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DETERMINANTS OF THE MORTALITY OF PATIN FISH IN TEMERLOH, PAHANG, MALAYSIA

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ABSTRACT

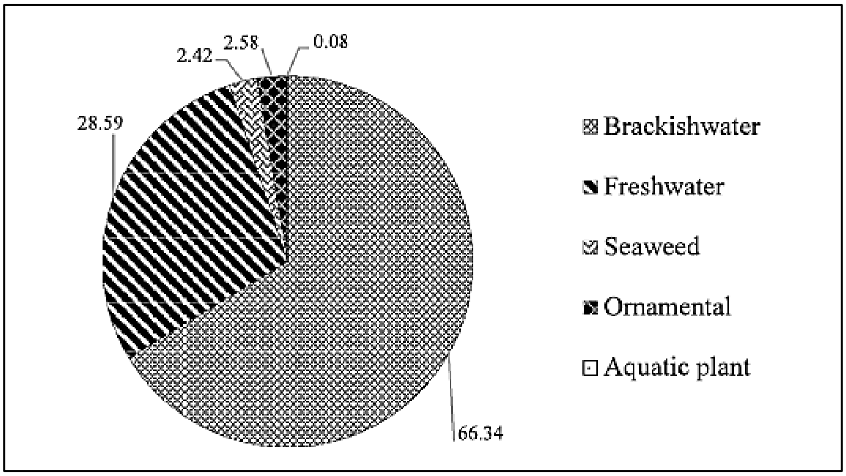
This study explores the factors influencing Patin fish mortality in Malaysia's expanding aquaculture industry, which is crucial for meeting the rising global demand for fish and seafood. Analysing data from 135 fish farmers through SPSS Software, it finds significant correlations between mortality rates and variables like fish species, time until sale, and fish quantity per cage. At the same time, factors such as partnership numbers and feeding frequency have minimal impact. These results highlight the critical role of water quality management in fish health and production costs. The findings are vital for developing strategies to improve fish farming and water quality control in Malaysia, addressing the need to consider various factors to reduce fish mortality. Despite the significance of certain variables, the low adjusted R-squared value points to other yet unidentified factors affecting fish deaths, suggesting ongoing data collection and model refinement for stakeholders. This research contributes to understanding aquaculture costs and fish health, informing theories such as Interactive Governance Theory, Stress Response Theory, and Disease Ecology Theory and underscoring the importance of comprehensive strategies for sustainable aquaculture practices.

1 Introduction

In Malaysia, the aquaculture business has grown at an average annual rate of 10% over the last five years, following a notable pattern that started in the 1920s. This advancement has been crucial in restructuring the nation's food security position (Food and Agriculture Organisation, 2021). Malaysia's fishing industry, which adds about 0.2% to the country's GDP, has experienced significant enhancements in farming techniques, variety, and financial effects. The nation has adopted numerous farming techniques for local and global markets, including marine, briny, and freshwater cultures. According to Dauda et al. (2018) and the Food and Agriculture Organisation (2021), Malaysia exports several items, including tiger prawns, molluscs, and marine fish. The government's prioritisation of aquaculture as a critical component in eliminating poverty in coastal regions has resulted in significant expenditures in research and development, therefore assuring long-term and environmentally friendly expansion (Poon et al., 2016; Mat et al., 2018). Nevertheless, aquaculture is faced with obstacles related to environmental concerns, including land use changes and wastewater control. The government's proposal to designate an extra 40,000 hectares for aquaculture by 2040 underscores the importance of balancing freshwater requirements and wastewater control. The growth of the aquaculture industry relies on the responsible utilisation of resources (Karim et al., 2018; Waiho et al., 2020; Lee & Viswanathan, 2019). To deal with the concerns related to wastewater, which includes significant amounts of natural materials and various other detrimental compounds, it is crucial to utilise technical approaches to treat and recycle the water in tank farming practices. This technique lines up with the goals of sustainable development, as stressed by Dauda et al. (2018), Yusoff (2015), and Hamdan et al. (2015).

As Kurniawan et al. (2020) reported, the overall labour force was circulated throughout different fields of the tank farming market in Malaysia in 2019. The data shows that most employees participated in brackish water tank farming, comprising 66.34% of the workforce, while freshwater tank farming utilised 28.59%. The industry's remaining labour percentages consisted of seaweed (2.42%), ornamental fish (2.58%), and aquatic plants (0.08%) (Syawal et al., 2021). This number is pertinent to the study as it illustrates the importance of the aquaculture business, namely the saltwater and freshwater sectors, in terms of job prospects. To preserve the sector's long-term viability and financial success, it is essential to identify and mitigate the variables that contribute to fish mortality and water quality degradation, given the significant number of workers engaged (Kurniawan et al., 2020). The findings of this study may provide valuable insights for enhancing fish farming techniques and water quality control, eventually leading to improved lives for persons engaged in these industries.

Figure 1: Total workforces in different sectors of the aquaculture sector (%) in 2019 (Malaysia)



Source: Kurniawan, Syawal and Effendi (2020)

The fishing industry, especially aquaculture, is a cornerstone of Malaysia's economy, providing income, employment, and food security (Ramzani & Ismail, 2018). While workforce data offers context, it might not directly influence variables such as fish mortality or water quality (Wei et

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al., 2017; Mustafa et al., 2018). Consequently, this study focuses on factors directly impacting these outcomes while recognising that employment data underscores the industry's human impact. Understanding workforce distribution facilitates targeted interventions (Mattar, 2012; Mustafa et al., 2018), making actionable research insights vital to protect livelihoods and communities (Haslawati et al., 2023; Rashid et al., 2015). Given the industry's economic significance, ongoing fish health and water quality studies are essential to address environmental challenges (Yew et al., 2008). Malaysia's impressive economic progress (Lee & Viswanathan, 2019; Husin & Ibrahim, 2022) makes sustainable sectors like aquaculture crucial for achieving high-income status. Government and NGOs play a vital role in income generation, particularly in rural areas (Poon et al., 2016). Although ocean fishing remains significant, limited freshwater landings necessitate aquaculture expansion to compensate for declining coastal catches (Department of Fisheries Malaysia, 2023). Exporting high-value species like grouper and snapper provides significant economic benefits, mitigating agricultural deficits and enhancing economic resilience (Mat et al., 2018; Mustafa et al., 2018). Aquaculture's contribution to the Gross National Income (GNI) reached approximately USD 5.08 billion in 2021, demonstrating its growth and alignment with Malaysia's economic goals (Department of Fisheries Malaysia, 2023).

Moreover, in Malaysia, particularly in Pahang and its district Temerloh, located on the eastern coast of Peninsular Malaysia, Patin fish mortality has emerged as a significant concern for the aquaculture industry, mainly driven by microbial infections like Aeromonas hydrophila (Marpaung et al., 2015). This region, known for its thriving aquaculture industry that focuses on species such as tilapia, catfish, and Patin using pond and cage systems, has seen a considerable increase in aquaculture production. From 18,387 metric tonnes in 2015, production rose to 23,936 metric tonnes in 2019, with tilapia production alone reaching 21,000 metric tonnes by 2022, accounting for over 76% of the state's total aquaculture output (Department of Fisheries Malaysia, 2023). Despite the industry's growth, driven by market demand for Patin fish (Dauda et al., 2018), it faces challenges such as disease outbreaks, poor water quality, high stocking density, and environmental degradation, including water pollution and habitat destruction (Putra et al., 2020; Syawal et al., 2021). These factors contribute to the fish's increased susceptibility to diseases and stress, further exacerbated by using low-quality or contaminated feeds (Syawal et al., 2021). The financial implications of Patin fish mortalities, such as market price fluctuations and impacts on export opportunities, highlight the crisis's severity (Anuar, 2017; Marpaung et al., 2015). To address these issues, recommended practical actions include improved farm management practices, regular water quality monitoring (Kurniawan et al., 2020), standardised feeding regimens, and a shift from antibiotics to probiotics and immunostimulants (Putra et al., 2020), aiming for sustainable, environmentally friendly, and cost-effective strategies in Malaysia's aquaculture sector. This growth and the accompanying challenges underscore the Malaysian government's commitment to promoting sustainable development within the aquaculture industry through strategic initiatives despite the hurdles of disease outbreaks and market access (Food and Agriculture Organization, 2021).

The Patin Fish, or Pangasius Hypophthalmus, plays a crucial role in Malaysia's aquaculture, vital for both domestic consumption and export, yet faces high mortality rates leading to significant economic losses, highlighting the need for in-depth research into the biological, environmental, and socio-economic factors affecting its mortality (Fathi et al., 2018). Key issues include suboptimal water quality in earthen ponds and recirculating systems, leading to overcrowding, overfeeding, poor water rotation, and reduced dissolved oxygen levels (Arza & Tirtavani, 2017). Disease outbreaks, particularly from Aeromonas hydrophila bacteria and parasitic infestations like Margulis and anchor worms, further contribute to these mortality rates (Marpaung et al., 2015; Putri et al., 2023). Compounded by nutritional deficiencies and inadequate feeding practices, these conditions weaken fish immunity and enhance disease susceptibility (Wicaksana et al., 2014). Poor farm management practices, such as insufficient biosecurity and disease management plans, exacerbate the situation (Fani et al., 2018). The COVID-19 pandemic's Movement Control Order (MCO) in March 2020 worsened these challenges, causing supply chain disruptions, reduced demand and prices, labour shortages, and a significant drop in seafood exports, notably a 50% decrease to Singapore by mid-February 2020, affecting the livelihoods of aquaculture workers with a 33% reduction in jobs or working hours and about 80% reporting income losses (Syawal et al., 2021). Despite these adversities, Malaysia remains a significant global aquaculture player, underpinning the importance of developing resilient and adaptive strategies to overcome such global disruptions and emphasising sustainable practices to address fish stock depletion, climate change, diseases, and poor stakeholder interaction for the industry's prosperity (Fadli et al., 2022; Fani et al., 2018; Ahmad & Zabri, 2016). Additionally, the aggressive inter-species interactions, particularly from tilapia, pollution from high-density farming, and disease spread highlight the pressing need for sustainable, effective management strategies to mitigate these factors affecting Patin fish health and survival (Iruo et al., 2018; The Star, 2022), including tackling diseases like Streptococcus agalactiae associated with dense fish farming practices.

Previous research suggests a complex relationship between storage duration, stocking density, feeding practices, and fish mortality. Studies in India and Indonesia confirm that prolonged storage and overcrowding directly contribute to increased fish deaths (Mahmud et al., 2019; Syifa et al., 2021; Yasin et al., 2021). However, these relationships remain under-researched within the specific context of Malaysian aquaculture, particularly regarding Patin fish. The potential impact of feeding frequency on fish growth and mortality rates warrants further investigation (Sukmiwati et al., 2020; Hor et al., 2017). Understanding these factors is crucial for Malaysian aquaculture farmers, as fish losses translate into significant economic setbacks, including production decline

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and escalating operational costs (Ramzani & Ismail, 2018; Iqbal et al., 2020). This study aims to bridge this knowledge gap by meticulously investigating the relationship between fish mortality and several critical elements in Malaysian Patin fish farming. Specifically, it will address the following research questions: RQ1: Is there any significant relationship between the specific fish species present in Patin ponds and fish death? RQ2: Does the number of partners in a fish farming operation influence mortality rates? RQ3: How does the storage period of fish before sale correlate with fish death? RQ4: What is the relationship between the quantity of fish (per cage) and fish death? RQ5: How does daily feeding frequency affect fish health and mortality? By carefully examining these questions, the study will identify common fish species in Patin ponds and provide Malaysian aquaculture farmers with actionable insights. These insights will empower farmers to develop concrete strategies to reduce fish losses, leading to healthier ponds, improved productivity, and more excellent economic stability within the industry.

This study provides a comprehensive understanding of practices used by neighbourhood Patin fish farmers in Temerloh, Pahang. Findings benefit stakeholders, including fish-related industries, government agencies, and policymakers. The research aligns with the Malaysian Agro-Food Policy, potentially leading to improved farm profits and national food security. Insights contribute to fish health and aquaculture knowledge, promoting sustainable practices. The study addresses aquaculture's environmental impact, aiming to minimise negative effects and foster eco-friendly operations.

2 Hypothesis Development

The freshwater catfish, Pangasius hypophthalmus, commonly known as Patin fish, is highly sought after globally, significantly benefiting the socioeconomic status of numerous Malaysian manufacturers through commercial pangasius culture. However, the survival and development of Patin fish are heavily influenced by various factors, with water quality paramount. The entire lifecycle of the fish depends on its habitat quality, making the control of water quality a critical component of successful fish production strategies (Sukmiwati et al., 2020). The success or failure of aquaculture operations hinges on water quality, as it directly impacts fish farming effectiveness. Poor water quality can impede fish growth and development, reducing aquaculture products' overall quality (Syawal et al., 2021). As a result, the compatibility of the water supply for generating high-quality tank farming products is a necessary consideration, stressing the requirement for reliable water top-quality administration in tank farming systems.

2.1 Fish species

Aquaculture, or fish farming, involves the commercial rearing of fish in enclosures or tanks; aquaculture, primarily aimed at human consumption, faces challenges in ensuring efficient and sustainable fish production, with water quality being a crucial factor (Fadli et al., 2022). Farmers often reduce the production cycle to 6-8 months by stocking larger fish in cages, leading to overcrowding and deteriorated water quality, which can slow fish growth rates (Sayed, 2007; Jusadi et al., 2015). Maintaining optimal water quality is essential for fish reproduction and development (Putri et al., 2019), as biowaste from intensive fish farming, particularly in net cages, significantly impacts water quality (Arza & Tirtavani, 2017). Overcrowding, intensive feeding, and not removing large fish can result in poor water quality and unhealthy fish (Fani et al., 2018). The National Aquaculture Plan aims to increase aquaculture's contribution to total fish output to 50% by 2020, expecting significant growth in Malaysia's aquaculture production (Fani et al., 2018). Adequate land and access to clean water are crucial for fish farming, as these factors limit the types of facilities, species, and production rates (Mustafa et al., 2021; Putra et al., 2020). The partnership between fish species and fish mortality has been thoroughly researched, emphasising the relevance of understanding species-specific characteristics that influence mortality rates in tank farming (Daud & Zailani, 2011; Hamdan et al., 2015; Mahyadin et al., 2014; Yew et al., 2008). Human activities, especially tank farming, have negatively impacted the top quality of water (Haszlinna et al., 2009; Yew et al., 2008). To meet the enhancing demand, the Food and Farming Company estimates that tank farming outcomes should rise by 40% in the next decade (Food and Agriculture Organization, 2021). Freshwater ecological communities supply diverse ecosystem services: wetlands, rivers, lakes, and floodplains (Rohman et al., 2021). Changes in ecosystem structure, function, and composition often alter the supply of these services (Kwan et al., 2018). This study measures water quality through the number of fish deaths, as it is crucial for productive and profitable aquaculture, minimising fish health issues, and producing higher-quality products (Mat et al., 2018). The hypothesis is that maintaining water quality is essential to reduce the risk of fish deaths in catfish farming:

H1o: There is no significant relationship between fish species and fish death.

H1a: There is a significant relationship between fish species and fish death.

2.2 Number of Partners in Farming Operations

Optimal water quality in aquaculture systems is critical for the health and growth of fish, including Pangasius species. It requires monitoring factors such as temperature, dissolved oxygen, pH, nitrite levels, salinity, alkalinity, hardness, and ammonia (Putri et al., 2023). Agricultural limestone helps maintain alkalinity and control turbidity, while soluble carbonates maintain pH levels. Filters are crucial for removing suspended solids like sand, mud, or coral (Syawal et al., 2021). The Aquaculture Stewardship Council (ASC) advises farmers to record feed types and quantities, retain samples, and conduct laboratory analyses to monitor nitrogen and phosphorus levels (Arza & Tirtavani, 2017). Monitoring dissolved oxygen levels is recommended to understand photosynthesis and respiration effects, with measurements taken in the early morning

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and late afternoon when levels fluctuate significantly. The connection between the number of partners in aquaculture operations and fish mortality underscores the importance of cooperative management for profitability and sustainability (Food and Agriculture Organization, 2021; Putri et al., 2019; Anuar, 2017). A hand-held oxygen meter can measure salinity, temperature, and dissolved oxygen levels (Utami et al., 2014). Successful Pangasius farming requires understanding water quality, regular health checks, and adherence to biosecurity practices and globally recognised standards, with further research needed to assess the costs of these methods (Mat et al., 2018): Therefore, the following hypothesis can be proposed:

H2o- There is no significant relationship between the number of partners in farming operations and fish death.

H2a- There is a significant relationship between the number of partners in farming operations and fish death.

2.3 Storage Period of Fish Before Sale

As global aquaculture production expands, addressing disease-related concerns is increasingly vital. Diseases in aquaculture, affected by fish health, environmental conditions, and pathogen presence, necessitate practices that mitigate disease risks (Al-Eidan et al., 2019). Biosecurity, including cleaning and disinfecting facilities and maintaining optimal water quality, is critical for controlling infectious diseases (Lu et al., 2016). Good water quality is essential for fish survival and growth, especially with the growing demand for protein-rich food like fish (Carli & Canavari, 2013). Managing water quality effectively in fishponds is crucial for satisfying this demand, yet many fish farmers lack awareness of its importance. Enhancing knowledge and guidance on water quality management can increase fish production and reduce costs (Lu et al., 2016). Studies have identified the duration of fish kept before sale as a factor influencing mortality (Kwan et al., 2018; Mat et al., 2018; Rohman et al., 2021). Pangasius, an air-breathing fish, exhibits a reduced need for aeration, consumes organisms in pond soil, and improves water quality. It thrives in specific water conditions, including optimal temperature, pH, turbidity, dissolved oxygen, and mineral levels (Kwan et al., 2018). Extended exposure to suboptimal temperatures can decrease growth rates and disease resistance. Efficiently managing the time from when fish reach marketable size to sale is critical to minimising mortality (Hong et al., 2017; Department of Fisheries Malaysia, 2023). Optimising water conditions and supply chain management practices can reduce mortality rates, enhancing productivity. Further research is needed to explore this relationship, considering factors like water quality, stocking density, and management patterns. Therefore, the following hypothesis is proposed:

H3o- There is no significant relationship between the storage period of fish before sale and fish death.

H3a- There is a significant relationship between the storage period of fish before sale and fish death.

2.4 Quantity of fish (Per Cage)

The relationship between fish equipping density and mortality in aquaculture manufacturing is a substantial location of study, revealing that higher fish densities can bring about enhanced mortality rates (Mahmud et al., 2019; Kwan et al., 2018; Ramzani & Ismail, 2018; Lee & Viswanathan, 2019). Research studies have shown that greater equipping thickness, like in cases of adolescent Japanese sea bass and tilapia, causes enhanced stress, cannibalism, and condition episodes, consequently enhancing death (Mustafa et al., 2021; Molnár et al., 2006). This stresses the relevance of managing fish amounts per cage and keeping optimal stocking thickness for sustainable tank farming. Appropriate feeding monitoring is crucial for high water quality, expense reduction, and enhanced production. Overstocking, combined with heavy feeding and not removing bigger fish, can result in considerable water quality and fish health issues. Overfeeding is a standard error leading to sick fish and excessive waste production, stressing the organic reduction capability and triggering water quality decrease (Kurniawan et al., 2020; Wijoyo et al., 2020; Fernández-Montero et al., 2020). The ideal feed pellet size, usually 20-30% of the fish's mouth gape, is essential for efficient feeding. Smaller-sized pellets can result in ineffective feeding, while larger bullets can reduce feeding and cause choking. Intensive aquaculture tasks also contribute to water top quality wear and tear, highlighting the requirement for fish breeders to think about water quality aspects and feed types to avoid fish death and ensure the production of high-quality fish (Mubarok & Fajar, 2020; Dao, 2020). Consequently, thoroughly handling stocking thickness, feeding methods, and water top quality is necessary for reducing mortality and maximising efficiency in tank farming procedures. Therefore, it can be recommended that:

H4o- There is no significant relationship between the type of Quantity of fish (Per Cage) and fish death.

H4a- There is a significant relationship between the type of Quantity of fish (Per Cage) and fish death.

2.5 Daily Feeding Frequency

Tank farming feeding patterns, crucial for fish health, wellness, and development, differ dramatically throughout varieties and growth stages. Nadia et al. (2020) keep in mind that while many fish require one dish daily, growing fish may require several feedings, and nocturnal types, like particular catfish, take advantage of nighttime feeding. The fisheries market in Malaysia, adding 0.91% to the 2019 GDP, is increasingly concentrating on aquaculture, with Malaysia ranking 16th in global capture fisheries and 7th in tank farming manufacturing (Department of

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Fisheries Malaysia, 2023). Studies have revealed that fish death in tank farming is influenced by variables such as stocking density, feeding practices, and high water quality (Dao, 2020; Ndah et al., 2017; Ramzani & Ismail, 2018; Fernández-Montero et al., 2020). As an example, greater stocking thickness can cause increased tension and cannibalism in types like Japanese sea bass (Mustafa et al., 2021), and improper feeding techniques can contribute to water quality destruction and fish health and wellness issues (Wijoyo et al., 2020; Fernández-Montero et al., 2020). In Bangladesh, the fisheries industry plays an essential function in the economy, with recent agricultural techniques favouring aquaculture over typical crop farming (Akter et al., 2018; Stanciu & Mihăilescu, 2014). Despite obstacles in meeting manufacturing assumptions, this change has significantly enhanced tank farming outcomes (Karim et al., 2018). Reliable supply administration in Malaysian mini-selling organisations, as studied by Lee and Viswanathan (2019), and the financial elements of marine fisheries in East Malaysia (Safa, 2004), show the complexity of the fisheries market and the requirement for effective procedures and management to guarantee sustainability and success. Therefore, the proposed hypothesis for this research is:

H5o- There is no significant relationship between the type of Daily Eating frequency (X5) and fish death.

H5a- There is a significant relationship between the type of Daily Eating frequency (X5) and fish death.

3 Implications of Cost Management

The profitability and longevity of the aquaculture industry, particularly Patin fish farming in Peninsular Malaysia, are heavily dependent on effective cost management, influenced by factors like fish species selection, duration before sale, and fish density in cages. The choice of fish species is crucial, with resilient species leading to reduced mortality and costs; hence, focusing on research and development for enhancing Patin fish resilience through selective breeding and genetic improvements is vital (Al-Eidan et al., 2019; Cardos & Pete, 2011). Efficient supply chain management, particularly reducing the time lapse between harvest and sale, can decrease costs related to fish mortality (Lu et al., 2016; Kumar & Mahto, 2013). Maintaining optimal stocking densities is also essential to prevent stress and disease spread (Hor et al., 2017; Rohman et al., 2021). Feed cost management, accounting for a significant portion of production costs, can be optimised through alternative ingredients, improved feed conversion ratios, and precision feeding technologies (Al-Eidan et al., 2019; Setala & Gunasekaran, 1996; Cagwin & Bouwman, 2002). Labour cost management can be achieved through automation, skilled worker training, and efficient farm practices (Carli & Canavari, 2013). Infrastructure and equipment costs vary based on the chosen production system, each having different cost and efficiency implications (Yusoff et al., 2016; Barasa et al., 2018). Environmental sustainability, encompassing waste management and resource conservation, is increasingly significant in cost management, influencing operating costs and marketability (Lu et al., 2016; Amirrudin et al., 2023; Karim et al., 2018). In summary, the Patin fish farming industry's sustainability and competitiveness hinge on effective cost management across the feed, labour, infrastructure, and environmental considerations, necessitating strategic adoption of innovative practices and technologies.

4 Theoretical Framework

Understanding the factors contributing to Patin fish mortality requires examining various theories and frameworks, specifically Interactive Governance Theory (IGT), Stress Response Theory, and Disease Ecology Theory, which provide comprehensive insights into the aquaculture industry's complexities. IGT highlights the importance of collaboration among diverse stakeholders for effective governance, emphasising participation and negotiation for sustainable outcomes (Fathi et al., 2018; Gazali, 2018; Mat et al., 2018; Cahyati et al., 2019). Stress Response Theory explains how fish react to stress by releasing cortisol, with prolonged exposure potentially suppressing immunity and increasing infection and mortality risks (Husin & Ibrahim, 2022; Azra et al., 2021; Lee & Viswanathan, 2019). Disease Ecology Theory delves into the environmental, host, and pathogen factors affecting disease prevalence in fish populations, highlighting the interplay of these factors in disease transmission dynamics (Minai et al., 2016; Mat & Kadir, 2016; Ahmad & Zabri, 2016). These theories underscore the need for comprehensive strategies in managing Patin fish health, including addressing stress factors, environmental conditions, and pathogen management to reduce mortality rates and ensure sustainable aquaculture practices.

5 Method

The research design for studying Patin fish mortality in aquaculture, as informed by Bloomfield and Fisher (2019), employs a quantitative approach from the social sciences to analyse numerical data through structured questionnaires and correlational studies (Creswell, 2020). Primary data were collected from 2019 to 2021 through interviews, site visits, and observations involving 135 fish farmers in Temerloh, Pahang. This investigation aimed to understand Malaysian aquaculture products and services, focusing on educational backgrounds, cage management, fish types, costs, and marketable size. The study also incorporated qualitative insights to grasp fisheries' social, economic, and environmental implications (Singh, 2022; Pandey & Pandey, 2021). Focusing on Temerloh, known for its prominent role in Patin fish farming and its unique environmental conditions conducive to Patin growth, the study sought comprehensive insights into this specific aquaculture context (Sekaran & Bougie, 2016; Creswell, 2020). The census study approach was used, encompassing all members of the fish farming population in Temerloh, with individual fish farmers serving as the unit of analysis, allowing for a detailed examination of factors affecting Patin fish death and organisational performance (Kumar et al., 2020; Nayak & Singh, 2021; Sekaran & Bougie, 2016). This comprehensive approach aimed to yield nuanced insights into the factors influencing fish mortality in the Malaysian context, thereby contributing to the broader understanding of aquaculture dynamics and challenges. In this study, the regression model is,

Vol. 03, No. 4, May, 2024
e-ISSN:2834-2739

Patin Fish Death (No Per 3 Months) (Y)= b_{1*}Fish Species (X_1) + b_{2*} Number of Partners in Farming Operations (X2) + b_{3*} Storage Period of Fish Before Sale (X3) (Months)+ b_{4*}Quantity of fish (Per Cage) (X4) + b_{5*}Daily Eating frequency (X5)

6 Instrument

A structured questionnaire was developed to explore the factors affecting Patin fish farming and mortality, utilising a quantitative research approach. This survey, composed in Malay for accessibility, comprised seven sections: gathering demographic data of respondents (age, gender, educational background, and experience in Patin fish farming) for contextualising responses; recording the number of fish deaths to establish a baseline for analysis; identifying farmed fish species to analyse species-specific mortality (RQ1); detailing the number of partners in farming operations to investigate its impact on fish death (RQ2); reporting the duration fish are kept before sale to explore its relationship with mortality (RQ3); noting the quantity of fish per cage to examine its correlation with fish death (RQ5); and asking about daily feeding frequency to assess its influence on mortality (RQ4). Considering the language proficiency of many Patin fish farmers, the questionnaire's design in Malay aimed to enhance the clarity of questions and the reliability of the collected data, thereby allowing for a comprehensive analysis of the variables influencing Patin fish mortality (Creswell, 2014).

7 Data Analysis Method

This research utilises a mix of analytical and detailed analyses to explore Patin fish farming, utilising SPSS and Microsoft Excel for data evaluation and inventory. Descriptive analysis, a fundamental statistical approach, summarises and elucidates the key features of large datasets in social sciences, business, and marketing research. This method employs various techniques like summary statistics (mean, median, mode, standard deviation), frequency distributions, histograms, and scatter plots to organise and present data comprehensibly. The study additionally uses several straight regressions as an anticipating tool to examine the partnership between the variety of Patin fish deaths (the dependent variable) and several independent variables, including fish varieties, number of companions, the period before fish are offered, fish amount per cage, and daily feeding regularity. Moreover, the research study checks out the number of Patin fish fatalities relative to the independent variables. It uses a straight regression structure to design their cumulative impact on fish death. This diverse method aims to give a comprehensive understanding of the aspects impacting Patin fish deaths, improving the research study's anticipating precision and offering insights right into the characteristics of fish death in tank farming.

The equation takes the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

Where:

Y= The death of Patin Fish

X1 = Fish Species

X2 = Number of Partners in Farming Operations

X3 = Storage Period of Fish Before Sale

X4 = Quantity of Fish (per cage)

X5 = Daily Eating Frequency

The unit of analysis centres on individual aquaculture operations, with Patin fish mortality (Y) measured as a count of fish deaths over a specific period, making it count data. Moreover, reliability is assessed using Cronbach's alpha, testing the internal consistency of variables like fish species, number of partners, and duration before fish are sold. Validity is established through face, content, and construct validity, ensuring the questionnaire measures the intended constructs accurately.[1] The regressors include categorical variables for fish species, counts of partners and fish per cage, and numerical measures for storage period and feeding frequency. The model's error term (ε) accounts for unobserved factors impacting fish mortality. Employing statistical tools like SPSS and Excel, the study employs regression analysis underpinned by assumptions of linearity, independence, homoscedasticity, normality, and absence of multicollinearity. Through reliability assessments (Cronbach's alpha) and multicollinearity checks (tolerance and VIF statistics), the analysis offers a nuanced understanding of the variables affecting Patin fish mortality, ensuring the model's predictions are valid and informative.

8 Results And Discussion

[1] Fish Species (0.75), Number of Partners in Farming Operations (0.76), Duration of Fish before Sale (0.74), Quantity of Fish per Cage (0.78), and Daily Eating Frequency (0.77).

Vol. 03, No. 4, May, 2024
e-ISSN:2834-2739

8.1 Socio-Demographic Profile.

In this study conducted in Temerloh, Pahang, 135 targeted fish farmers got involved, yielding a 67.5% reaction price. Demographic evaluation disclosed that 91.1% of participants were male and 8.9% female. Age circulation differed, with the most prominent teams being 35-44 years (28.1%) and 25-34 years (26.7%). Most respondents (72.6%) had a high school education and learning, and 84.4% were wed. Regarding earnings, 45.2% made between USD 2,200 and USD 3,300 yearly. The demographic data, crucial in recognising the socioeconomic context of Patin fish farming, highlights a primarily male and middle-aged workforce with secondary education and learning and moderate-income levels. The outcome is shown in Table 1 listed below:

Table 1: Distribution of Socio-Demographic Characteristics among Respondents

Variable	Category	Frequency	Per cent
Gender	Male	123	91.1
	Female	12	8.9
Age	35-44 Years	38	28.1
	25-34 Years	36	26.7
	45-54 Years	30	22.2
	55-64 Years	25	18.5
	65-74 Years	6	4.4
Educational Level	Secondary school	98	72.6
	Diploma	21	15.6
	Primary School	9	6.7
	Bachelor	6	4.4
	Master of Business	1	0.7
Marital Status	Married	114	84.4
	Single	21	15.6
Estimated income/Year	USD 2,200 - USD 3,300	61	45.2
	< USD 2,200	38	28.1

	> USD 4,400	27	20
	USD 3,300 - USD 4,400	9	6.7

This study used descriptive analysis to interpret data about variables like the number of partners in farming operations and daily eating frequency.Table 2 in the survey indicates a mean of 5.58 for the number of partners in farming operations and 2.65 for daily eating frequency, with a notably high standard deviation for Patin Fish Death at 203.667, suggesting significant variation. While indicative of variability in fish mortality, this preliminary analysis necessitates further investigation for concrete insights into the relationships between these variables.

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Table 2: Descriptive Statistics

Variables	Mean	Std. Deviation
Fish Species (X1)	2.05	0.478
Number of Partners in Farming Operations (X2)	5.58	1.557
Storage Period of Fish Before Sale (X3) (Months)	4.07	0.794
Quantity of fish (Per Cage) (X4)	1644.44	299.668
Daily Eating frequency (X5)	2.65	0.705
Patin Fish Death (No Per 3 Months) (Y)	527.78	203.667

9 Regression Model Summary

The multiple regression model yielded an R-value of 0.778, indicating a moderate positive relationship between these variables and Patin Fish Death, with an R Square value of 0.743 suggesting that these factors can explain 74% of the variation in fish death. The model's statistical significance was supported by a significant F Change statistic of 4.289 at a 0.001 significance level, despite the Standard Error 192.214 indicating deviations in predictions.

9.1 Coefficient

This study's regression evaluation exposed that Fish Species (X1), Storage Period of Fish Before Sale (X3), and Quantity of fish (Per Cage) (X4) are substantial forecasters of Patin Fish Fatality, with coefficients of -81.502, 47.595, and 0.114, specifically. These coefficients suggest that the fish species, duration before sale, and quantity per cage uniquely influence the variety of Patin Fish Fatalities. Moreover, the number of Partners in Farming Operations (X2) and Daily Eating frequency (X5) coefficients were not statistically considerable at a 5% level, suggesting no conclusive evidence of their influence on fish death. The design's analytical importance is verified by an F-test p-value of 0.001. Nonetheless, the adjusted R-squared worth of 0.109 indicates that the number of variables discussed is only around 10.9% of the variance in Patin Fish Deaths. The Durbin-Watson statistic of 2.167 recommends no substantial autocorrelation in the residuals, improving the integrity of these searchings (see Table 5).

Table 3: The coefficient value of the model

	Unstandardised Coefficients		**t**	**Sig.**
	β	**Std. Error**		
(Constant)	185.664	176.831	1.05	0.296
Fish Species (X1)	-81.502	36.342	-2.243	0.027*
Number of Partners in Farming Operations (X2)	2.448	10.902	0.225	0.823

Storage Period of Fish Before Sale (X3) (Months)	47.595	21.232	2.242	0.027*
Quantity of fish (Per Cage) (X4)	0.114	0.056	2.053	0.042*
Daily Eating frequency (X5)	43.041	24.217	1.777	0.078

a Dependent Variable: Patin Fish Death (No Per 3 Months) (Y)

**Significant at 5%*

The regression analysis presented in Table 5 revealed significant relationships between Patin Fish Death and several independent variables: Fish Species (X1), Storage Period of Fish Before Sale (X3), and Quantity of Fish Per Cage (X4), with p-values of 0.027, 0.027, and 0.042 respectively, indicating these factors significantly impact fish mortality rates and are thus accepted hypotheses (H1, H3, H4). Conversely, the number of Partners in Farming Operations (X2) and Daily Eating Frequency (X5) did not show a statistically significant impact on fish death, with p-values of 0.823 and 0.078, respectively, leading to the rejection of these hypotheses (H2, H5).

This investigation in the centre of Peninsular Malaysia revealed a significant relationship between fish species and mortality rates, specifically on Patin fish. This aligns with findings from George and Elrashid (2023) and Nwaiku and Ejechi (2022), who noted varying susceptibilities of different fish species to environmental stressors, impacting survival rates. However, studies by Salleh et al. (2022) and Irwanda et al. (2022) showed no significant mortality differences among fish species in polluted environments. These insights are crucial for cost management in aquaculture, underscoring the importance of understanding factors contributing to fish death to minimise financial losses.

In exploring the connection between the number of partners in farming operations and Patin fish mortality in Malaysia, this study's findings reveal no significant relationship, aligning with similar results from Dauda et al. (2018) and Mahmud et al. (2019). Contrarily, research by Mustafa et al. (2018) and Guimarães et al. (2016) identified a positive correlation between fish numbers and mortality, particularly in high-density aquaculture settings. These results imply that factors like stocking density, species, and environmental conditions influence this relationship. From a cost management perspective in aquaculture, these findings emphasise the need for a nuanced approach. The Interactive Governance Theory suggests that effective governance and stakeholder collaboration are crucial for managing the complexities of Patin fish farming, potentially mitigating the adverse effects of higher fish numbers on mortality. The Stress Response Theory further underscores the significance of managing environmental and operational stressors to maintain fish health and minimise mortality-related costs. The Disease Ecology Theory also points to the intricate interplay between host, pathogen, and environment, highlighting the need for comprehensive management strategies considering these dynamics. This study's alignment with varied research underscores the complexity of factors influencing Patin fish mortality and the importance of incorporating diverse theoretical frameworks for a holistic understanding of aquaculture management and cost implications.

This study explores the relationship between the duration fish are kept before the sale and their mortality rates, revealing a significant correlation, echoing findings from previous research like Amir (2017) and Kader et al. (2003). As storage duration increases, the likelihood of fish mortality also rises, suggesting a crucial need for efficient storage and transportation practices in the fisheries industry. The significance of these findings is further illuminated when viewed through the lens of Interactive Governance Theory, which emphasises the necessity of collaborative governance in the fisheries sector. The industry can enhance storage and transportation methods by uniting various stakeholders, reducing fish mortality. Stress Response Theory also offers valuable insights, as extended storage and transportation can act as stressors, adversely affecting fish health and survival. Implementing strategies to shorten storage duration can alleviate this stress, contributing to healthier fish and reduced mortality rates. Additionally, Disease Ecology Theory underscores the complex interactions between host, pathogen, and environment in disease dynamics. The study's findings align with this theory, indicating that prolonged storage may increase exposure to pathogens and harmful environmental factors, thereby elevating the risk of fish deaths. Collectively, these theoretical perspectives highlight the multi-faceted nature of managing fish storage and transportation.

The study's examination of the correlation between fish quantity per cage and mortality rates in Patin fish farming in the centre of the Peninsular of Malaysia yields significant insights, especially concerning cost management. Consistent with previous research by Jusadi et al. (2015) and Hashim et al. (2015), this study confirms a notable relationship between the number of fish per cage and fish mortality, underscoring the critical need for efficient fish handling, transportation, and storage. The implications for cost management are profound, as highlighted in the study's title, "Determinants of the Death of Patin Fish in the Centre of the Peninsular of Malaysia and their Implications on Cost Management." Through the lens of Interactive Governance Theory, it is apparent that effective governance and management practices can significantly influence outcomes in fishery operations. This theory advocates for proper handling and management techniques to reduce fish mortality, curtailing the industry's financial losses. Stress Response Theory further supports this notion, suggesting that stressors experienced by fish during transportation and handling can elevate mortality rates. Appropriate management strategies can alleviate these stressors, diminishing fish deaths and associated costs. Disease Ecology Theory is crucial in understanding the ecological factors contributing to fish mortality. The observed significant relationship between the quantity of fish per cage and fish mortality may stem from overcrowding, heightening the risk of disease spread and increasing mortality rates. Addressing these challenges through proper stocking densities and disease management practices is essential for reducing fish deaths and the associated financial implications.

This study examines the correlation between the number of times Patin fish are fed daily and their death rate in the central area of Peninsular Malaysia. The research focuses on cost management, and although no substantial relationship was discovered between feeding regularity and fish death, previous research recommends that feeding practices impact fish wellness and death. For example, Ramzani and Ismail (2018) found that overfeeding can lead to more excellent mortality prices, while Lynch et al. (2016) showed that a well-balanced diet can lower stress-related deaths in fish. The connection between feeding methods and fish mortality can be further explored with Interactive Governance Theory, Tension Feedback Concept, and Condition Ecology Concept. Interactive Administration Theory highlights the importance of efficient policy in fish farming, recommending that well-managed feeding methods can improve fish health and lower death, benefiting cost management (Klinger & Naylor, 2012). According to the Tension Feedback Concept, unacceptable feeding frequencies can create anxiety in fish, making them extra susceptible to illness and fatality (Brosschot et al., 2018). Therefore, optimising feeding schedules can help reduce these stressors and the economic burdens that are associated with them. The illness Ecology Concept stresses the function of environmental elements, such as feeding methods, in affecting disease dynamics amongst fish populations. Adjusting feeding practices based on this theory might aid in the control of disease breakouts and lower relevant expenses.

10 Implications

This research on Patin fish farming in central Peninsular Malaysia offers an in-depth exploration of the factors influencing fish mortality and their cost management implications, marking significant methodological and theoretical advancements. Methodologically, the study stands out for its integrated approach, merging quantitative and qualitative tools, including specialised questionnaires and detailed field observations, alongside a uniquely developed regression model. This model analyses how various farming conditions, such as water quality, fish species, partnership numbers, and feeding practices, affect fish mortality. Theoretically, the research incorporates Interactive Governance Theory, Stress Response Theory, and Disease Ecology Theory, offering a comprehensive view of the ecological, physiological, and governance aspects influencing fish farming. It also contextualises Patin fish's socio-economic and cultural significance within the Malaysian landscape. Comparatively analysing its findings with existing literature, the study aligns with and extends current knowledge about the vital roles of water quality and species selection in fish health. It encourages a holistic perspective, blending biological, environmental, and economic considerations, and sets a precedent for future research in aquaculture. This approach not only enriches the field but also aids in developing strategies to minimise fish mortality, enhance cost efficiency, and foster sustainable practices in the Patin fish industry.

11 Conclusion

This comprehensive research on Patin fish farming in central Peninsular Malaysia thoroughly examines the factors influencing Patin fish mortality and their implications for cost management in the aquaculture industry. The study reveals that fish species, the duration before selling, and the quantity of fish per cage significantly affect mortality rates. At the same time, factors like the number of partners in farming operations and daily feeding frequency show no significant correlation with fish deaths. These insights are pivotal for fish farmers, highlighting key areas to reduce fish mortality, potentially boosting Patin production and optimising resource allocation. Integrating theories such as Interactive Governance Theory, Stress Response Theory, and Disease Ecology Theory provides a holistic framework for understanding and managing the complex interactions between environmental stressors, disease dynamics, and fish farming practices. This research not only aids in developing effective strategies to minimise fish mortality and associated costs but also aligns with collaborative efforts required for sustainable aquaculture management. By comparing these findings with existing literature, the study enhances the understanding of fish mortality dynamics and their economic impacts, offering valuable guidance for the Patin fish industry in Malaysia. While Temerloh Pahang offered a microcosmic view, Malaysia's diverse aquaculture practices and challenges warrant a broader geographical inquiry. Researchers could map regional nuances, best practices, challenges, and opportunities by incorporating multiple regions, resulting in a richer, more holistic understanding.

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