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Managing Complexities in Giant Freshwater Prawn Breeding Facilities in Perak, Malaysia: A Case Study

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Abstract: Malaysia's aquaculture industry has seen significant growth in recent years, with the giant freshwater prawn (Macrobrachium rosenbergii) emerging as a key species of economic importance. This study examines the intricate challenges faced by hatchery owners' breeding facilities in Manjung, Perak, Malaysia as they strive to maintain and improve the brood stock production of this valuable crustacean. The research focuses on the multifaceted, operational aspects of managing giant freshwater prawn (Macrobrachium rosenbergeii) hatcheries. Through a combination of field studies guided by the qualitative methodology, the identification of primary obstacles encountered at the Manjung breeding facilities was evaluated via current management practices. The findings revealed that hatchery owners lack adequate managerial skills in handling operational matters such as budgeting, labor utilization, utilities, marketing, and networking. The most critical factor was the cost-effective sourcing of healthy, brood stock supply from local fishermen. Furthermore, the research underscores the importance of genetic diversity in broodstock populations as hatcheries struggle with inbreeding depression, necessitating the development of more robust breeding programs. From the socio-economic standpoint, a holistic approach to addressing these issues, emphasizes the need for increased collaboration between research institutions, government agencies, and private sector stakeholders. The study provided a comprehensive overview of the complexities inherent in managing giant freshwater prawn breeding facilities in Malaysia. By identifying key challenges and potential solutions, it aims to contribute to the sustainable development of this vital sector of Malaysia's aquaculture industry. The findings have implications for policy-making, industry practices, and future research directions in the field of freshwater prawn (udang galah) aquaculture and food security agenda.

Keywords: *Hatchery management, giant freshwater prawn, broodstock, aquaculture facilities*

1. Introduction and Background

Aquaculture production has shown a significant increase after the pandemic lockdowns to meet the national agenda for food security. Specifically, the Malaysian aquaculture sector produced approximately 411,781 tons of total aquaculture production with an estimated economic value of USD 700 million in 2019 (Tan et al., 2024). Malaysia's giant freshwater prawns, locally known as *udang galah* (*Macrobrachium rosenbergii*), have always remained firm in demand. From aquaculture reports, *udang galah* farming is a lucrative endeavor resulting in many *udang galah* farming ventures, including hatcheries for larvae production. Introduced in the 1970s, this species has gained prominence due to its economic value and cultural significance in local cuisine. The industry has seen steady growth, particularly in states like Perak, Kedah, and Johor, where climatic conditions favor prawn cultivation. However, the sector faces numerous challenges, especially in hatchery management. These facilities, crucial for supplying quality seed stock, grapple with issues ranging from water quality management in Malaysia's tropical climate to disease control, particularly white tail disease and vibriosis. The government has recognized the industry's potential, implementing supportive policies through the National Aquaculture Development Plan and providing research backing via institutions like the Fisheries Research Institute. Despite these efforts, hatcheries continue to face complexities in areas such as nutrition management, genetic improvement to combat inbreeding depression, and adaptation to evolving market demands. Furthermore, the industry must navigate socio-economic hurdles, including labor shortages in rural areas and competition for resources with other aquaculture species. As Malaysia aims to solidify its position in the ASEAN prawn market, understanding and addressing these hatchery management challenges becomes crucial for the sustainable growth and competitiveness of the giant freshwater prawn industry.

Nonetheless, the supply of giant freshwater prawns has been limited for various reasons. *Udang Galah* farmers in Perak Tengah have faced the closure of their business project because of the need for more quality broodstock. Thus, the paper aims to provide insights into the complexities and challenges faced by hatchery owners in Perak Tengah.

2. Literature Review

Food sources and finding alternatives to shorten organic farming for a consistent supply chain of aquaculture products are essential to a country's food security balance. Hence, the aquaculture industry in Malaysia plays an essential role in ensuring supply continuity. Therefore, there is a need to ensure that these entities practice good management strategies for the longevity of the business and sustainable practices. In doing so, there are challenges in aquaculture farming. Thus, this paper aims to showcase the challenges in hatchery management in the *macro brachium rosenbergeii* broodstock production. Challenges abound With any business setup, much so for giant freshwater farming, which requires hatchery owners or managers to diligently ensure that profits are made to cover the operational expenses. (Tambalque et al., 2015).

Aquaculture for Socioeconomic Growth

Aquaculture farming has become critical to a country's economy and community well-being. Fish farming, whether freshwater or sea-based marine animals, has been an entrepreneurial project for decades, but the intensity of aquaculture farming has become prominent after the coronavirus lockdowns from early 2020 to late 2021. Aside from fish farming, other food sources from the water, such as prawns and crabs, have become popular among entrepreneurs. According to Liew et al. (2024), mud crabs, for example, are economically important for aquaculture entrepreneurs. Like other aquaculture production, the domestic seafood demand is higher than the supply making *udang galah* priced above other prawn species. (Liew et al., 2024). Realizing the market potential for giant freshwater prawns as a billion-dollar industry, Brazil's aquaculture production relies on small farms (Valenti et al., 2021). Also, Malaysia can emulate the strategy by pooling resources from small hatcheries in rural areas, such as Segari, Lumut, and Perak.

The potential of Udang Galah (Macrobrachium rosenbergeii) Farming for Sustainability and poverty alleviation

For decades, freshwater prawn farming has been shown to have a significant potential for sustainable socioeconomic Growth and food security (Yasmin et al., 2010). In tropical regions, freshwater prawns can be farmed year-long and outdoors. Hence, the profitability of prawn farming in other developing countries has evidence of economic and environmental success. (Yasmin et al., 2010). The potential for giant freshwater prawn farming has evidenced success for local farmers (Jalil, 2020; Mat Isa, 2022; Urana, 2021).

Agriculture and food production will remain the income staple for most rural communities. However, in the new normal, the Digital Era requires farmers to innovate using technology. For instance, e-commerce will provide pathways to sustainability for poverty, as evidenced in Sub-Saharan Africa (Cordes & Marinova, 2023). Utilization of the Internet and various social media platforms will assist with community inclusion and product marketing for the low-income population. Through digital engagement, rural communities will boost their entrepreneurship skills, innovate, and collaborate with other stakeholders that could provide potential benefits (Cordes & Marinova, 2023).

Many countries evidenced an increase in poverty after the COVID-19 pandemic. As such, it is vital for developing countries, particularly for reversals of fortune for poverty alleviation and shared prosperity. (World-Bank, 2020). Also, in the wake of COVID-19, the study's outcome is relevant to the United Nations Sustainable Development Goal (SDG) to end poverty in all its forms everywhere (UN-SDG, 2017; World-Bank, 2020). Poverty reduction plans and policies need rethinking, implementation, and monitoring of the projects as practiced in Hubei Province and Liupanshui City, China. (Duan et al., 2019). The literature shows that geographic considerations are crucial for wealth creation through the implementation of aquaculture projects in rural areas (Gilson et al., 2023; Singh et al., 2023). As noted by Aanesen et al. (2023), aquaculture's substantial increase in production is currently the fastest-growing food industry globally. Hence Malaysia should heed this strategy by expanding the country's aquaculture projects.

Challenges in aquaculture farming and hatchery management

Like other businesses, managing aquaculture projects is challenging (Liew et al., 2024). In the case of crab farming, some challenges include inadequate seed supply, cannibalism, disease outbreaks, and no commercially formulated feed for the Scylla mud crabs (Liew et al., 2024). As Zhang et al. (2023) pointed out, fish welfare in various aquaculture systems has garnered significant attention. Similarly, for this paper, giant freshwater prawns welfare has been brought to the attention of the relevant stakeholders, but with little effort made to assist rural hatchery owners through private investments. (Banu & Christianus, 2016), innovations and technological advances such as the Internet of Things (IoT) and artificial intelligence (AI) (Khairuddin & Majid, 2023).

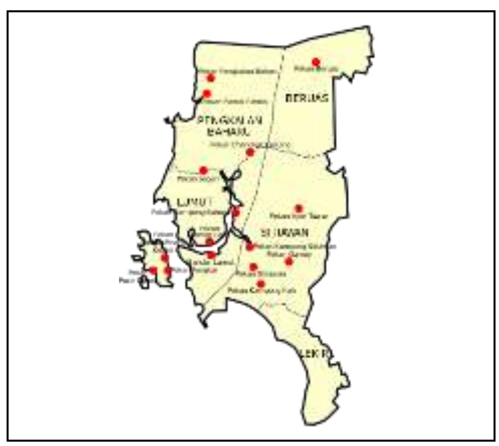
The reproduction capacity of the indigenous river species, the *udang galah,* in Malaysia, depends on several environmental factors. Although there have been reports on the dwindling catches by fishermen in Malaysian rivers, the capacity to reproduce the non-indigenous Macrobrachium rosenbergii in estuaries of the Amazon Coast, north Brazil has been favorably sustainable (Iketani et al., 2016). This successful project showed that good environmental conditions would ensure a higher population of giant freshwater prawns in Malaysian rivers.

Another challenge that aquaculture entrepreneurs and hatchery managers must consider is climate change. (Galappaththi et al., 2020). Adapting to extreme weather changes such as global warming is crucial to the continuity of aquaculture projects. Coping mechanisms such as at the local level (for example, water quality management techniques), multilevel adaptive strategies (for example, changing culture practices), and management approaches (for example, adaptation planning, and community-based adaptions) will ensure limited losses. (Galappaththi et al., 2020). Again, in the digital era, technology, such as global information systems (GIS) and remote sensing, will provide the essential cost-effective tools for developing adaptation strategies and responses. (Galappaththi et al., 2020; Iliyasu et al., 2016). However, for rural hatchery owners and inland aquaculture entrepreneurs in Segari, Perak, the budgeting for these contingencies would be an added challenge.

About the district of Manjung, Perak, Malaysia

The Manjung district in Perak, Malaysia, is located in the middle section of the state (Figure 1a & 1b) (PDT-Manjung, 2021). There are five *mukim* (translated meaning township or administrative division) in Manjung, namely, Mukim Beruas (with ten villages), Mukim Lekir (with ten villages), Mukim Lumut (with 11 villages), Mukim Pengkalan Bharu (with 12 villages and, Mukim Sitiawan (with 14 villages) (see Figure 1b). The hatchery for this study is located in Segari, Mukim Lumut, Perak. Manjung's population is 246,977 people.

Figure 1: (a) Manjung district in Perak, Malaysia; (b) The districts in Manjung



Source: maya47.atspace.com and Wikiwand, 2023

3. Research Methodology

Research design

For this study on managing complexities in giant freshwater prawn breeding facilities in Malaysia, a qualitative methodology would be appropriate to gain in-depth insights into exploring the complexities of the challenges and practices (Barclay et al., 2017; Thompson et al., 2024). The case study design justified the focus on specific, multiple hatcheries management practices and farming methods undertaken (Bjørkan & Eilertsen, 2020; Choudhury et al., 2017). To reiterate, the qualitative methodology would allow for a rich, contextual understanding of the complexities involved in managing giant freshwater prawn breeding facilities in Malaysia, providing nuanced insights that might not be captured through quantitative methods alone.

The data collection method for the qualitative approaches was through semi-structured interviews with hatchery managers or owners, discussions with local agency fisheries officials, and researchers from aquaculture-based institutions. Direct observations on hatchery operations were also done from repeated site visits. To ensure data viability, document analysis of hatchery records and industry guidelines obtained from fishery agencies and online were conducted. In addition, secondary data from the Fisheries Department and other available statistics were used to corroborate the research objective: to explore the efficiency of hatchery management in giant freshwater prawn broodstock production. Funding received under the Malaysian Social Innovation (MySI) grant permitted the conduct of the project implementation with the availability of hatchery owners or managers in Segari, Lumut, Perak and Kampung Hujung Rintis, Kota Setia, Perak. Consequently, these project scopes made this a case study investigation. Nonetheless, the goal of the funding is to infuse technology in *udang galah* broodstock farming in a hatchery and monitor the project's success (or failure) for two years. In addition, the study is guided by the theory of management consisting of four elements: planning, organizing, leading, and controlling, with a particular focus on aquaculture management concepts (Meade, 2012).

The sampling strategy used purposive sampling to select diverse hatchery operations varying in size, location, and management practices (Bendassolli, 2013). However, only two, rural located hatcheries in Segari, Manjung, Perak became the key informants for this study as many hatcheries were no longer in operation. Repeated interviews and focus group protocols were applied on-site where regular meetings were held. Open-ended questions covering key areas such as water management, disease control, nutrition, and genetic management were asked. Before these discussions, a pilot testing session of interview guides to ensure clarity and relevance was undertaken. The observational techniques on site involved non-participant observation of daily hatchery operations and the use of field notes and observational checklists

The data analysis from the interviews, documents, and observational notes were thematically analyzed to identify recurring patterns and themes. Before this, the coding of transcripts using qualitative data analysis software (e.g., NVivo). Consequently, the development of conceptual frameworks to illustrate relationships between the themes identified the complex challenges and management practices of the case study. In addition, the trustworthiness and validation of the outputs require triangulation of data sources and methods via member checking with participants to ensure accurate interpretation of their perspectives as well as peer debriefing with other researchers in the field of aquaculture.

In ensuring ethical considerations, informed consent from all participants was obtained earlier in the project timeline and assurance of the confidentiality and anonymity of the information gathered from the hatcheries and individuals adhered to the ethical guidelines for research involving human subjects.

It is important to note that the limitations and reflexivity of the study require acknowledging potential researcher bias and its impact on data interpretation including recognizing limitations in generalizability due to the qualitative and case study method of the project.

In summary, the primary or empirical data were collected through repeated interviews with a hatchery owner cum udang galah broodstock breeder in Segari, Lumut, Perak. The second respondent has a mini hatchery and field ponds at Kampung Hujung Rintis, Kota Setia, Perak. To supplement the aquaculture farming method and infrastructure, a tilapia fish farmer from Kampung Pulau Tiga, Kg. Gajah, Perak was also interviewed. From the interviews, data saturation was achieved when similar responses were noted. The interview transcripts were read repeatedly, such as through content analysis, to identify themes or categories based on valid inference and interpretation. Also, the explorative process has incompleteness of inductive reasoning in organizational dilemma research projects, as in the case of this study. Ketokivi and Mantere (2010) suggested two practical reasoning strategies, idealization, and contextualization, which can lead to more effective argumentation and evaluation. "Appreciating the methodological incompleteness of both strategies helps distinguish between the method and the policy dimensions of organization-scientific debates" (Ketokivi & Mantere, 2010). Bendassolli (2013) also pointed out that the problem of induction refers to the difficulties involved in justifying experience-based scientific conclusions, which happened to this project. Although theory-building is not proposed for this study, the justification for using inductive reasoning is adequate for the assumptions of undertaking qualitative research methods (Walters, 2001) as the design allows for researchers to seek information from data gathered and analyzed yet do not proceed to a project looking for specific findings. In other words, the findings of this study are informative, with narratives to support the project's objective. Using the inductive reasoning approach, the researchers will genuinely learn from their subjects while remaining empathetic and reflective (Bogdan & Biklen, 1997; Walters, 2001).

4. Findings

The demographic breakdown of the respondents was 100% male owners aged 50 years and above. The hatchery operations are self-funded. The hatcheries were located in a rural area, far from the main road but close to the river. The hatcheries were built on the owner's land. The findings based on the research objective are shown in Table 1. The elucidation of each finding will be done in the next section.

Table 1: Hatchery management challenges

Management element	Challenges	Comments
Planning	No proper strategic plan	Unrecorded and undocumented plans for hatchery operations
Organizing	Routine feeding and infrastructure upkeep	Hatchery owner's helpers include family members and intermittent interns
Leading	Manages hatchery as deemed fit	Self-led
Controlling	Has no control over broodstock supply	Hatchery depends on supplies from local, artisanal fishermen. Diseased *udang galah* broodstock cannot be used. Outsourcing for other broodstock means going outstation. Technical know-how; use of IoT and AI in the broodstock breeding process

Discussion

During the starting phase of the project, the Movement Control Order (MCO) was mandated from early 2020 to late 2021 because of the coronavirus (COVID-19) pandemic (Bernama, 2021). The MCO took almost two years to break the chain of infection, making it impossible to cross the state borders and the hatcheries to operate normally.

The limitation of the study was the focus of two cases in one state. The study was impeded by the pandemic lockdown lasting almost eighteen months resulting in the closure of many hatcheries except for these two. The closure was due to weak operations management, and non-communication with externalities or broodstock suppliers, which led to losses. This is the risk that nobody expected, but after the pandemic, only two *udang galah* farmers continued with the project.

From the research objective, the four elements of management are considered. Firstly, the planning element where the findings showed that the hatchery owners do not have a formal strategic plan; however, the goal of running the hatchery is to make enough profits to recover the capital expenses and expand the business. For the second element, the hatchery operations are organized daily for feeding and infrastructure upkeep. Family members made up the labor force; however, from time to time, local colleges would send students to intern at the hatchery. After the pandemic lockdowns, no interns were sent as the hatchery could not operate at standard capacity. The third management element is leading; the hatchery manager leads the operations as he sees fit, following the traditional way of running the entity. Lastly, the controlling element sees hatchery owners needing more control over the broodstock supply, which is the major problem for hatcheries to close down. This issue requires intervention from the local Fisheries Department and colleges or universities with marine studies to advise and assist with the supply. Outsourcing for udang galah broodstock from other locations requires proper logistics to keep the marine animals alive when they arrive at the hatchery.

To reiterate, hatchery management needs managers to have the four management skills and experience to plan, organize, lead, and control operations. The hatchery business type is a sole proprietorship. Therefore, the owner bears all the risks (and losses). It is recommended that hatcheries should operate and manage as a partnership or through collaborative efforts with other hatcheries, the private sector, the fisheries department, and the university.

In broodstock production, other external factors need to be considered, such as the consistent supply of healthy, free-range adult prawns. Having a formal agreement with the prawn providers or suppliers should be documented. Oral agreements are not binding as the artisanal fishermen have the right to sell their catches to the ever-ready markets.

Hatchery owners should also practice realistic management by operating within their capacity. There are seven essential control factors in *udang galah* breeding: water management, disease control, feeding and nutrition, larval survival rates, broodstock management, environmental sustainability, and market demand and pricing. (Hashim, 2023). These control factors can be efficiently and effectively managed using disruptive technologies like the Internet of Things (IoT) and artificial intelligence (AI). In fact, during the project timeline, Universiti Teknologi MARA's innovative contribution to the hatchery was by installing a device named SAMS-MKII. This device significantly enhanced the hatchery operations and increased larval production for a short period. SAMS-MKII was able to monitor the water quality (temperature, pH levels, dissolved oxygen, and ammonia levels) using IoT sensors deployed in the breeding containers. SAMS-MKII systems were linked to the server, and real-time data can be seen in a specially-innovated smartphone application with dashboards showing these conditions (see Figure 2). The IoT devices and AI algorithms enabled remote monitoring and control of the hatchery operations, giving the hatchery owner the freedom to travel outstation as he will receive alerts and make the necessary adjustments through a centralized dashboard or a mobile application. This capability allows for efficient management, reduced labor requirements, and prompt addressing of emergencies (Hashim, 2023). For the university project members, the predictive analytics from leveraging historical data on environmental conditions, feeding patterns, and growth rates, AI algorithms can provide predictive analytics to optimize the hatchery's operations. These algorithms can forecast optimal feeding schedules, prawn growth rates, and potential challenges; these insights allow hatchery managers to make informed decisions, streamline resource allocation, and improve overall productivity. (Hashim, 2023). However, SAMS-MKII capability cannot be fully utilized when no udang galah stock is in the containers from exhausted broodstock supply.

During the project's initial phase, implementing the Movement Control Order (MCO) due to the COVID-19 pandemic greatly affected the progress. The MCO, which lasted for nearly two years, aimed to curb the spread of the virus, resulted in restrictions on crossing state borders and disrupted normal operations of hatcheries (Bernama, 2021; Yusoff et al., 2020). This prolonged lockdown created limitations and challenges for the study, as it focused on only two cases in one state. The hatcheries needed help operating and communicating with external suppliers or broodstock providers, leading to financial losses. The unexpected nature of the pandemic made it challenging to recover and rebuild the business after the restrictions were lifted.

The research objective encompassed four management elements. Firstly, in terms of planning, it was found that hatchery owners needed a formal strategic plan. However, they aimed to generate sufficient profits for capital recovery and business expansion. Secondly, organizing the hatchery operations involved daily routine tasks such as feeding and infrastructure maintenance. Family members constituted the labor force, occasionally supplemented by interns from local colleges. However, the pandemic disrupted the ability to receive interns, further affecting operations. The third management element, leading, relied on the hatchery manager's decisions based on traditional practices. Lastly, the controlling element revealed that hatchery owners had little control over broodstock supply, which became a significant challenge leading to hatchery closures. Moreover, when IoT and AI in aquaculture were introduced, the hatchery in Segari experienced electricity disruption and weak internet access. It is important to have sound control over electricity and seamless internet access. Addressing this issue requires intervention and assistance from the local Fisheries Department, colleges, or universities with marine studies and proper logistics for outsourcing broodstock from other locations.

To emphasize effective hatchery management requires managers with skills and experience in planning, organizing, leading, and controlling hatchery operations. As hatcheries typically operate as sole proprietorships, the owner assumes all risks and losses. It is recommended that hatcheries consider operating as partnerships or through collaborative efforts involving other hatcheries, the private sector, fisheries departments, and universities.

Additional factors must be considered in broodstock production, such as ensuring a consistent supply of healthy adult prawns from free-range sources. Establishing formal agreements with prawn providers or suppliers is essential, as informal oral agreements may not be legally binding, and fishermen can sell their catches in the market.

Hatchery owners should practice realistic management by operating within their capacity. Seven critical control factors in udang galah breeding include water management, disease control, feeding and nutrition, larval survival rates, broodstock management, environmental sustainability, and market demand and pricing (Hashim, 2023). These factors can be effectively managed using disruptive technologies like the Internet of Things (IoT) and artificial intelligence (AI). The introduction of the SAMS-MKII device by Universiti Teknologi MARA significantly enhanced hatchery operations briefly. SAMS-MKII employed IoT sensors to monitor water quality parameters (temperature, pH, dissolved oxygen, and ammonia levels) in breeding containers. Real-time data was transmitted to a server and accessible through a specially developed smartphone application with intuitive dashboards (see Figure 2). This IoT-enabled remote monitoring and control gave hatchery owners flexibility, allowing them to receive alerts and adjust from a centralized dashboard or mobile application. This capability improved efficiency, reduced labor requirements, and enabled prompt response to emergencies (Hashim, 2023).

Additionally, leveraging historical data and AI algorithms, predictive analytics can optimize hatchery operations by forecasting optimal feeding schedules, prawn growth rates, and potential challenges. Hatchery managers can make informed decisions, allocate resources effectively, and enhance productivity using these insights (Hashim, 2023). However, the full potential of SAMS-MKII cannot be realized when there is no *udang galah* stock in the containers due to the exhausted broodstock supply.

Lastly, aquaculture farming will continue to contribute to Malaysia's socioeconomic growth and population well-being. It is important to provide insights into the key challenges, government involvement, and the broader context within Malaysia and the region for aquaculture projects, specifically, farming giant freshwater prawns or *udang galah*. It sets the stage for further studies and a more detailed exploration of the complexities of managing giant freshwater prawn breeding facilities.

Figure 2: SAMS-MKII version 4 dashboard, 2023

5. Managerial Implications and Recommendations

Udang galah or giant freshwater prawns (Macrobrachium rosenbergeii) farming is lucrative if the hatchery is managed efficiently. Using technology to assist with farming will further enhance the business project. Developing a sustainable production system using new technologies, such as simple disruptive innovation, can increase productivity and improve the outputs for the domestic markets. For future studies, it is recommended that hatchery owners from other states in Malaysia be sampled. The comparative analysis of management and operational methods undertaken by these hatcheries would provide new insights into the success of other young, enterprising individuals embarking on aquaculture projects. The complexities in managing hatcheries can be overcome with financial backing from interested parties and to development of sustainable production using technology in collaboration with universities, relevant government agencies, industry partners, and private investors including telecommunication and utilities companies. In this case, the state government can also oversee the Segari, Manjung, and Perak hatcheries by providing adequate, continuous assistance, networking, and monitoring.

As in the discussion section and to reiterate, it is time that aquaculture farming makes use of technology to assist in dealing with the complexities. Another managerial implication of the project is the full utilization of the Internet of Things (IoT) and artificial intelligence (AI). Partnering with local universities and industries would be the way forward in the business project to be sustainable. Schedule visits with other successful prawn farming projects will also ensure new learning and shared experiences for the owners of this case study. From Figure 1.0, SAMS-MKII has been integrated with both IoT and AI. Other entities in aquaculture adopted technology in prawn hatcheries to enhance efficiency, productivity, and sustainability. These technologies are being applied to ensure (Khairuddin & Majid, 2023):

Water Quality Monitoring
- IoT sensors continuously monitor parameters such as temperature, pH, dissolved oxygen, and ammonia levels.
- AI algorithms analyze this data in real-time, predicting potential issues before they become critical.
- Automated alerts notify staff of any deviations from optimal conditions.

Feeding Systems
- IoT-enabled feeders dispense precise amounts of feed based on prawn growth stages and biomass.
- AI algorithms optimize feeding schedules and quantities, reducing waste and improving feed conversion ratios.

Disease Detection
- AI-powered image recognition systems can detect early signs of diseases by analyzing prawn behavior and appearance.

- IoT devices can collect and transmit data on prawn health indicators for rapid response to potential outbreaks.

Environmental Control
- Smart systems regulate lighting, aeration, and water circulation based on real-time data and predetermined optimal conditions.
- AI predictive models adjust these parameters in anticipation of changing environmental conditions.

Genetic Management
- AI algorithms can analyze genetic data to optimize breeding pairs for desired traits.
- IoT devices can track individual broodstock performance and health.

Energy Efficiency
- Smart systems optimize energy use in heating, cooling, and pumping systems.
- AI predictive maintenance schedules prevent equipment failures and reduce downtime.

Data Analytics
- AI-driven analytics platforms integrate data from various IoT devices to provide comprehensive insights into hatchery operations.
- These insights can inform decision-making on everything from production planning to resource allocation.

Automated Sorting
- AI-powered image recognition combined with robotic systems can sort prawns by size or quality, reducing labor costs and improving consistency.

Remote Monitoring
- IoT enables remote monitoring and control of hatchery operations, allowing managers to oversee multiple facilities or respond to issues off-site.

Predictive Modelling
- AI can create predictive models for prawn growth, market demand, and production outcomes, aiding in strategic planning.

While these technologies offer significant benefits, their adoption in Malaysian prawn hatcheries faces challenges such as high initial costs, the need for specialized training, and potential reliability issues in rural areas with limited connectivity. However, as these technologies become more accessible and adapted to local conditions, they have the potential to revolutionize hatchery management practices in Malaysia. (Siddeeg, 2016). Lastly, the way forward for *Udang Galah* hatcheries is to have proper policy initiatives to facilitate the entities towards efficient business processes for expansion and aquaculture commercialization towards a sustainable blue economy.

Conclusion
The objective of this paper was to provide insights through the exploration of the complexities and challenges faced by the giant freshwater prawn hatchery owners in Perak Tengah. The findings revealed that hatchery owners lack adequate managerial skills in handling operational matters such as budgeting, labor utilization, utilities, marketing, and networking. The most critical factor was the cost-effective sourcing of healthy, brood stock supply from local fishermen. Furthermore, the research underscores the importance of genetic diversity in broodstock populations as hatcheries struggle with inbreeding depression, necessitating the development of more robust breeding programs. From the socio-economic standpoint, a holistic approach to addressing these issues, emphasizes the need for increased collaboration between research institutions, government agencies, and private sector stakeholders. The study provided a comprehensive overview of the complexities inherent in managing giant freshwater prawn breeding facilities in Malaysia. By identifying key challenges and potential solutions, it aims to contribute to the sustainable development of this vital sector of Malaysia's aquaculture industry. The findings have implications for policy-making, industry practices, and future research directions in the field of freshwater prawn (udang galah) aquaculture and food security agenda.

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