this decrease in production was a viral disease that attacked vannamei shrimp and caused harvest failure resulting in considerable losses. Several studies on the impact of diseases on several commodities spread across several countries include the impact of diseases that attacked barramundi (*Lates calcarifer*) in the Mediterranean (Fernández-Sánchez et al 2022) and in Malaysia (Nor et al 2019). The impacts of diseases affecting marine and fishery products have also been reported to attack salmon (*Salmo salar*) by Abolofia et al (2017) and Iversen et al (2020) in Norway and by Iversen et al (2020) in Canada, Chilli, Faroe Islands, and Scotland; catfish (*Ictalurus punctatus*) by Peterman & Posadas (2019) in East Mississippi America; penaeid shrimp by Valderrama & Engle (2004) in Honduras, Centra America; vannamei shrimp by Patil et al (2021) in India which resulted in many deaths and caused significant losses of production and yield. Vannamei shrimp aquaculture is a high-risk, capital-intensive yet profitable business if the business is successful. However, if the ponds are attacked by a viral disease which causes many deaths, it results in decreased production and even losses. Nonetheless, there has not been any research to identify the amount of the economic loss due to infectious myonecrosis virus (IMNV) infection in Indonesia. Therefore, this study aims to estimate the profit, production, and population loss due to IMNV disease in vannamei shrimp aquaculture in Kendal Regency, Central Java, Indonesia.

Material and Method. The data were collected through direct observation conducted to 74 plots of intensive vannamei shrimp aquaculture ponds in kendal regency. There were primary and secondary data collected in this study. Primary data were obtained by direct observation and structured interviews using questionnaires. The primary data was in the form of "cross section" data during May to December period in 2022. The data covered economic aspects, consisting of variable total fixed costs, production costs, prevention costs, revenue, yield, expenses, profitability, and business efficiency (revenue/cost (R/C) ratio).

Data analysis in this study included cost analysis consisting of fixed costs and variable costs. Fixed costs in this study consisted of depreciation costs and monthly labor costs. Whilst variable costs consisted of production costs and prevention costs. Production costs included costs for feed, seeds, electricity, fuel, and consumption, while prevention costs involved lime, minerals, probiotics and drugs (Wijayanto et al 2017). The analysis methods used to determine the profitability of the intensive vannamei shrimp aquaculture in kendal regency are as follows:

1. Calculating the total costs incurred during one cultivation cycle by adding up the total fixed costs and the total variable costs (Wijayanto et al 2017) as follows:

$$TC = TFC + TVC$$

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

2. Calculating the total yields obtained during one cultivation cycle by multiplying harvested shrimp number by shrimp price (Fernández-Sánchez et al 2022) as follows:

$$TR = Q \times P$$

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

3. Calculating the total yield obtained during one cultivation cycle by reducing total revenue by total cost (Fernández-Sánchez et al 2022) as follows:

$$Y = TR - TC$$

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

4. Calculating profitability obtained by dividing profit by total expenses multiplied by one hundred percent (Majer et al 2020) as follows:

$$Profitability = \Pi/TC \times 100$$

where: Π = profit from vannamei shrimp aquaculture (Rp/production cycle);
TC = total expenses of vannamei shrimp aquaculture(Rp/production cycle).

Criteria used in calculating profitability are as follows:
Profitability > 0 means that vannamei shrimp aquaculture yields profits;
Profitability = 0 means that vannamei shrimp aquaculture is even;
Profitability < 0 means that vannamei shrimp aquaculture is losing.

5. Calculating R/C ratio obtained by dividing total revenue by total cost (Wijayanto et al 2017) with the following formula:

$$R/C = TR / TC$$

where: R/C = revenue/cost ratio;
TR = total revenue (Rp/production cycle);
TC = total cost (Rp/production cycle.

Criteria used in calculating R/C ratio is 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.

Result ad Discussion

***Infectious myonecrosis virus (IMNV) disease**.* IMN is a highly contagious shrimp viral disease that occurs in several countries in the world. This disease was first reported in Brazil and the geographic locations of the spread of this infection are in Brazil and Indonesia (Prasad et al 2017). In Indonesia, IMNV was first reported infecting vaname shrimp aquaculture in Situbondo, East Java in 2006 (Mai et al 2019), in 2009 this virus spread throughout all regions in Indonesia (Jha et al 2021). This virus was also discovered in India in 2017 (Hameed et al 2017; Shyam et al 2017; Jithendran et al 2021). IMNV is taxonomically included in the Totiviridae family which is similar to protozoa viruses and fungi (Lee et al 2022). IMNV is a non-enveloping, double-stranded RNA virus forming a monopartite genome with a length of 7561-8230 bp, the particles are icosahedral non-enveloped with a diameter of 40 nm and protrusions like fibers on the surface (Jha et al 2021). This virus does not cause rapid death compared to white spot syndrome virus (WSSV) (Supono 2021; Lee et al 2022), but there is high mortality when the environmental conditions are very bad (Prasad et al 2017).

The results of intensive aquaculture research in Kendal Regency, Central Java, Indonesia found that several vannamei shrimp ponds were infected with IMNV spread across five districts. These include Rowosari, Kangkung, Kaliwungu, Patebon and Kendal districts. In Kendal District, particularly, it was difficult for the researchers to obtain research data because the farmers were not open, did not keep records neatly, and were not willing for a visit. As a result, the research was only conducted in four districts with a total sample of 74 pond plots. There were as many as 22 vannamei shrimp ponds infected with IMNV in the area. IMNV has infected shrimp aquaculture spread in several areas in Indonesia, including in East Java (Taukhid et al 2010; Mai et al 2019), West Java (Koesharyani et al 2019), Lampung (Supono 2021), Bali and West Nusa Tenggara (Taukhid et al 2010). In other words, IMNV has spread throughout Indonesia. However, East Java and Lampung are two vannamei shrimp farming centers which continue to be the two places most infected with IMNV (Naim et al 2014).

***Clinical symptoms of IMNV infected shrimp**.* The results showed that vannamei shrimp infected with the IMNV which attacked ponds in Kendal Regency had clinical symptoms as follows: red shrimp tails, pale white shrimp bodies, these symptoms were as reported by Jha et al (2021) and Mai et al (2019) that the clinical symptoms of vannamei shrimp infected with the IMNV indicate that the flesh muscles that experience necrosis will change color from transparent to white all over the body of the shrimp, especially in the last two segments of the base of the tail and finally reddish and rot. The main target of IMNV is to attack skeletal muscle tissue that is not a vital organ, this infection is not too severe compared to other shrimp viruses such as WSSV, yellow head virus (YHV) and taura syndrome virus (TSV) (Lee et al 2022). The muscle tissue requires a lot of oxygen, meanwhile necrosis causes reduced oxygen supply, eventually the tissue dies and changes color from transparent to white and finally red. This disease is called "cotton shrimp disease" because of the whitish appearance of the muscles, which resemble cotton (Sunarto & Naim 2016). Histopathological analysis revealed coagulative necrosis of striated muscle, hemocytic filtration, and presence of spheroid lymphoid organs. This pathognomonic lesion is a hallmark of IMNV infection in both the acute and chronic phases of infection (Mai et al 2019). The target of IMNV infection originates from the mesodermal tissue, in different phases of infection, the target tissue of IMNV is also different. In the acute phase the main targets of IMNV infection are striated muscle (skeletal muscle), connective tissue, haemocytes and tubular parenchyma cells of lymphoid organs. Whereas in the chronic phase the main target of IMNV is the lymphoid organs. Although IMNV spreads systemically, this virus does not replicate in enteric tissues (intestines, caeca and hepatopancreas) (Sunarto & Naim 2016). Vannamei shrimp infected with IMNV and healthy shrimp in Kendal Regency can be seen in Figure 1.

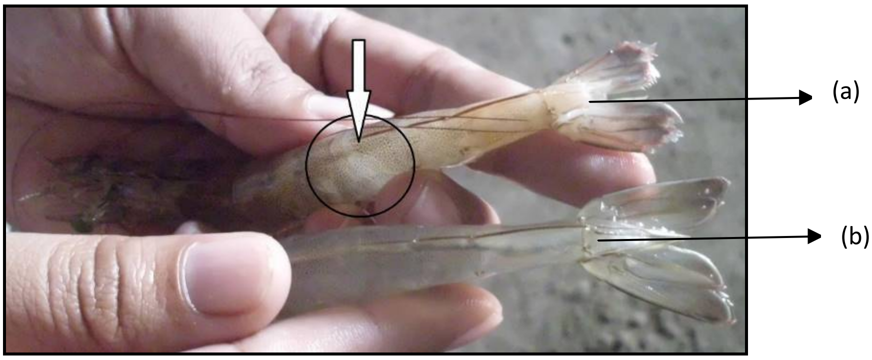

Figure 1. Differences of shrimp infected with infectious myonecrosis virus (IMNV) (a) and healthy shrimp (b) in Kendal Regency.

It was found that there were 22 pond plots infected with IMNV spreading across four districts in Kendal Regency. The viral disease that infected vannamei shrimp resulted in many deaths of vannamei shrimp at various ages, most vannamei shrimp in Kendal district infected with IMNV ranged in age from 40 to 80 days in 6 plots and most attacked at the age of more than 80 days in 16 plots. Vannamei shrimp infected with IMNV in the ponds of Kendal Regency were mostly at the age of more than 80 days or more than 3 months after stocking, according to what was reported by Prasad et al (2017) and Kumar et al (2021) that IMNV is known to only infect Penaeid shrimp at all stages of life both larvae, juveniles and adults, but the most deaths were in juveniles and adults. According to Mai et al (2019), in 2018 the death of vannamei shrimp began around the age of 50-60 days in Situbondo ponds, East Java, Indonesia. In 2006-2007, IMNV infected shrimp aged 70-90 days. In 2008-2009, IMNV infected shrimp aged 40-60 days. After that, IMNV infected 30 days old shrimp. It can be concluded that IMNV infects vannamei shrimp in Indonesia at the age of 30-90 days (Sunarto & Naim 2016).

Average profit of intensive vannamei shrimp aquaculture in Kendal Regency. High profit is what all vannamei shrimp farmers are expecting in whichever aquaculture locations are. However, the emergence of diseases has greatly affected the income and yield of vannamei shrimp production in Kendal Regency and some even stop cultivating due to bankruptcy or are still surviving but switching to other cultivation commodities. Revenue decreased due to many deaths of vannamei shrimp infected with IMNV and there had been high costs due to it. The disease burden is identified with the amount of money, time and energy sacrificed due to the disease (Rushton et al 2021). In other words, it is the amount of loss caused by the disease. Economic losses were calculated by calculating the profitability of each pond plot so that average data per pond infected with IMNV in Kendal Regency were obtained which then compared with healthy shrimp pond plots in Kendal Regency. The data are presented in Table 1.

Table 1
Average per cycle of IMNV infected pond plots in Kendal Regency

Parameters	*Average value*	
	Infected with IMNV	*Healthy*
Plot area (m^2)	2,711.18	1,400
Stocking density (head m^{-2})	128	135
Stocking number (head $plot^{-1}$)	312,574	184,369
Shrimp age (day $plot^{-1}$)	86	110
Survival rate (%)	70.14	85.61
Mortality (%)	29.86	14.39
FCR	1.35	1.36
Average fixed cost (Rp $plot^{-1}$)	19,120,242	13,101,207
Average fixed cost (Rp $plot^{-1}$ m^{-2})	9,849	11.209
Average fixed cost (%)	12.48	11.76
Average production cost (Rp $plot^{-1}$)	144,368,630	96,426,391
Average production cost (Rp $plot^{-1}$ m^{-2})	63,586	72,225
Average production cost (%)	76.10	78.74
Average prevention cost (Rp $plot^{-}$)	26,679,135	11,178,572
Average prevention cost (Rp $plot^{-1}$ m^{-2})	8,305	8,798
Average prevention cost (% total cost)	11.42	9.5
Average production (kg $plot^{-1}$)	3,650,32	2,594,09
Average production (kg $plot^{-1}$ m^{-2})	1.41	1.96
Average population death (head $plot^{-1}$)	97,274	27,277
Average population death (head $plot^{-1}$ m^{-2})	38	19
Average population loss (kg $plot^{-1}$)	1,677,92	627,45
Average population loss (kg $plot^{-1}$ m^{-2})	0.68	0.44
Average total expenditure (Rp $plot^{-1}$)	190,168,008	120,706,169
Average total expenditure (Rp $plot^{-1}$ m^{-2})	81,740	92,232
Average total yield (Rp $plot^{-1}$)	217,399,933	172,907,024
Average total yield (Rp $plot^{-1}$ m^{-2})	84,444	132,135
Profitability (Rp $plot^{-1}$)	27,231,925	52,200,855
Profitability (Rp $plot^{-1}$ m^{-2})	2,704	39,903
Profitability (%)	5.05	42.60
R/C ratio	1.05	1.43
Total IMNV-infected plots in Kendal	22	-
Total plots not infected with IMNV in Kendal	-	16
Average reducing profits doe to IMNV infection (Rp $plot^{-1}$)	24,968,930	

Table 1 shows the average area of ponds infected with IMNV covering an area of 2,711.18 meters/plot with a total of 22 plots. Meanwhile, healthy plots are 1,400 meters/plot with a total of 16 plots. The average stocking density infected with IMNV was 128 heads $plot^{-1}$ m^{-2} while the healthy plots had an average stocking density of 135 heads m^{-2}. The average number of stockings infected with IMNV was 312,574 heads $plot^{-1}$ while healthy plots were 184,369 heads $plot^{-1}$, the average age of harvested vannamei shrimp was 86 days due to IMNV infection while healthy plots had an average age of harvesting of 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 IMNV infection was around 15% lower than healthy shrimp. The average mortality due to IMNV infection was 29.86%, this was higher than the mortality of healthy shrimp, which was 14.39%. In 2018, IMNV infection in Situbondo vannamei shrimp ponds, East Java, Indonesia, resulted in a death rate of around 30-50%. There was also mortality recorded due to IMNV infection in vannamei shrimp around 20-30% depending on the environmental conditions in the grow-out pond (Mai et al 2019).

Feed costs contribute more than 50% of total expenditure (Asche & Oglend 2016). The average feed conversion ratio (FCR) due to infection with IMNV was 1.35, a slight difference compared to the average FCR of healthy shrimp at 1.36. Vannamei shrimp infected with IMNV still want to eat, differently from shrimp infected with WSSV (Jha et al 2021) which causes a higher FCR due to IMNV infection compared to WSSV. The higher the FCR, the higher the costs incurred as reported by Iversen et al (2020). The cost of feed affects the amount of production costs and total expenses. The total cost of feed in healthy ponds was slightly higher than those infected with IMNV. This is influenced by the length of time the shrimp are cultivated, the longer the age of the shrimp, the higher the average FCR.

The average fixed cost of IMNV-infected ponds was 0.72% higher than that of healthy ponds. This fixed cost was affected by the different pond facilities owned by each farmer and the monthly labor costs. The average production cost of healthy ponds was 2.64% higher than the average production cost of ponds infected with IMNV. The average production cost is influenced by the amount of feed costs and the length of time the shrimp are cultivated. The longer the shrimp are cultivated, the greater the production costs incurred during the production process. The average cost of prevention due to IMNV infection was 1.92% higher than the average cost of prevention for healthy ponds. This is in accordance with Iversen et al (2020) that the impact of the disease has 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 kept and is influenced by the actions of the farmer in making decisions when vannamei shrimp are attacked by disease. It is common that prevention costs are always carried out before the shrimp are infected with disease, whether or not there is a disease that infects vannamei shrimp, this prevention cost is always calculated. The average total expenditure due to IMNV infection was IDR 190,168,008 per plot and the average income from shrimp harvest due to IMNV infection was IDR 217,399,933 per plot.

Due to IMNV infection, the average profit reduced by IDR 24,968,930 per plot or IDR 37,199 per plot m^{-2} or 37.55%. Meanwhile, the average vannamei shrimp population that died due to IMNV infection was 69,997 heads $plot^{-1}$ or 19 heads $plot^{-1}$ m^{-2}, which was larger than that of healthy ponds. Meanwhile, the average R/C ratio as a result of being attacked by IMNV was 1.05, which means that the business experienced little profit, compared to the average R/C ratio for healthy plots of 1.43. It shows that MNV disease impacts on the reduced profits by IDR 24,968,930 per plot even though the business is still said to be profitable, but the profit earned is not optimal. According to Nguyen et al (2020), the cost greatly affects profits. The greater the costs incurred, the less profit is obtained.

As stated by Iversen et al (2020), disease outbreaks have an important role in changing production costs in salmon farming in 5 main producing countries, including Canada, Chilli, Faroe Islands, Norway, and Scotland. Estimated costs spent on disease prevention in shrimp aquaculture around the world have reached USD 15 billion since the onset of the disease.

Estimated loss of profit, production and population of vannamei shrimp due to IMNV in Kendal Regency in 2022. Estimation of lost profits, production, and population due to IMNV infection in vannamei shrimp aquaculture in ponds in Kendal Regency in 2022 by making the assumption of loss of profits, production and population due to IMNV infection in intensive vannamei shrimp aquaculture in Kendal Regency can be seen in Table 2.

Table 2 shows the total area of productive ponds in Kendal Regency in 2022 in cycle 1 of 610,480 m^2 and cycle 2 of 502,475 m^2. In the 2nd cycle of 2022, there were 52 pond plots that were not used for intensive vannamei shrimp aquaculture. This was caused by the losses due to a viral disease that attacked vannamei shrimp and the selling price of vannamei shrimp had decreased so that many farmers had gone out of business. This phenomenon is very sad, the impact of viral diseases is very large on the sustainability of aquaculture businesses. The estimated percentage of the total area of ponds infected with IMNV was 42% higher than those infected with WSSV in Kendal District. It is estimated that the area of plots infected with IMNV in cycle 2 decreased by

45,362.1 m^2 compared to cycle 1 in 2022. The population loss assumption in 2022 cycles 1 and 2 is a difference of 861,879 individuals. The total estimated production lost due to IMNV infection in 2022 was 257,092.6 kg or 257 tons and the estimated total population lost due to IMNV infection was 8,881,381 individuals. The estimated total profit loss due to IMNV infection in 2022 was IDR 17,388,341,478 equivalent to USD 1,159,223 with an IMNV infected plot area of more than 467,441.1 m^2 or 46.7 ha. In Indonesia, the total loss of shrimp production is estimated at $150-200 million in 2009 to 2011 due to IMNV (Sunarto & Naim 2016) it can be calculated that the average annual loss is estimated at $75-100 million. The global shrimp industry economic loss due to IMNV is estimated at more than USD 1.0 billion (Prasad et al 2017).

Table 2

Assumptions of lost profit, production, population due to IMNV infection in intensive vannamei shrimp aquaculture 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 IMNV infection percentage (%)	42	42
Estimated plot area infected with IMNV (m^2)	256,401.6	211,039.5
Estimated lost population (head)	4,871,630	4,009,751
Estimated lost profit (Rp m^{-2})	37,199	37,199
Estimated lost profit (kg plot^{-1} m^{-2})	0.55	0.55
Estimated lost production per cycle (kg)	141,020.88	116,071.72
Estimated lost profit per cycle (Rp)	9,537,883,118	7,850,458,360
Estimated total lost profit due to IMNV in 2022 (Rp)		17,388,341,478
Estimated total lost production due to IMNV in 2022 (kg)		257,092.6
Estimated total lost population due to IMNV in 2022 (head)		8,881,381

In 2022, the estimated profit loss due to IMNV infection in intensive vannamei shrimp aquaculture in Kendal Regency, Central Java, Indonesia, was IDR 372,341,359 per hectare, equivalent to $24,822.76 per hectare. The estimated production loss was 5,505.19 kg ha^{-1} or 5.5 tons ha-1 and the vannamei shrimp population that was lost was 190,179 heads ha^{-1}.

Factors influencing the emergence of IMNV. Recently, IMNV has been attacking intensive vannamei shrimp aquaculture in ponds in Kendal Regency. The existence of intensive vannamei shrimp farming ponds with high stocking densities in Kendal Regency has started to develop since 2006. Intensive shrimp aquaculture is cultivation with high stocking densities and the use of chemicals and drugs results in the emergence of diseases as a result of complex interactions between hosts, pathogens and the environment (Millard et al 2021). Changes in the environment and high density so that the transmission spreads very quickly (Trang et al 2019) are also caused by erratic weather changes that cause extreme temperature changes (Millard et al 2021; Nguyen et al 2021), 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 water quality parameters such as temperature, pH, ammonia, nitrate, dissolved oxygen are more susceptible to disease (Nor et al 2019; Jha et al 2021). Stress due to mass molting and lunar cycles, full moons and new moons, is also a challenge for shrimp farmers, because the vannamei shrimp are weak when molting occurs. Most of the water sources for vannamei shrimp aquaculture in Kendal Regency come from sea water. Research conducted by Sánchez-Paz (2010) found that the oceans contain many organisms, including millions of virus particles per milliliter contained in seawater. The place where vannamei shrimp live is in water that is saline and contains a lot of viruses so that most of the diseases that infect shrimp are caused by viruses. The negative impact of viral diseases is four times greater than bacterial diseases (Lee et al 2022).

Prevention of IMNV disease. Several studies conducted by Jha et al (2021) found several findings to deactivate IMNV, including that the IMNV virus will be maximally inactivated in water with a salinity of 0 ppt, proven in several countries such as Vietnam, China and parts of Thailand cultivating shrimp with a salinity < 10 ppt which made the virus did not develop. Wild crabs, artemia and shrimp are found as carriers of the IMNV virus, while birds as vectors are not carriers of the virus. The IMNV virus is very sensitive to heat, this virus will inactivate at temperatures above 80^{o}C. Chemicals containing chlorine such as sodium hypochlorite (30 ppm), chlorine (20 ppm), TCCA (30 ppm), Hi-Clon, calcium hypochlorite (20 ppm) and chloramine T (40 ppm) show anti-IMNV. Polyculture of tilapia can reduce the IMNV virus in the water, because the role of tilapia mucus can deactivate the IMNV virus. The effect of pH can also deactivate IMNV under acidic conditions at pH 1.5. Some of the solutions above can be done to suppress the presence of the IMNV virus in aquaculture ponds. Disease prevention is still being carried out to control this viral disease by increasing the provision of nutritional composition of the feed, application of probiotics (Kumar et al 2016), by providing vitamins, immunstimulants and vaccinations and carrying out environmentally friendly cultivation to prevent WSSV disease (Haryanti et al 2014; Feng et al 2017; Rajkumar et al 2017).

Prevention before the disease appears is always carried out by intensive vannamei shrimp farmers in Kendal Regency, starting from preparing the ponds by carrying out water treatments to enter sterile ponds, buying shrimp seeds that are specific pathogen free (SPF) certified, providing vitamins through feed, and maintaining the quality of this water. However, not all cultivators carry out regular water quality measurements due to the limitations of the tools they have. Farmer awareness has not arisen in managing cultivation waste before it is discharged into the river because the treatment is considered to increase the operational costs of cultivation. Aquaculture waste water that is discharged into rivers also causes pollution because chemical residues and antibiotics can pollute the environment and damage aquatic ecosystems (Henriksson et al 2018; Sargenti et al 2020). There is also suspected transmission of viral diseases to all aquatic ecosystems, both farmed animals and wild animals in rivers or seas around the cultivation site according to what was stated by Ganjoor (2015) that viral infections are not only found in cultivated shrimp but also in wild shrimp. Therefore, the handling was carried out by several shrimp farmers in Kendal Regency when the shrimp they cultivated were infected with IMNV by giving "Pondgoard". Pondgoard contains three essential oils, namely *Eucalyptus globulus*, *Pinus sylvestris* and *Lavandula latifolia* which have anti-viral and immunomodulating properties that have been successfully tested against IMNV (Jha et al 2016). Implementation of good management and tightened biosecurity will reduce the burden of disease (Subasinghe et al 2023), related to the regulatory system (Nadarajah & Flaaten 2017; Murray & Munro 2018) in making policies related to supervision of cultivation, the traffic flow of seeds and broodstock needs to be tightened so that there is no transfer of disease from the infected zone to the disease-free zone. To implement sustainable aquaculture in Indonesia, the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia requires vannamei shrimp aquaculture in Kendal to have a good fish cultivation method certificate (CBIB) to prevent disease and achieve food safety.

Conclusions. The losses caused by IMNV infection were not as severe as those caused by WSSV infection that occurred in Kendal District. IMNV is slower and can still be overcome by administering vitamins, probiotics and immunostimulants to increase the resistance of the shrimp and maintain optimal water quality. In 2022 the estimated total loss of intensive vannamei shrimp aquaculture due to IMNV in Kendal Regency was IDR 17,388,341,478 equivalent to $1,159,222.76 with a total IMNV infected plot area of 46.74 ha. Therefore, it can be said that the estimated total loss due to IMNV in Kendal Regency was IDR 372,022,710 per ha and the estimated lost production due to IMNV iwas 257,092.6 kg or 257.09 tons or 5.5 tons ha^{-1} and an estimated lost population of

8,881.381 heads or 190,017 heads ha^{-1}. Continuous studies are needed in various regions in Indonesia to determine the amount of the impact of IMNV in Indonesia and how to deal with it.

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