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Outbreak of Enterocytozoon Hepatopenaei (EHP) in the Cultivation of Vannamei Shrimp (Litopenaeus Vannamei) on the North Coast of East Java: Risk Management and Biosecurity Approach

Siti Rokhmaniati[1], Akhmad Farid[2], Haryo Triajie[3], Triana Retno Palupi[4], Apri Arisandi[5*,] Mas Ahsan Sandya Firmansyah[6], Nurul Musyaffa[7]
Trunodjoyo University Madura
Corresponding Author: Apri Arisandi apriarisandi@trunojoyo.ac.id

A R T I C L E I N F O

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A B S T R A C T

Vanamei shrimp farming on the northern coast of East Java is facing serious disruption due to an outbreak of Enterocytozoon hepatopenaei (EHP), which is causing stunted growth without mass mortality. This study aims to analyse the risks associated with the EHP outbreak, develop a risk matrix based on probability and severity, and formulate priority biosecurity mitigation strategies for farmers. The approaches employed were Enterprise Risk Management (ERM), ISO 31000:2018, and an epidemiological review. Risk identification yielded 15 main categories, covering biological, ecological, operational, human resources, economic, reputational and regulatory aspects. Contamination with EHP spores via non-SPF fry, the disposal of waste without decontamination, and horizontal transmission via water and vectors are classified as very high and high risk levels. Recommended mitigation measures include regulations on SPF-certified fry, the implementation of multi-layered biosecurity, the construction of integrated wastewater treatment plants, routine PCR testing, feed management, and an early growth monitoring system.

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INTRODUCTION

East Java is one of the largest shrimp cultivation centers in Indonesia, after West Nusa Tenggara. The northern coastal areas of East Java that are known as the cultivation centers of vannamei shrimp (Litopenaeus vannamei) are Tuban, Lamongan, Gresik and Banyuwangi. Vannamei shrimp (Litopenaeus vannamei) as a leading fishery aquaculture commodity supports most of the national shrimp export volume. Production centers are widely distributed on the north coast of East Java. Vannamei shrimp have the characteristics of being responsive to feed, tolerant to high stocking density, and have a relatively short maintenance cycle (90 - 100 days per cycle) making them suitable for intensive and super intensive cultivation systems(Afandy et al., 2025)

Upgrading the cultivation system to intensive or superintensive can increase the risk of disease contamination, if it is not balanced with the application of biosecurity. This species is quite susceptible to disease. One of the things to watch out for is the outbreak of Enterocytozoon hepatopenaei (EHP), an intracellular microsporidia parasite that infects shrimp hepatopancreatic epithelial cells and causes the condition of hepatopancreatic microsporidiosis (Lu et al., 2025) . EHP is different from White Spot Syndrome Virus (WSSV) or Acute Hepatopancreatic Necrosis Disease (AHPND) which causes mass mortality in a short period of time. EHP generally does not show specific clinical symptoms and rarely causes immediate death. The real impact of EHP infection is a slowdown in growth that makes stunted shrimp and harvest size not uniform, resulting in a longer production cycle. Economic losses are cumulative and often unrealized in the early stages of shrimp infection vannamei (International Organization for Standardization, 2018; Ma et al., 2024) .

Shrimp's energy metabolism is disrupted due to increased glycolysis activity and decreased oxidative phosphorylation, changes in mitochondrial morphology, and oxidative stress in hepatopancreatic tissue (Ma et al., 2024) (Cao et al., 2023). EHP infection has been shown to disrupt the balance of the microbiota, decrease the population of beneficial dominant bacteria, and increase the colonization of opportunistic pathogenic bacteria such as Vibrio spp. in the intestine. Disruption of metabolism in the intestine leads to the occurrence of white feces syndrome(Cao et al., 2025; Liu et al., 2023). EHP transmission can occur horizontally through water, spore-contaminated feces, cannibalism, invertebrate vectors (dragonfly nymphs), polycaeta worms, and shellfish that act as natural reservoirs of parasites in the pond environment (Cao et al., 2025). The many factors that can transmit EHP make handling parasites complicated. Control must be carried out comprehensively, starting from seed quality, water quality management, feed management, equipment sanitation, control of disease-carrying organisms and the implementation of strict biosecurity.

The prevalence rate of EHP in intensive ponds on the northern coast of East Java varies depending on the level of biosecurity implementation of each pond. East Java BKHIT data: the prevalence of EHP in 2025 at the research site is 23.5%. Similar conditions have also been reported in other intensive shrimp farming centers in Indonesia, where long-term EHP and white feces disease pressure can be one of the main determinants of productivity variation between pond plots

(International Organization for Standardization, 2018; Jongkor et al., 2026) . The point to note is that EHP is not just a technical or biological problem that can be solved at the pond plot level, but a risk management problem that touches productivity, the economic condition of farmers, and the reputation of products in the market.

Enterprise Risk Management (ERM) provides a systematic framework to identify, assess, and mitigate operational risks in an integrated manner with business strategies, as stipulated in the COSO ERM 2017 framework and the international standard ISO 31000:2018 (International Organization for Standardization, 2018; Jongkor et al., 2026) . Previous research in the field of aquaculture has generally discussed EHP from a biomolecular perspective or analyzed the feasibility of vannamei pond business separately from the disease aspect (Thitamadee et al., 2016) ; so far, studies that combine the latest EHP epidemiology with the ERM framework quantitatively in the context of coastal ponds in East Java are very limited. This gap is the basis for the urgency of the research.

The objectives of the study are (1) to identify the sources of operational risks caused by the EHP outbreak on the north coast of East Java; (2) to develop a risk matrix based on likelihood and severity; (3) to formulate mitigation and biosecurity strategies that are priorities for farmers based on the highest level of risk.

LITERATURE REVIEW

Enterocytozoon hepatopenaei (EHP): Pathogenesis and Growth Impacts

Enterocytozoon hepatopenaei (EHP) was identified as an intracellular microsporidia parasite that infects hepatopancreas tubule epithelial cells (*hepatopancreas*) in penaeid shrimp, including Litopenaeus vannamei(Biju et al., 2016a), (Kmmari et al., 2018). Unlike many other shrimp pathogens, EHP does not directly cause rapid mass death, but rather triggers a condition known as *Hepatopancreatic Microsporidiosis* (HPM)(Nguyen et al., 2023),(Salachan et al., 2016). At the cellular level, EHP replicates within the cytoplasm of epithelial cells, specifically in hepatopancreatic B cells, leading to cell desquamas, impaired nutrient absorption, and severe tissue necrosis (Aranguren Caro et al., 2021; Nkuba et al., 2021; Tangprasittipap et al., 2013).

The pathogenic mechanism of EHP involves manipulating the host's metabolism to meet the very high energy needs of the parasite during the replication stage(Biju et al., 2016; Ma et al., 2024) . EHP infection has been shown to increase the glycolysis process and the expression of hexokinase genes and pyruvate kinase, while the oxidative phosphorylation process is significantly reduced(Li et al., 2025; Ma et al., 2024). These metabolic disorders, along with alterations in proteomic expression and the composition of the gut microbiota, result in the host lacking energy for muscle growth and normal physiological regulation (Cao et al., 2025; He et al., 2026; Srisapoome et al., 2025) .

The most obvious clinical impact is severe slow growth or growth retardation which often causes shrimp to be inuniform in size within a population (Aras et al., 2023; Biju et al., 2016a; Marimuthu et al., 2021) . This retardation is usually only observed significantly after 60 to 90 days of cultivation

(Salachan et al., 2016) . Other supporting symptoms include a shrinking and pale hepatopancreas, soft carapace, empty intestine, and lethargy (Nkuba et al., 2021b; Shirsak Mondal et al., 2023) . With regard to White Feces Syndrome (WFS), the literature suggests a strong association in which EHP loads are significantly higher in WFS-affected pools (Aranguren Caro et al., 2021a; Raveendra, Suresh, et al., 2018) . Important research by (Tangprasittipap et al., 2013) emphasizes that EHP is not a single cause of WFS, but rather a factor that contributes to the interaction of complex pathobiomes with pathogenic bacteria such as Vibrio spp (Babu et al., 2024; Piamsomboon & Han, 2022) .

EHP Transmission and Early Detection Methods

The success of risk management is highly dependent on understanding pathogen transmission pathways. EHP is transmitted horizontally through fecal-oral routes, cannibalism, and environmental exposure (Biju et al., 2016; Tang et al., 2016) . Healthy shrimp can become infected after consuming sick shrimp feces containing solid spores or through cohabitation (coexistence) in contaminated pond water(Aranguren Caro et al., 2021; López-Carvallo et al., 2022) . In addition, EHP spores have the ability to survive in pond bottoms and can be carried by a variety of mechanical or vector hosts, including polycaetas, mollusks (such as Mytilopsis leucophaeata), wild crustaceans, and aquatic insects(Desrina et al., 2020; Mondal et al., 2023; Munkongwongsiri et al., 2022; Venkateswarlu, 2019) . The use of infected raw natural feed for shrimp broodstock is one of the critical points for the entry of diseases into the aquaculture supply chain(Nkuba et al., 2021; Otta et al., 2016) .

Early diagnosis is a challenge due to the non-specific clinical symptoms of EHP that are difficult to observe with the naked eye in the early stages of infection(Nkuba et al., 2021). DNA-based molecular detection methods are becoming the primary standard. *Polymerase Chain Reaction* (PCR) and nested PCR targeting the 18S rRNA gene or the spore wall protein gene (SWP) are widely used for routine screening (Biju et al., 2016; Mondal et al., 2023; Wan Sajiri et al., 2021) . For more in-depth research purposes, Transmission Electron Microscopy (TEM) and In-Situ Hybridization (ISH) are used to visualize the ultrastructure of parasites and confirm the presence of parasites in tissues (Kmmari et al., 2018; López-Carvallo et al., 2022; Shen et al., 2017) .

In the context of farm operations, quantitative methods such as real-time qPCR are essential for assessing pathogen loads and predicting the risk of crop failure (Aranguren Caro et al., 2021; Chen et al., 2022; Piamsomboon et al., 2019) . In addition, rapid detection techniques such as Recombinase Polymerase Amplification (RPA) combined with Lateral Flow Dipstick (LFD) offer a sensitive point-of-care diagnostic solution (capable of detecting up to 10 coffees/µL) in a short time (approximately 20 minutes) without the need for complicated laboratory equipment (Ma et al., 2024; Pang et al., 2022) . The integration of these detection methods into surveillance protocols helps farmers to conduct early identification before infection spreads (Mondal et al., 2023; Nkuba et al., 2021) .

Biosecurity Strategy and Risk Management

Biosecurity in shrimp farming is defined as a set of management practices designed to prevent the introduction, spread, and impact of pathogens in aquaculture systems (Lightner, 2005; Palić & Scarfe, 2019) . The main mitigation

steps begin with the exclusion of pathogens through the use of fry (post-larvae) certified *Specific Pathogen Free* (SPF)(Afandy et al., 2025; Lightner, 2005; Venkateswarlu, 2019) . Strict screening of broodstock and fry using PCR is a mandatory procedure to ensure seeds are free of EHP prior to stocking(K.P. et al., 2024; Maria Agustina Pardede et al., 2025) .

Comprehensive pond preparation is the next line of defense. Recommended practices include total draining of the pond bottom, removal of organic deposits, tillage, and calcification with appropriate doses (70-120 kg/ha) (Bhowmick & Crumlish, 2017) . Disinfection of pond and water facilities using chlorine, acid leaching (HCl), or potassium permanganate ($KMnO_4$) spray has been shown to be effective in inactivating persistent parasitic spores (Gupta et al., 2004; Sankar et al., 2023) . During the cultivation period, water quality management should be optimized, especially for ammonia and nitrite parameters that are positively correlated with the prevalence of EHP infections(Nkuba et al., 2021) .

Operational mitigation strategies include the installation of physical fencing (such as bird and crab fencing) to prevent the entry of disease vectors, as well as the implementation of strict sanitation for personnel and equipment through footbaths and hands (Syah et al., 2025; Venkateswarlu, 2019) . The use of functional feeds enriched with probiotics or natural ingredients such as garlic can help boost the host's immune system and mitigate the clinical impact of infection (Raveendra, Suresh, et al., 2018) . In addition, targeted surveillance with regular sampling and monitoring of shrimp health every three days is recommended to detect anomalies at the beginning of the culture cycle (Mondal et al., 2023; Sankar et al., 2023) .

ISO:31000 Risk Management Framework in Aquaculture

A structured risk management system is indispensable for integrating various biosecurity strategies into farm operations. The ISO 31000:2018 standard provides generic but adaptive risk management principles, frameworks, and processes for various industries, including aquaculture (Aisyah & Dahlia, 2022; Safitri et al., 2021) . The ISO 31000 process includes five main stages: communication and consultation, contextualization, risk assessment, risk treatment, and monitoring and review (Alfatin & Leo, 2019; Putra et al., 2017) .

The risk assessment stage consists of risk identification, risk analysis, and risk evaluation (Barateiro et al., 2012; Putra et al., 2017) . Risk identification in this study was carried out through interviews with experts and field observations to map risk events, such as natural feed contamination or filtration system failure (Muniesa et al., 2017) . Risk analysis utilizes a 5x5 risk matrix to assess the relationship between likelihood and severity/impact of each identified risk event (MİNAZ et al., 2021; Shilova, 2020) .

The risk matrix allows the classification of risks into different levels of stress, such as Extreme (Red), High (Yellow), Medium (Green), or Low (Blue) (Dewi & Kitri, 2020; Rosdian et al., 2026) . For example, the risk of EHP transmission through uncertified brood feed can be classified as high risk that requires immediate mitigation through a change in feed source (Rosdian et al., 2026) . Risk evaluation helps management to decide on the most appropriate

treatment option among four main options: avoid, accept, reduce/mitigate, or transfer risk (Lizarzaburu & Salquero, 2011) .

The integration of literature findings on transmission routes (such as infected polycaetas) and EHP pathogenesis (such as growth loss) provides an objective database for scoring on the risk matrix (Mondal et al., 2023; Raveendra, Hari Babu, et al., 2018) . With this risk-based approach, biosecurity strategies are no longer applied randomly, but are focused on the critical points that have the most significant impact on the sustainability of vannamei shrimp farming in regions such as East Java (Lestariadi et al., 2018; Scarfe & Palić, 2020) .

METHODOLOGY

The research was conducted on vannamei shrimp ponds on the north coast of East Java, namely Gresik, Lamongan and Tuban. The three districts are vannamei shrimp centers in East Java. The main sampling location was ponds that had been found to have consistent non-uniform growth symptoms and indicated EHP infection. Primary data was collected by conducting field observations, interviews with fisheries extension workers, pond owners and technicians. Respondents were selected from two main groups directly involved in shrimp farming, namely farmers and employees of the regional fisheries office. The selection used the purposive sampling method. Risk identification was obtained from interviews with 15 farmers and 3 fisheries extension workers. The selection of respondents was based on criteria such as shrimp farming experience for at least 5 years, active management of shrimp ponds, willingness to provide information on disease occurrences, cultivation practices, and the application of biosecurity. Fisheries extension workers are staff of the district fisheries office who are responsible for aquaculture in the research area, and fisheries extension workers who regularly interact with farmers and have a deep understanding of the conditions of the research site. Respondents represent the actual population.

Interviews with respondents were conducted based on questionnaires that had been prepared. The questionnaire contained age, cultivation period, farmers' perception of risks, incidence of disease attacks, competence

technicians, cultivation methods, application of biosecurity, waste management and other socio-economic. Government agency reports, cultivation technical guidelines, ISO 31000:2018 risk management standards, framework Enterprise Risk Management (COSO ERM)(Ahmad & Teo, 2024; Commission, 2017), and various scientific publications that discuss the epidemiology, transmission, detection, and control of EHP are used as additional secondary data to support the writing.

Risk Analysis Approach

Risk analysis was carried out using five stages: (1) risk identification; (2) risk assessment analysis with an ordinal scale of 1-5 for the chance of occurrence (L) and impact level (S);

(3) preparation of a 5 x 5 risk matrix to determine the risk level (Low, Medium, High, Very High) based on the results of the multiplication of L x S visualized in the risk map (*Risk Map*); (4) Preparation of risk priorities by considering the results of the calculation of risk levels and several aspects that are considered necessary (5) formulation of priority mitigation strategies,

following the standard stages of risk management that are commonly used in other industrial sectors and are beginning to be adapted in the aquaculture sector (International Organization for Standardization, 2018; Jongkor et al., 2026).

The opportunity assessment (L) was determined based on the results of interviews with farmers and information from fisheries extension workers. Respondents were asked to fill out a questionnaire and score the risk source. The determination of the level of incidence opportunity was divided into 5 scales: (1) very low (< 1 time in 5 years); (2) rare (1–2 times in 5 years); (3) moderate (1–2 times in 3 years); (4) high (< 2 times a year); (5) very high (> 2 times a year). Respondents also assessed the impact caused by these risk sources on the potential for EHP attacks and the success of shrimp farming they worked. The grouping of impacts was also divided into 5 scales: (1) Very low, not intrusive; (2) Low, minor disturbance, easy to overcome; (3) Moderate, begin to interfere with the cultivation process; (4) High: hinders the achievement of targets; (5) Very high, causing great losses, the spread of diseases, or damage to the reputation of the organization.

Table 1. Likelihood Scale and Impact of Risk Assessment

Score	**Categories**	Description of Likelihood	**Impact Description**
5	Very High	(>2 times a year	causing huge losses, Spread of disease, or reputational damage organization.
4	Height	< 2 x a year	hinders the achievement of targets
3	Medium	1-2x in 3 years	Starting to interfere with the cultivation process
2	Low	1 -2 x in 5 years	minor disturbances, easy to overcome
1	Very Low	(< 1x in 5 years	Unobtrusive

Table 2. Risk Level Classification Matrix Based on Score Range (*Likelihood x Severity*)

Score Range	**1 - 4**	**5 - 9**	**10 - 16**	**17 - 25**
Level Classification	Low	Medium	Height	Very High

RESEARCH RESULT

Identify Operational Risks

The results of the search obtained fifteen main sources of operational risk associated with EHP outbreaks in vannamei shrimp farming. These risks are grouped into eight categories: biological, ecological, operational, human resources, detection, economics, reputation, and regulation (Table 3). Biological categories – especially the quality of fry that are not certified *specific pathogen free/specific pathogen resistant* (SPF/SPR) and carrier/vector media that can

transmit EHP (worms, dragonflies, molluscs), source of disease-contaminated water is further a source of risk with the highest combination of opportunity and impact, in line with the findings that EHP has a wide range of natural roles in the pond environment. The high biological and ecological risk score is not only due to the biological nature of EHP, but also the lack of awareness of farmers on the importance of implementing biosecurity. Waste disposed of does not go through treatment first even though it is indicated to be positive for EHP. The majority of ponds do not have sewage treatment plants.

Table 3. Identification and Assessment of Operational Risks Related to EHP Outbreaks in Vannamei Shrimp Farming

Yes	Categories	Sources of Risk	L	S	Risk Level Value	Status
1	Biological	The use of fry that is not SPF/SPR certified, has the potential to carry EHP spores [9]	4	5	20	Very High
2	Biological	Carrier media that can transmit EHP is around ponds (worms, dragonflies, mollusks)	4	4	16	Height
3	Environment	Disease-contaminated water sources	4	4	16	Height
4	Environment	Disposal of wastewater contaminated with diseases that have not gone through treatment first	4	4	16	Height
5	Environment	Accumulation of organic matter and feed residues at the bottom of the pond [9]	3	3	9	Medium
6	Environment	Extreme water quality fluctuations due to weather conditions	3	3	9	Medium
7	Operational	High stocking density without adequate management support	3	4	12	Height
8	Operational	Buildup of organic matter and increased ammonia in water due to overfeeding	3	3	9	Medium
9	HR	Farmers' minimal knowledge related to the prevention and handling of EHP	2	3	6	Medium
10	Detection	Lack of monitoring in the form of routine PCR tests on fry and water sources	3	5	15	Height
11	Economy	Decrease in selling value due to size inconsistency	4	3	12	Height
12	Economy	Limited farmers' capital in fulfilling the implementation of biosecurity and quality fry	3	4	12	Height

Yes	Categories	Sources of Risk	L	S	Risk Level Value	Status
13	Reputation	Price rejection/reduction by the buyer due to the inconsistency of size	2	3	6	Medium
14	Regulation	Gaps in biosecurity standards required by fisheries authorities (Kumar et al., 2024)	2	4	8	Medium
15	Regulation	Hatchery not yet CKIB certified	4	2	8	Medium

Note: L = odds (*likelihood*, scale 1-5), S = impact (*severity*, scale 1-5)

Risk Matrix

The results of the multiplication of L and S values are mapped into a 5 x 5 risk matrix to determine the priority level of handling. The risk of contamination of non-SPF fry, the risk of horizontal transmission through water and other carrier/vector media around the pond, and the application of weak biosecurity in the majority of ponds are in the very high and high quadrants, so they must be a top priority in the allocation of control resources. Medium category risks such as the accumulation of pond basic organic matter or technician competence should not be ignored and need to be mitigated or controlled. This pattern is consistent with

ERM principles related to the priority of the controlled risk. Risks with high chance and high impact at the same time (upper right quadrant of the matrix) must be intervened first compared to high single-value risks on only one axis (Jongkor et al., 2026) . The source of biological risk of EHP outbreaks is systemic: EHP spores enter through fry or vectors, their spread within the pond plot is rapid through fecal-oral routes and cannibalism, resulting in a very narrow intervention time (Cao et al., 2025) . Risk *mapping* in the *likelihood-impact* matrix is visualized in two dimensions of the assessment and presented in the Risk *Map*. This mapping is intended to make it easier to create risk clusters to determine control priorities.

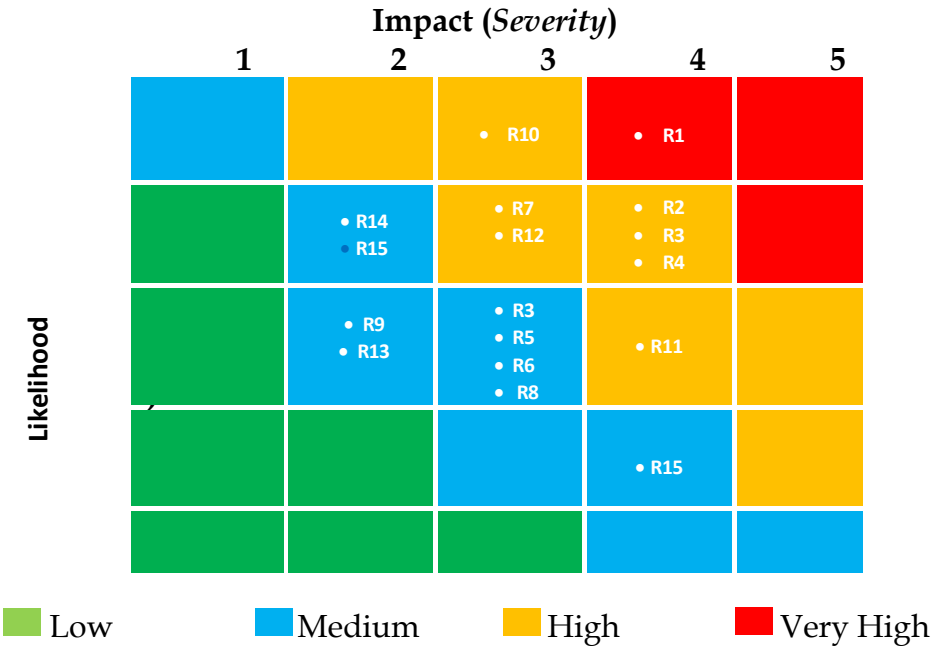


Figure 1. Map of the Risk of EHP Outbreak in Vannamei Shrimp Cultivation on the North Coast of East Java

R1 risk (use of non-SPF fry) is included in the extreme / very high category, 7 risks are in the high category (water sources contaminated with diseases, carrier media that can transmit EHP (worms, dragonflies, mollusks), disposal of water waste contaminated with diseases that do not go through treatment first, high stocking density without adequate management support, **lack of monitoring in the form of routine PCR tests, decrease in selling value due to size disparities, limited farmers' capital in fulfilling the implementation of biosecurity and quality fry). The** remaining 7 risks are in the medium category. Control priorities are determined from the results of the risk analysis presented in the risk map. The results of the analysis show 4 priority risks that must be controlled immediately. (Table 4).

Table 4. Risk of EHP Outbreak Priority in Vannamei Shrimp Cultivation

Categories	Sources of Risk	L	S	Risk Level Value	Status	Mitigation / Control
Biological	The use of fry that is not SPF/SPR certified, has the potential to carry EHP spores	4	5	20	Very High	SPF/SPR certification on all fry supplies accompanied by independent PCR tests before stocking
Biological	Carrier/vector media that can transmit EHP are around ponds (worms, dragonflies, mollusks)	4	4	16	Height	installing a water treatment plant in the form of filters or UV rays before use and installing facilities to prevent the entry of vectors to reduce the

Categories	Sources of Risk	L	S	Risk Level Value	Status	Mitigation / Control
						chance of spores entering from external vectors
Environment	Disease-contaminated water sources	4	16		Height	Reservoir creation and water treatment/filtration before use
Environment	Disposal of wastewater contaminated with diseases that have not gone through treatment first	4	16		Height	The creation of integrated WWTP in cultivation centers and increasing farmers' awareness of the importance of waste management

DISCUSSION

Biological Mechanisms Underlying High Risk of EHP

The high level of risk in the biological category is due to the unique pathogenesis characteristics of EHP. EHP spores are about 1 micrometer in size and colonize the cytoplasm of hepatopancreatic cells, increasing the number of mitochondria, but their morphology is compacted, and increasing the expression of hexokinase and pyruvate kinase genes related to energy metabolism(Eissa et al., 2026). Shrimp experience dwarfism and growth failure due to impaired energy metabolism. Most farmers say that EHP attacks cause an increase in production cycles. The final impact is decreased productivity, high operational costs, and sometimes even greater losses when compared to the consequences of mass deaths.

At the intestinal microbiome level, recent metagenomic studies in shrimp with different degrees of infection (normal, mild, moderate, severe) show that the increase in the severity of EHP infection is in line with the condition of the intestinal microbiota imbalance and the emergence of discriminating bacterial species related to virulence factors (Lu et al., 2025) . These findings reinforce the reason why the risk of EHP in Table 3 is considered to be closely related to secondary risks such as the emergence of white feces syndrome due to opportunistic Vibrio spp. proliferation(Jongkor et al., 2026) . The results of interviews with farmers are similar to the theory that EHP control cannot be separated from the simultaneous management of gut microbiota health and water quality. Information from the field: the discovery of a case of white feces syndrome in ponds infected with EHP.

The challenge of early detection also increases the risk of the detection system in Table 3 because the clinical symptoms of EHP are vague and appear to be evident in the variation in shrimp size at harvest. A synergistic diagnostic

approach that combines conventional parasitology, histopathology, and molecular detection (loop-mediated isothermal amplification/LAMP and PCR/qPCR) has proven to be more accurate compared to a single method in identifying infections in the early stages (Lu et al., 2025) . The East Java Animal, Fish, and Plant Quarantine Center as a competent authority in the control of quarantine fish diseases has carried out activities to prevent the spread of these diseases through Quarantine Fish Disease Spread Area Monitoring Activities and the Establishment of a Fish Disease Emergency Response Task Force. However, in its implementation, there are still several technical, operational, and external obstacles. The breadth of the monitoring area that must be reached, the high mobility of fishery commodities causes the need for monitoring to be more complex.

The level of collaboration of all stakeholders, both the central government, local governments, fisheries extension workers, laboratories, farmers, and stakeholders affects the effectiveness of control. The awareness of farmers to report diseases early and the lack of uniformity of laboratory testing facilities also add to the obstacles to disease control. Farmers tend to hide information about outbreaks, not conducting tracing because of the deaths of farmed shrimp. This is the basis for recommendations that pond business units on the north coast of East Java allocate a routine budget for molecular testing on fry and reservoir water samples, not only when symptoms are already visible in the field.

Operational Implications and Mitigation Strategies

Based on the risk levels in Table 1 and Table 3, this study has formulated three layers of mitigation strategies that are in line with the principles of risk-based biosecurity):

a. Mitigation at sources of risk is very high and high. Business units are advised to require SPF/SPR certification on all fry supplies accompanied by independent PCR tests before stocking, install water treatment plants in the form of filters or UV rays before use to reduce the chance of spores entering from external vectors, and implement layered biosecurity zoning that restricts the movement of equipment, and inter-plot personnel without disinfection procedures, wastewater treatment before discharging into public waters.(Eissa et al., 2026) . The government needs to consider the creation of integrated WWTP in cultivation centers and increasing farmers' awareness of the importance of waste management.

b. Mitigation at moderate risk. Management of pond bottom organic matter can be carried out through periodic pond bottom discharge programs and regular probiotic applications to suppress the accumulation of organic waste and maintain water quality stability. Probiotic applications and pond bottom discharge have been proven to be effective in intensive ponds in Indonesia. Capacity building of technicians through EHP early symptom recognition training is also recommended to accelerate response in the field. Local governments, especially fisheries extension workers, as parties who are in direct contact with farmers, are expected to play a more active role in increasing the competence/understanding of farmers about early detection, control, and handling of EHP attacks.

c. Sustainable risk monitoring and management, clear coastal spatial planning and coordination with local governments. Integrated waste treatment plants need to be built in cultivation areas to minimize the spread of disease from ponds that have been contaminated with EHP. Farmers are advised to establish a system of recording average daily growth indicators periodically as an early warning signal against potential performance degradation due to EHP, so that intervention decisions, including partial early harvest if necessary, can be taken before losses increase (International Organization for Standardization, 2018) .

The effectiveness of the mitigation strategy can only be proven after it is actually implemented in the field. If the mitigation strategy is implemented consistently, the risk at high and very high levels can shift to medium or low levels in the next few production cycles. This improvement is ultimately not only a matter of reducing losses in ponds, but also concerns ensuring food safety and uniformity of the quality of vannamei shrimp products from the north coast of East Java.

CONCLUSIONS AND RECOMMENDATIONS

a) Risk analysis using the Enterprise Risk Management approach proved that the outbreak of Enterocytozoon hepatopenaei (EHP) in vannamei shrimp cultivation on the north coast of East Java gave rise to fifteen risk sources.
b) The compiled risk matrix shows that two risk sources stand out and must be the main priority for control: contamination of non-SPF/SPR fry, horizontal transmission through water and carrier vectors/media around the pond; both are at very high and high risk levels.
c) Four steps must be prioritized: molecular certification and testing of fry, water quality management accompanied by biosecurity zoning, improving the competence of field technicians, and an early monitoring system based on growth indicators. These steps must be carried out jointly by farmers, central and regional governments, fisheries extension workers, and stakeholders according to their roles.

ADVANCED RESEARCH

To build upon the identified Enterprise Risk Management framework for EHP outbreaks, future research should transition toward dynamic risk modeling by integrating machine learning algorithms and Bayesian networks to predict real-time transmission risks across coastal shrimp farming landscapes. Empirical studies are urgently needed to evaluate the field efficacy and economic viability of advanced molecular diagnostic tools, such as CRISPR-based point-of-care assays, for rapid non-SPF fry screening at the hatchery-farm interface. Furthermore, epidemiological investigations should explore EHP spore viability, environmental persistence, and horizontal transmission pathways involving local aquatic carriers and sediment dynamics under fluctuating water quality parameters. Finally, expanding this framework through multi-region longitudinal studies will validate standardized mitigation protocols, establish cost-effective biosecurity thresholds, and enhance overall resilience in sustainable vannamei aquaculture management.

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REFERENCES

Afandy, A. A., Anwar, K., & Ridhowati, S. (2025). Strategi Penanganan Penyakit Budidaya Udang Vanamei (Litopenaeus Vananmei) Skala Intensif Di Kabupaten Takalar. *Jurnal Akuakultur Sungai Dan Danau*. https://api.semanticscholar.org/CorpusID:283837605

Ahmad, S. A., & Teo, P.-C. (2024). The Implementation of Enterprise Risk Management (ERM) Frameworks in Small and Medium Enterprises (SMES): A Literature Review. *International Journal of Academic Research in Business and Social Sciences*, *14*(9). https://doi.org/10.6007/IJARBSS/v14-i9/22353

Aisyah, A. P., & Dahlia, L. (2022). Enterprise Risk Management Berdasarkan ISO 31000 Dalam Pengukuran Risiko Operasional pada Klinik Spesialis Esti. *Jurnal Akuntansi Dan Manajemen*, *19*(02), 78–90. https://doi.org/10.36406/JAM.V19I02.483

Alfatin, H. N., & Leo, L. (2019). *Risk Analysis in A Manufacturing Company's Inventory Cycle*. https://doi.org/10.2991/APRISH-18.2019.20

Aranguren Caro, L. F., Alghamdi, F., De Belder, K., Lin, J., Mai, H. N., Millabas, J., Alrehaili, Y., Alazwari, A., Algetham, S., & Dhar, A. K. (2021). The effect of salinity on Enterocytozoon hepatopenaei infection in Penaeus vannamei under experimental conditions. *BMC Veterinary Research*, *17*(1), 65. https://doi.org/10.1186/s12917-021-02778-0

Aras, A. K., Fikriyah, A., Pratiwi, G. A. I., & Nurlita, W. (2023). PREVALENSI INFEKSI EHP (Enterocytozoon Hepatopenaei) PADA UDANG VANAME (Litopenaeus vannamei) BERDASARKAN DATA SURVEILLANCE DI BALI, INDONESIA. *Media Akuakultur*, *17*(2), 59. https://doi.org/10.15578/ma.17.2.2022.59-65

Babu, S. G., Uma, A., & Shanmugam, S. A. (2024). Metagenomic Profiling Identifies Potential Biomarkers for Shrimp Health Assessment and Pathobiome-like Association Involving WFS/AHPND Associated Bacteria in Enterocytozoon hepatopenaei (EHP)-infected Penaeus vannamei. *Indian Journal of Animal Research*, (Of). https://doi.org/10.18805/IJAR.B-5394

Barateiro, J., Antunes, G., & Borbinha, J. (2012). Manage risks through the Enterprise Architecture. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 3297–3306. https://doi.org/10.1109/HICSS.2012.419

Bhowmick, B., & Crumlish, M. (2017). AQUACULTURE HEALTH MANAGEMENT AND BIOSECURITY PRACTISES IN SOUTH WEST OF BANGLADESH. *Bangladesh Journal of Veterinary Medicine*, *14*(2), 263–269. https://doi.org/10.3329/BJVM.V14I2.31407

Biju, N., Sathiyaraj, G., Raj, M., Shanmugam, V., Baskaran, B., Govindan, U., Kumaresan, G., Kasthuriraju, K., & Chellamma, T. (2016a). High prevalence

of Enterocytozoon hepatopenaei in shrimps Penaeus monodon and Litopenaeus vannamei sampled from slow growth ponds in India. *Diseases of Aquatic Organisms*, *120*(3), 225–230. https://doi.org/10.3354/dao03036

Cao, Z., Chen, C., Wang, C., Li, T., Chang, L., Si, L., & Yan, D. (2023). Enterocytozoon hepatopenaei (EHP) Infection Alters the Metabolic Processes and Induces Oxidative Stress in Penaeus vannamei. *Animals 2023, Vol. 13, Page 3661*, *13*(23), 3661. https://doi.org/10.3390/ANI13233661

Cao, Z., He, C., Yin, Z., Chen, C., Li, F., Yan, D., Li, T., Chang, L., & Si, L. (2025). Effects of Enterocytozoon hepatopenaei infection on intestinal immune defense and physiological processes of Penaeus vannamei. *Frontiers in Marine Science*, *12*, 1522448. https://doi.org/10.3389/FMARS.2025.1522448/TEXT

Chen, W. F., Fu, Y. W., Zeng, Z. Y., Guo, S. Q., Yan, Y. L., Tu, Y. F., Gou, T. G., & Zhang, Q. Z. (2022). Establishment and application of a TaqMan probe–based qPCR for the detection of Enterocytozoon hepatopenaei in shrimp Litopenaeus vannamei. *Parasitology Research*, *121*(8), 2263–2274. https://doi.org/10.1007/S00436-022-07559-8

Commission, C. of S. O. of the T. (2017). *Enterprise Risk Management: Integrating with Strategy and Performance*. Committee of Sponsoring Organizations of the Treadway Commission. https://www.coso.org/enterprise-risk-management

Desrina, Prayitno, S. B., Haditomo, A. H. C., Latritiani, R., & Sarjito, S. (2020). Detection of Enterocytozoon hepatopenaei (EHP) DNA in the polychaetes from shrimp ponds suffering white feces syndrome outbreaks. *Biodiversitas*, *21*(1), 369–374. https://doi.org/10.13057/BIODIV/D210144

Dewi, L., & Kitri, M. L. (2020). *Operational Risk Analysis in Department of Enterprise Risk Management of PT. XYZ Based on ISO 31000: 2018 Framework*. https://doi.org/10.2991/AEBMR.K.200415.007

Eissa, A. E., Abd El-Lateif, R. S. A., Younis, E. M., Alzentani, S., Rashwan, E. H., Korany, R. M., Ragab, R. H., Abulelkasem, S. S., Elnakeeb, M. A., Afiffi, E., Abdel Hady, H. A., & Abouelhassan, E. M. (2026). WITHDRAWN: Detection of Enterocytozoon hepatopenaei in pond-cultured Litopenaeus vannamei shrimp: Unveiling the epidemiological significance of some invasive macrofauna, synergistic diagnostic approach and treatment trial. *Journal of Invertebrate Pathology*, *217*, 108602. https://doi.org/https://doi.org/10.1016/j.jip.2026.108602

Gupta, M. V. ., Bartley, D. M. ., & Acosta, B. O. . (2004). *Use of genetically improved and alien species for aquaculture and conservation of aquatic biodiversity in Africa*. WorldFish Center.

He, C., Yin, Z., Tian, Y., Yang, F., Cao, Z., Wang, C., Yan, D., Li, T., Chang, L., & Si, L. (2026). Transcriptome analysis provides molecular evidence for muscle growth regulation in Litopenaeus vannamei infected with Ecytonucleospora hepatopenaei (EHP). *Journal of Invertebrate Pathology*, *218*, 108648. https://doi.org/https://doi.org/10.1016/j.jip.2026.108648

International Organization for Standardization. (2018). *ISO 31000:2018 Risk management – Guidelines* (2nd ed., Number ISO 31000:2018). https://www.iso.org/standard/31000

Jongkor, F., Noor, T., & Yusrudin. (2026). PRODUKTIVITAS BUDIDAYA UDANG VANAME (Litopenaeus vannamei) SECARA INTENSIF DI PT. PYRAMIDE PARAMOUNT INDONESIA FARM GEROKGAK, BULELENG, BALI. *Jurnal Perikanan Pantura (JPP)*, *9*(1), 72–80. https://doi.org/10.30587/jpp.v9i1.11395

Kmmari, S., Rathlavath, S., Pillai, D., & Rajesh, G. (2018). Hepatopancreatic Microsporidiasis (HPM) in Shrimp Culture: A Review. *International Journal of Current Microbiology and Applied Sciences*, *7*(1), 3208–3215. https://doi.org/10.20546/ijcmas.2018.701.383

K.P., J., Areekkal, N. K., Vengatesan, J., Francis, B. I., Peter, E. P., & Thangavelu, B. (2024). *Susceptibility of Five Penaeid Shrimp Species to Experimental Infection of <i>Enterocytozoon Hepatopenaei</i>* https://doi.org/10.2139/SSRN.4696175

Kumar, V., Das, B. K., Dhar, S., Bisai, K., Pande, G. S. J., Zheng, X., Parida, S. N., Adhikari, A., & Jana, A. K. (2024). Ecytonucleospora hepatopenaei (EHP) disease prevalence and mortality in Litopenaeus vannamei: a comparative study from Eastern India shrimp farms. *BMC Microbiology 2024 24:1*, *24*(1), 523-. https://doi.org/10.1186/S12866-024-03681-Y

Lestariadi, R. A., Yamao, M., & Yamao, M. (2018). WHERE DO RISKS IN SHRIMP FARMING COME FROM? EMPIRICAL RESULTS FROM SMALL FARMERS IN EAST JAVA, INDONESIA. *Journal of Agribusiness and Rural Development*, *47*(1), 39–47. https://doi.org/10.17306/J.JARD.2018.00366

Li, S., Wu, Y., Jin, J., Wu, B., Zhao, C., Lin, Z., Liu, M., & Peng, Z. (2025). Transcriptomic and Metabolomic Responses to Growth Differences in Litopenaeus vannamei Infected with Enterocytozoon hepatopenaei. *Fishes*, *10*(12), 652. https://doi.org/10.3390/fishes10120652

Lightner, D. V. (2005). Biosecurity in shrimp farming: Pathogen exclusion through use of SPF stock and routine surveillance. *Journal of the World Aquaculture Society*, *36*(3), 229–248. https://doi.org/10.1111/J.1749-7345.2005.TB00328.X

Liu, H., Shen, M., He, Y., Li, B., Pu, L., Xia, G., Yang, M., & Wang, G. (2023). Analysis of differentially expressed proteins after EHP-infection and characterization of caspase 3 protein in the whiteleg shrimp (Litopenaeus vannamei). *Fish & Shellfish Immunology*, *135*, 108698. https://doi.org/https://doi.org/10.1016/j.fsi.2023.108698

Lizarzaburu, E. R., & Salquero, J. Q. (2011). ISO standards a potential path for emerging markets: An initial literature review. *Risk Governance and Control: Financial Markets and Institutions*, *1*(4), 65–71. https://doi.org/10.22495/RGCV1I4ART5

López-Carvallo, J. A., Cruz-Flores, R., & Dhar, A. K. (2022). The emerging pathogen Enterocytozoon hepatopenaei drives a degenerative cyclic pattern in the hepatopancreas microbiome of the shrimp (Penaeus vannamei). *Scientific Reports*, *12*(1), 14766. https://doi.org/10.1038/S41598-022-19127-2

Lu, Y.-M., Lu, J.-Q., Zhao, Q., Chen, J., Xiong, J.-B., Lu, Y.-M., Lu, J.-Q., Zhao, Q., Chen, J., & Xiong, J.-B. (2025). Pathogenic mechanisms of *Enterocytozoon hepatopenaei* through the parasite-gut microbiome-shrimp (*Litopenaeus vannamei*) physiology axis. *Zoological Research, 2025, Vol. 46, Issue 2, Pages: 401-413*, *46*(2), 401–413. https://doi.org/10.24272/J.ISSN.2095-8137.2024.411

Ma, R., Zhu, B., Xiong, J., & Chen, J. (2024). The Pathogenic Mechanism of Enterocytozoon hepatopenaei in Litopenaeus vannamei. *Microorganisms 2024, Vol. 12, Page 1208*, *12*(6), 1208. https://doi.org/10.3390/MICROORGANISMS12061208

Maria Agustina Pardede, Silvani Tri Julianti, Putri Puspita Sari, Hesti Listiyani, Dewi Kartika, Siti Mufidah, Muhammad Adrian Fauzi, & Mohamad Fathoni. (2025). Pemeriksaan EHP dan AHPND pada Litopenaeus vannamei dengan Metode PCR di BKHIT Jawa Timur. *Jurnal Pendidikan Kimia, Fisika Dan Biologi*, *1*(4), 136–151. https://doi.org/10.61132/JUPENKIFB.V1I4.489

Marimuthu, S., Raju, C. S., & Bhassu, S. (2021). Clinical Investigation and Molecular Diagnosis of Microsporidian Enterocytozoon hepatopenaei (EHP) in Shrimps from Selangor, Malaysia. *Genetics of Aquatic Organisms*, *5*(2), 67–75. https://doi.org/10.4194/2459-1831-v5_2_03

MİNAZ, M., AK, K., & KURTOĞLU, İ. Z. (2021). Occupational Health and Safety Risk Analysis in Trout Aquaculture Facility. *OHS ACADEMY*, *4*(3), 14–21. https://doi.org/10.38213/ohsacademy.989585

Mondal, S., Deepika, A., Hundare, S., Poojary, N., Abraham, T. J., Sreedharan, K., Tripathi, G., & Rajendran, K. V. (2023). A study on the natural host range of Enterocytozoon hepatopenaei in different species of shrimp and co-habiting aquatic fauna. *Indian Journal of Fisheries*, *70*(3), 98–106. https://doi.org/10.21077/IJF.2023.70.3.129795-13

Muniesa, A., Perez-Enriquez, R., Cabanillas-Ramos, J., Magallón-Barajas, F. J., Chávez-Sánchez, C., Esparza-Leal, H., & de Blas, I. (2017). Identifying risk factors associated with White Spot Disease outbreaks of shrimps in the Gulf of California (Mexico) through expert opinion and surveys. *Reviews in Aquaculture*, *9*(3), 257–265. https://doi.org/10.1111/RAQ.12136

Munkongwongsiri, N., Thepmanee, O., Lertsiri, K., Vanichviriyakit, R., Itsathitphaisarn, O., & Sritunyalucksana, K. (2022). False mussels (Mytilopsis leucophaeata) can be mechanical carriers of the shrimp microsporidian Enterocytozoon hepatopenaei (EHP). *Journal of Invertebrate Pathology*, *187*. https://doi.org/10.1016/J.JIP.2021.107690

Nguyen, D.-A. Le, Byadgi, O. V., Cheng, L.-W., Pulpipat, T., Wang, P.-C., & Chen, S.-C. (2023). EVALUATION OF *ENTEROCYTOZOON HEPATOPENAEI* (EHP) IN FARMED *PENAEUS VANNAMEI* IN TAIWAN. *Taiwan Veterinary Journal*, *48*(03n04), 55–62. https://doi.org/10.1142/S1682648523500038

Nkuba, A. C., Mahasri, G., Lastuti, N. D. R., & Mwendolwa, A. A. (2021). Correlation of nitrite and ammonia concentration with prevalence of enterocytozoon hepatopenaei (EHP) in shrimp (litopenaeus vannamei) on several super-intensive ponds in east java, Indonesia. *Jurnal Ilmiah Perikanan Dan Kelautan*, *13*(1), 58–67. https://doi.org/10.20473/JIPK.V13I1.24430

Otta, S. K., Patil, P. K., Jithendran, K. P., Rajendran, K. V., Alavandi, S. V, & Vijayan, K. K. (2016). *Managing Enterocytozoon hepatopenaei (EHP), microsporidial infections in vannamei shrimp farming: An Advisory*. https://api.semanticscholar.org/CorpusID:182104805

Palić, D., & Scarfe, A. D. (2019). Biosecurity in aquaculture: practical veterinary approaches for aquatic animal disease prevention, control, and potential eradication. *Biosecurity in Animal Production and Veterinary Medicine: From Principles to Practice*, 497–523. https://doi.org/10.1079/9781789245684.0497

Pang, J., Zhao, C., Liu, Z., Lu, Q., He, X., Weng, S., & Jianguo. (2022). *Rapid visual detection of Enterocytozoon hepatopenaei by recombinase polymerase amplification combined with a lateral flow dipstick*. https://doi.org/10.22541/AU.164997007.71272524/V1

Piamsomboon, P., Choi, S. K., Hanggono, B., Nuraini, Y. L., Wati, F., Tang, K. F. J., Park, S., Kwak, D., Rhee, M. H., Han, J. E., & Kim, J. H. (2019). Quantification of enterocytozoon hepatopenaei (Ehp) in penaeid shrimps from southeast asia and latin america using taqman probe-based quantitative PCR. *Pathogens*, *8*(4). https://doi.org/10.3390/PATHOGENS8040233

Piamsomboon, P., & Han, J. E. (2022). White Feces Syndrome, A Multifactorial Syndrome of Cultured Shrimp: A Mini Review. *Fishes*, *7*(6), 339. https://doi.org/10.3390/fishes7060339

Putra, Z., Chan, S., & IHA, M. (2017). Design of Risk Management Based on Iso 31000 in PDAM Tirta Meulaboh. *AFEBI Management and Business Review*, *2*(01), 21. https://doi.org/10.47312/AMBR.V2I01.55

Raveendra, M., Hari Babu, P., Neeraja, T., Pamanna, D., Madhavan, N., Sahul Hameed, A. S., & Srilatha, C. H. (2018). Screening for Incidence of Microsporidian Parasite Enterocytozoon hepatopenaei (EHP) in Litopenaeus vannamei from Aquaculture Ponds in SPSR Nellore District of Andhra Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*, *7*(03), 1098–1109. https://doi.org/10.20546/IJCMAS.2018.703.131

Raveendra, M., Suresh, G., Nehru, E., Pamanna, D., Venkatesh, D., Yugandhar Kumar, M., Sahul Hameed, A. S., Srilatha, Ch., Hari Babu, P., & Neeraja, T. (2018). Effect of Microsporidian Parasite Enterocytozoon hepatopenaei (EHP) on Pond Profitability in Farmed Pacific White Leg Shrimp Litopenaeus vannamei. *International Journal of Current Microbiology and Applied Sciences*, *7*(05), 1625–1638. https://doi.org/10.20546/ijcmas.2018.705.192

Rosdian, A. R., Yasyfa, A., Hamdah, H. H. L., Azahra, S. M., & Alfiana, A. (2026). Analisis Manajemen Risiko Pada UMKM Pertanian Menggunakan Pendekatan ISO31000 dan Matriks Risiko: Studi Kasus "Berkah Tani." *Ekopedia: Jurnal Ilmiah Ekonomi*, *2*(1), 172–185. https://doi.org/10.63822/3PVCF219

Safitri, D. N., Sari, R. F., & Dharmawan, Y. S. (2021). *Analisis manajemen risiko sistem enterprise resource planning menggunakan kerangka kerja iso 31000 pada pt. xyz*. *3*(1), 58–67. https://doi.org/10.30604/JTI.V3I1.58

Salachan, P. V., Jaroenlak, P., Thitamadee, S., Itsathitphaisarn, O., & Sritunyalucksana, K. (2016). Laboratory cohabitation challenge model for shrimp hepatopancreatic microsporidiosis (HPM) caused by Enterocytozoon hepatopenaei (EHP). *BMC Veterinary Research*, *13*(1), 9. https://doi.org/10.1186/s12917-016-0923-1

Sankar, G., Mansingh, V. R., & B, G. (2023). The impact of Enterocytozoon hepatopenaei (Ehp) on penaeus vannamei shrimp seed growth in a nursery and grow out system in andhra pradesh, south east coast of India. *Mediterranean Aquaculture Journal*, *10*(1), 23–31. https://doi.org/10.21608/MAJ.2023.200232.1021

Scarfe, A. D., & Palić, D. (2020). Aquaculture biosecurity: Practical approach to prevent, control, and eradicate diseases. *Aquaculture Health Management: Design and Operation Approaches*, 75–116. https://doi.org/10.1016/B978-0-12-813359-0.00003-8

Shen, H., Jiang, G., Wan, X., Fan, X., Qiao, Y., Shi, W., Li, H., & Wang, L. (2017). Multiple Pathogens Prevalent in Shrimp Penaeus vannamei Cultured from Greenhouse Ponds in Jiangsu Province of China. *Journal of Aquaculture Research & Development*, *8*(10). https://doi.org/10.4172/2155-9546.1000516

Shilova, T. (2020). Risk-based approach to enterprise value generation. *Socio-Economic Research Bulletin*, *0*(2(73)), 164–173. https://doi.org/10.33987/VSED.2(73).2020.164-173

Shirsak Mondal, Deepika, A., Hundare, S., Poojary, N., Abraham, T. J., K. Sreedharan, Tripathi, G., & K. V. Rajendran. (2023). A study on the natural host range of Enterocytozoon hepatopenaei in different species of shrimp and co-habiting aquatic fauna. *Indian Journal of Fisheries*, *70*(3). https://doi.org/10.21077/ijf.2023.70.3.129795-13

Srisapoome, P., Jun-On, P., Uchuwittayakul, A., & Limyada, C. (2025). Therapeutic effects of fumaric acid on proteomic expression and gut microbiota composition in Pacific white shrimp (Penaeus vannamei) infected with Ecytonucleospora hepatopenaei (EHP). *Fish & Shellfish Immunology*, *158*, 110122. https://doi.org/https://doi.org/10.1016/j.fsi.2025.110122

Syah, I. F., Akbarurrasyid, M., Pietoyo, A., Aldiansyah, R., & Priyana, R. (2025). STRATEGI BERBASIS SWOT UNTUK MENINGKATKAN BIOSEKURITI PADA PERUSAHAAN IMPORTIR IKAN KOI (Cyprinus carpio). *Jurnal Salamata*, *7*(2), 63. https://doi.org/10.15578/SALAMATA.V7I2.18182

Tang, K. F. J., Han, J. E., Aranguren, L. F., White-Noble, B., Schmidt, M. M., Piamsomboon, P., Risdiana, E., & Hanggono, B. (2016). Dense populations of the microsporidian Enterocytozoon hepatopenaei (EHP) in feces of Penaeus vannamei exhibiting white feces syndrome and pathways of their transmission to healthy shrimp. *Journal of Invertebrate Pathology*, *140*, 1–7. https://doi.org/10.1016/J.JIP.2016.08.004

Tangprasittipap, A., Srisala, J., Chouwdee, S., Somboon, M., Chuchird, N., Limsuwan, C., Srisuvan, T., Flegel, T. W., & Sritunyalucksana, K. (2013). The microsporidian Enterocytozoon hepatopenaei is not the cause of white feces

syndrome in whiteleg shrimp Penaeus (Litopenaeus) vannamei. *BMC Veterinary Research*, *9*(1), 139. https://doi.org/10.1186/1746-6148-9-139

Thitamadee, S., Prachumwat, A., Srisala, J., Jaroenlak, P., Salachan, P. V., Sritunyalucksana, K., Flegel, T. W., & Itsathitphaisarn, O. (2016). Review of current disease threats for cultivated penaeid shrimp in Asia. *Aquaculture*, *452*, 69–87. https://doi.org/https://doi.org/10.1016/j.aquaculture.2015.10.028

Venkateswarlu, V. (2019). A Study on Diseases Affecting Litopenaeus vannamei Farming in Coastal Districts of Andhra Pradesh, India. *International Journal for Research in Applied Science and Engineering Technology*, *7*(7), 1301–1306. https://doi.org/10.22214/IJRASET.2019.7212

Wan Sajiri, W. M. H., Borkhanuddin, M. H., & Kua, B. C. (2021). Occurrence of Enterocytozoon hepatopenaei (EHP) infection on Penaeus vannamei in one rearing cycle. *Diseases of Aquatic Organisms*, *144*, 1–7. https://doi.org/10.3354/DAO03571