STUDY ON THE IMPLEMENTATION OF MS1998:2017 - GOOD AQUACULTURE PRACTICES FOR SMALL-SCALE TILAPIA FARMERS IN SELANGOR

NUR SAFIRAH BINTI SAPUAN

FACULTY OF SCIENCE
UNIVERSITI MALAYA
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NUR SAFIRAH BINTI SAPUAN

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ABSTRACT

Fisheries have been a long-established way for humanity to obtain food. As the world's top natural protein provider in the diet of many nations, it has retained its significance, with 75% of global fish production being intended for direct human consumption. One of the government's initiatives to improve food security is encouraging agriculture players to meet the Good Aquaculture Practices (GAqP) standard in getting the Malaysian Good Agricultural Practices (MyGAP) certificate. Participation in meeting GAqP standards will also assist smallholders in achieving maximum yield. However, small-scale fish farmers are having difficulties achieving the GAqP standards. This study was carried out to investigate such difficulties faced by the farmers in meeting GAqP standards. 30 out of 58 small-scale fish farmers in Selangor were used in this study. Their compliance with GAqP standards was evaluated together with their economic return. Benefit-Cost Ratio (BCR) projection and regression analysis were carried out to determine the economic return in an attempt to comply with the GAqP standards. The finding shows that the average BCR for smallholder aquaculture farms for a 5-year period was estimated at 1.23, and 64.7% of the GAqP standard complied. At the moment, the economic return was found to be profitable. Better economic return can be expected when the percentage of compliance increases. This study implies that greater commitment from both the government and fish farmers is needed in order to overcome the challenges of meeting the GAqP standards.

KAJIAN PELAKSANAAN MS1998:2017 - AMALAN AKUAKULTUR YANG BAIK UNTUK PETANI TILAPIA KECIL DI SELANGOR

ABSTRAK

Bidang perikanan telah lama wujud bagi manusia untuk mendapatkan makanan. Sebagai penyedia protein semula jadi yang terbaik di dunia dalam diet banyak negara, ia mengekalkan kepentingannya, dengan 75% pengeluaran ikan global bertujuan untuk penggunaan langsung manusia. Salah satu inisiatif kerajaan untuk meningkatkan sekuriti makanan adalah dengan menggalakkan peserta pertanian memenuhi piawaian Amalan Akuakultur Baik (GAqP) dalam mendapatkan sijil Amalan Pertanian Baik Malaysia (MyGAP). Penyertaan dalam memenuhi piawaian GAqP juga akan membantu pekebun kecil mencapai hasil maksimum. Penternak ikan berskala kecil menghadapi kesukaran untuk mencapai standard GAqP. Kajian ini dijalankan untuk menyiasat kesukaran yang dihadapi oleh petani dalam memenuhi standard GAqP. 30 daripada 58 penternak ikan berskala kecil di Selangor telah digunakan dalam kajian ini. Tahap pematuhan mereka kepada standard GAqP dinilai bersama dengan pulangan ekonomi mereka. Analisis unjuran dan regresi Nisbah Faedah-Kos (BCR) telah dijalankan untuk menentukan pulangan ekonomi dalam usaha untuk mematuhi piawaian GAqP. Dapatan menunjukkan bahawa purata BCR untuk ladang akuakultur pekebun kecil untuk tempoh 5 tahun dianggarkan pada 1.23 dan 64.7% daripada standard GAqP telah dipatuhi. Pada masa ini, pulangan ekonomi didapati menguntungkan. Pulangan ekonomi yang lebih baik boleh dijangkakan apabila peratusan pematuhan meningkat. Kajian ini menunjukkan bahawa komitmen yang lebih tinggi daripada kerajaan dan penternak ikan diperlukan untuk mengatasi cabaran untuk memenuhi standard GAqP.

Kata kunci: Perikanan, Perternak Ikan, Jaminan Makanan, Pulangan Ekonomi, MyGAP, GAqP, BCR.

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LIST OF SYMBOL AND ABBREVIATIONS

%	:	Percent
°C	:	Degree Celcius
AI	:	Annual Income Indicator
AN	:	Ammoniacal Nitorgen
BCR	:	Benefit-Cost Ratio
BOD	:	Biochemical Oxygen Demand
CITES	:	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COD	:	Chemical Oxygen Demand
COFI	:	Committee on Fisheries
COVID	:	Coronavirus Disease
DO	:	Dissolved Oxygen
DOE	:	Department of Environment
DOF	:	Department of Fisheries
EU	:	European Union
FAO	:	Food and Agriculture Organization
GAP	:	Good Agriculture Practice
GAqP	:	Good Aquaculture Practice
GIFT	:	Genetically enhanced fish tilapia
ha	:	Hectar
kg	:	Kilogram
LKIM	:	Lembaga Kemajuan Ikan Malaysia
mg/L	:	milligrams per liter
MOA	:	Ministry of Agriculture and Agro-based Industry
MS	:	Malaysian Standards

MyGAP	:	Malaysian Good Agricultural Practices
NAP	:	National Agricultural Policy
pH	:	potential of Hydrogen
ppm	:	parts per million
RM	:	Ringgit Malaysia
ROI	:	Return of Investment
SDG	:	Sustainable Development Goals
SPLAM	:	Malaysian Aquaculture Farm Certification Scheme
SPSS	:	Statistical Package for Social Sciences
SS	:	Suspended Solids
t	:	Tonne
USD	:	United States Dollar
WQI	:	Water Quality Index

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CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter included background information on the current fisheries and aquaculture sectors and the government's alternatives for enhancing food security. The problem statement, research aim and objectives, study scope and constraints, and the significance of the study are all presented in this chapter.

1.2 Study Background

Fisheries have been a long-established way for humanity to obtain food. As the world's top natural protein provider in the diet of many nations, it has retained its significance, with 75% of global fish production being intended for direct human consumption. However, overfishing happens in the ocean when more fish from the ocean population is captured by the fishing industry than can be regenerated by ocean reproduction. Fishing as many fish as possible from the ocean may seem profitable, but it seriously impacts ocean fish stocks. Sim Tze Tzin, Deputy Minister of Agriculture and Agro-Industry, stated that the seized fisheries' supplies were depleting at an alarming rate. Malaysian fishermen are encouraged to move into aquaculture due to a significant drop in the income of the captured fisheries, resulting in increased demand for marine products (Dermawan, 2019).

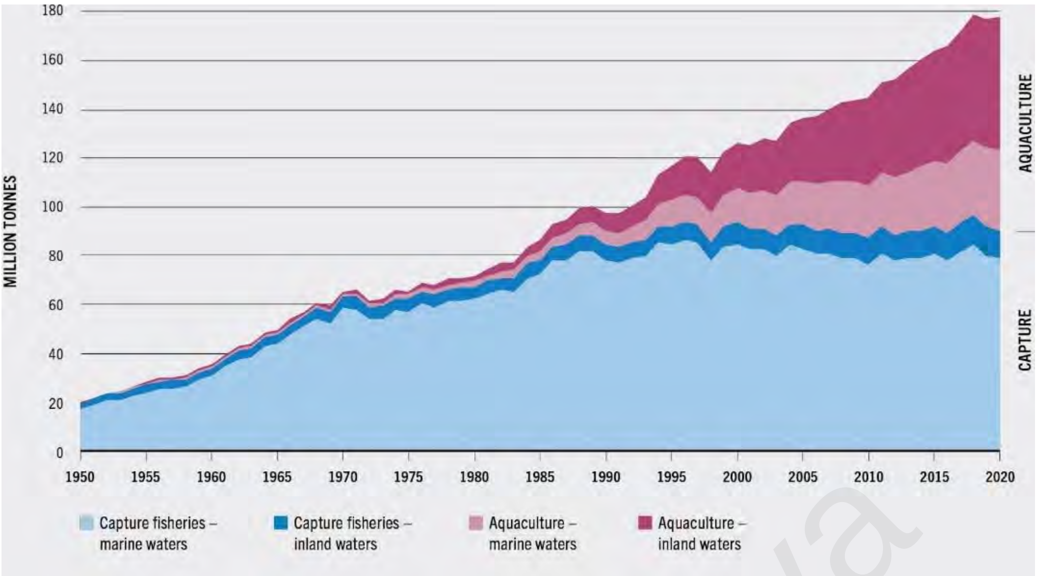

Figure 1.1: World Capture Fisheries and Aquaculture Production (Food and Agriculture Organization [FAO], 2022)

Recent history have shown that aquaculture can support the level of performance needed to live within the resource boundaries of the planet when it is most efficient. Figure 1.1 shows that aquaculture has a bright future in providing a higher fish supply over time compared to captured fisheries. The aquaculture sector is becoming more widely recognised for their critical role in food security and nutrition. Aquaculture's contribution to the global supply is expected to increase further until it reaches parity with capture fisheries by 2030 (FAO, 2022). Practitioners have learned that aquaculture must not only maximise gains but also reduce the accumulation of negative impacts on the natural and social environment (Popp et al., 2019). The goal of the aquaculture industry is to offer a continuous supply of farmed aquatic nutrients that are helpful to human diets without hurting current ecosystems or exceeding the planet's ability to regenerate the natural resources required for aquaculture production (Boyd et al., 2020).

One of the government's alternatives to improving our food security is introducing guidance for Good Aquaculture Practice certification. MS 1998:2007 – General guidelines was first used as a guideline to get the aquaculture certification. Good Aquaculture Practices (GAqP) was revised in 2017 and implemented in 2018 to ensure the fish farmers complied with the standard aquaculture requirements (Manap & Fauzi, 2020). GAqP has been used as a guideline in MyGAP for the aquaculture industry. For the aquaculture sector, MyGAP is a coherent certification scheme used as a reference to encourage the production of healthy and high-quality products without sacrificing the environment, animal welfare, and compliance with workplace safety and health needs (DOF, 2022). By meeting the criteria of GAqP, it ensures the farm's contribution to producing healthy produce from aquaculture and growing consumer trust when getting the MyGAP certificate (Jumatli & Ismail, 2021). It will also expand consumer access to aquaculture products in Malaysia and across ASEAN.

1.3 Problem Statement

Despite the many advantages of the aquaculture business, this industry is still closely linked to environmental issues (Kurniawan et al., 2021). Even though GAqP has been used as a guideline in MyGAP for the aquaculture industry to encourage the production of healthy and high-quality products, a low level of GAqP compliance will still reduce the efficiency of the fish farmers' aquaculture business. On top of that, will the small-scale fish farmers be able to meet the GAqP standard? Moreover, the need for more information from the stakeholders and the association page websites is crucial to help the small-scale fish farmers' business efficiency. The lack of effective interaction between the aquaculture players and the fisheries authorities has been a significant challenge in the Aquaculture industry in Malaysia (Sharihan et al., 2018). If the lack of information and communication continues, how will the fish farmers receive support from the government to help manage their business?

1.4 Aim and Objectives

This study aims to improve the standard of living of small-scale fish farmers by looking at the ways the business is run. This study suggests several research objectives be attained as follows:

i. To quantitatively assess the level of compliance with GAqP among a representative sample of smallholders in the tilapia aquaculture industry within Klang Valley.

ii. To identify and analyse the primary factors and underlying causes contributing to non-compliance with GAqP among smallholders in the tilapia aquaculture industry through questionnaire method.

iii. To establish a quantitative relationship between production costs and fish harvest yields in small-scale tilapia aquaculture operations within a year.

1.5 Scopes of Study and Limitations

The scope of the study is divided into three parts: the level of compliance of GAqP amongst the selected smallholders in the tilapia aquaculture industry. Followed by the efficiency of the capital used to retain the fish farmers in the industry, and lastly, the current aquaculture issues faced by the fish farmers.

In Malaysia, a Malaysian Standard (MS)-based accreditation and certification strategy is used to encourage better management practices. Questionnaires are given to the aquaculture players based on the MS Good Aquaculture Practice (GAqP) aquaculture farm (first revision). A site visit is conducted to observe the current practice of fish farmers. Secondary data collection is used to determine the level of water quality in the aquaculture industry and support the fish farmers' experience in handling their business.

The limitation of this study is the availability of the fish farmers' data in Klang Valley. The COVID virus outbreaks have halted most businesses, and fish farmers cannot be contacted via mobile during the lockdown. The medium of communication with the authority posed a significant challenge, as the data was outdated, and the contact details were not updated regularly. There is also limited data about small-scale fish farmers' socioeconomic position and way of life.

1.6 Significant of Research

As fish is essential in feeding the world's growing population, ensuring the industry thrives is crucial. Since the government's focus in the aquaculture industry is mainly on the big companies, this research can be an indicator for the government to realise there is much potential in our small-scale fish farmers. This research will provide new insights into the importance of helping our small-scale fish farmers to sustain themselves in the aquaculture business sustainably. The fish farmers' community will also realise the importance of running a business in a healthy environment and consistently seek knowledge or training to improve their business. Moreover, the analysis presented in this study will convey valuable information for future research exploring the various benefits of doing sustainable business for the community.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter expands on the literature review, which focuses on the international and regional aquaculture industry, the significance of Good Agricultural Practices (GAqP) standards, and the issues facing the aquaculture business from an economic and environmental standpoint.

2.2 Global Aquaculture Industry

The World Health Organization (WHO) declared the 2019 coronavirus infection (COVID-19) a global pandemic in March 2020. The lockdowns significantly impacted the entire value chain for fisheries and aquaculture (FAO, 2022). The effect on global trade and consumer behaviour was unprecedented. Due to a significant shift in selling from food services to stores, food service surplus and retail product shortages affect prices (Kent, 2021). COVID-19 has made already existing disparities worse. Women, SMEs, informal and migrant workers, small-scale fisheries and aquaculture, and other vulnerable groups must be adequately safeguarded because they are progressively marginalised. It is crucial to maintain the efficient operation of all points of the supply chains, supporting food security, income, and employment with particular consideration for the unique challenges faced by marginalised communities, including women and migrant workers, given that fisheries and aquaculture are an essential sector and critical component of the food system in many countries (FAO & WorldFish, 2021). Collaboration with key stakeholders is urgently required to create a short and extended supply chain for aquacultural players. Fortunately, the crisis has advanced the use of green and clean energies, accelerated the sector's digitalization, encouraged e-monitoring and regulation of capture fisheries, aided the growth of local markets, compelled fish farmers to manage limited production inputs like feeds effectively, and emphasised the significance of domestic production (Ahmed & Azra, 2022).

Going forward, the production from fisheries and aquaculture worldwide is at a record high, and this industry will continue to play a significant role in supplying food and nutrition. One hundred seventy-eight million tonnes of aquatic animals and 36 million tonnes of algae made up the record-breaking 214 million tonnes of total fisheries and aquaculture production in 2020, which was mainly attributed to the expansion of aquaculture, notably in Asia (FAO, 2022). The production of aquatic animals as a whole is anticipated to reach 202 million tonnes in 2030, mainly due to aquaculture's continued expansion, which is anticipated to exceed 100 million tonnes for the first time in 2027 and 106 million tonnes in 2030.

2.2.1 Aquaculture Industry in Asia Region

The fundamental forces behind the diversification of aquaculture in Asia have been cited as the rising demand for seafood and the anticipated far-reaching effects of climate change (FAO, 2022). With 92% of the live-weight volume of animals and seaweed produced in 2017, Asia remained the top aquaculture producer. Asia's most diverse aquaculture production is mainly in China (Metian et al., 2020). The increased aquaculture extension activities have significantly increased China's aquaculture capacity. In 2020, China began constructing the first intelligent fish-farming ship in the world, weighing 100,000 tonnes, in Qingdao (Yue & Shen, 2022). The ship is 45 m broad and 250 m long. 10 knots is the intended speed. The ship can avoid typhoons, red tides, and other severe weather events while it conducts aquaculture operations in oceans all over the world. (Huaxia, 2020). The societal consequences and impacts of offshore aquaculture are still not fully understood (Wang et al., 2021). It should be highlighted that establishments for offshore aquaculture demand large sums of money. Therefore, a key concern in maintaining the viability and profitability of this venture is how to lower the cost of offshore farming (Yue & Shen, 2022).

Southeast Asia has three sub-sectors, including marine capture fisheries, inland capture fisheries, and aquaculture, which contribute to fish production. The region's total fisheries output in 2019 showed that aquaculture accounted for about 54% of the production volume, followed by marine capture fisheries at about 39% and inland capture fisheries at 7% (Klinsukhon et al., 2022). Southeast Asia's largest aquaculture producer, Indonesia, accounts for 50% of the continent's total production. Vietnam, the Philippines, and Thailand round out the top five (Kaewnuratchadasorn et al., 2020). The aquaculture sub-sector helps nations like Indonesia, Myanmar, the Philippines, Thailand, and Viet Nam reduce trade deficits at lower opportunity costs (Salayo et al., 2022). High levels of domestic fish production also ensure domestic food security and significantly reduce fish imports. Since the governments encouraged aquaculture as a way to reduce poverty and ensure food supply in many rural regions, fish production is recognised as being important for food security and rural development in the subregion's less developed nations, including Viet Nam, Myanmar, Cambodia, and Lao PDR (FAO, 1997; The WorldFish Center, 2018).

2.3 Aquaculture Industry in Malaysia

Aquaculture in Malaysia started in the 1920s with comprehensive polyculture in ex-mining pools of introduced Chinese carp. In Johor, the southern state of Peninsular Malaysia, marine shrimp trapping ponds were first created (Liong et al., 1988). Commercial aquaculture was created possible by establishing government-owned and private-owned hatcheries of fish and shrimp, which began in the 1980s. The establishment of private feed mills in the 1980s led to aquaculture marketing. Aquaculture operations were improved by the early 1990s with the implementation of intensive commercial aquaculture with very elevated stocking density and total reliance on additional feeding (Chua, 1979). The aquaculture industry is expanding quickly and is now a key pillar of Malaysia's national food security (Samah & Kamarudin, 2015).

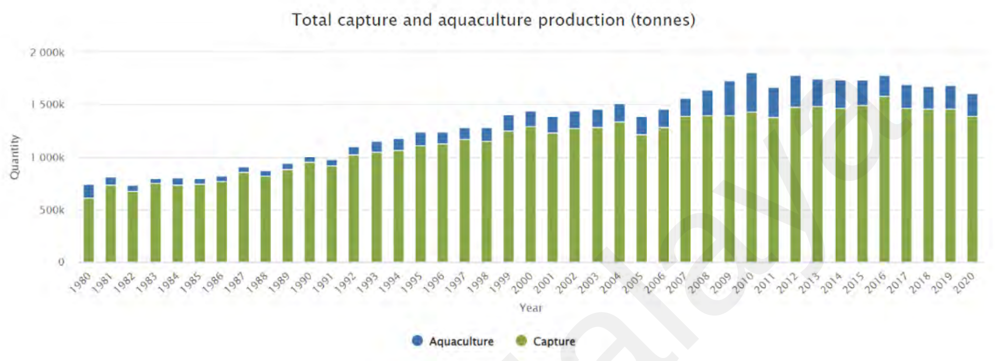

Figure 2.1: Total capture and aquaculture production in Malaysia from 1980-2020 (Food and Agriculture Organization FishStat, 2022)

Based on Figure 2.1, the total capture production is still higher than aquaculture production from 1980 - 2020. However, the aquaculture industry increased rapidly between 2007 - 2010 due to the awareness of aquaculture and overfishing (Fathi et al., 2018). In 2007 aquaculture production reached 178 239 tonnes (208 239 tonnes including aquatic plants). The sector has long been identified as having the most potential for further development (FAO, 2022).

2.3.1 Freshwater Aquaculture in Malaysia

Freshwater pond culture makes up most of the aquaculture production in terms of value (Kechik, 1995). As the Department of Statistics Malaysia reported in 2021, freshwater aquaculture production climbed by 9.0% compared to the prior year. In 2020, the aquaculture sector in Malaysia engaged a total of 15 719 fish farmers and cultivators (DOF, 2021). The bulk (94.8%) of the 14,917 workers were engaged in the freshwater aquaculture sub-sector. Freshwater aquaculture contributed 163,757 tonnes, valued at RM992 million. The main cultured species were freshwater catfish (Clarias sp.), black and red tilapia (Oreochromis spp.), riverine catfish (Pangasius sp.), and giant freshwater prawn (Macrobrachium rosenbergii) (Yusoff, 2015).

Freshwater aquaculture is dominated by pond cultivation which covers an area of 4,769 ha with 49,951 tons of output (Isa et al., 2021). It constituted about 30% of total aquaculture manufacturing in 2003. The cultivated region is spread nationally, with earthen ponds covering the largest area of 4,769 ha, producing more than 80% of freshwater aquaculture production, mainly composed of red hybrid tilapia, hybrid walking catfish, and climbing perch. Floating net-cage cultivation of red tilapia and river catfish, Pangasius, and Mystus is practiced in ponds, reservoirs, and ex-mining pools, covering an area of 2,734 ha. A tiny proportion of approximately 10% of the freshwater lake region is used for Chinese carp polyculture, Javanese carp, and common carp, and some for lake mahseer, snakehead, marble goby, Arowana, and giant freshwater prawns.

2.3.2 Aquaculture Authority in Malaysia

Fisheries and aquaculture development relies on the regulatory and institutional environment, which includes a wide range of laws, rules, administrative orders, institutions, services, infrastructural support, and incentives (Dey et al., 2008). The fishing industry has been contributing to the national economy, and the fish farmers are bound to observe the Federal Fisheries Act. which is divided between Federal, State, and Local Authorities. Different program implementation is subject to these three levels. At the federal level, the Ministry of Natural Resources and the Environment is the appropriate authority for concerns relating to land and water (FAO, 2022).

The 12th Malaysia Plan includes a national development strategy for the aquaculture industry for 2021–2025. Through the Malaysian Fisheries Department, the Malaysian government provides incentive assistance that is meant to encourage and return a portion of the investment made by the community and private sector to cover the necessary operational costs until sales returns are realised after the breeding period is reached. To enhance the production of domestic aquaculture products, the Malaysian Fisheries Department has proposed another aquaculture development programme dubbed the Aquaculture Integration Development Program (Integrated Cage System).

The Cage Fish Farming System is not restricted in terms of design, size, or type as long as it can be identified. The Department of Fisheries Malaysia has set a combined total production target for the Aquaculture Integration Development Program that will be attained by December 31, 2025. (DOF, 2022). This target is 15,000 metric tonnes of livestock production, and creating 2,500 direct and indirect job opportunities with the projects being worked on will serve as the program's metric for success.

The Development Program for the Integration of Aquaculture (Integrated Cage System) is directed at the community and the private sector that engage in freshwater or marine fish cage systems-based aquaculture. The fundamental federal law governing water resources is the Waters Act No. 418 (1920, as amended), which applies to the States of Negeri Sembilan, Pahang, Perak, Selangor, Malacca, Penang, and Federal Territory. This Act requires a license for the abstraction and use of water. However, aquaculture is not explicitly included (FAO, 2022). Fish farmers who register under the government will be supported with training, bags of feed, and other related equipment to help the fish farmers kick-start their businesses.

2.4 Tilapia Farming in Aquaculture Industry

Tilapia are native to Africa, and due to their higher flexibility and tolerance to environmental and ecological conditions, tilapia were introduced into other tropical, subtropical, and temperate parts of the world during the second half of the 20th century to increase catch fisheries (El-Sayed, 2006). Nile tilapia (*Oreochromis niloticus*), first introduced in Indonesia in 1944 (Ang et al., 1989), accounts for 44.7% of overall freshwater aquaculture production, led by salmon (36.7%) and carp (10.08%).

2.4.1 Tilapia Farming in Other Countries

As the world's top supplier of tilapia, China has developed a sizable tilapia farming business in its southern provinces (FAO, 2022e). The world's tilapia harvest has topped 6 million tonnes, making it the second-most frequently farmed freshwater fish behind carp (Abwao et al., 2021; FAO, 2020). Red tilapia is the most significant value valuation of USD 27 million (~RM 118 million) because of its color. Compared to the red hybrid tilapia introduced from Thailand sometime in 1979 (Ang et al., 1989), the black Nile tilapia introduced in the 1950s did not augur well. The successful production of all male tilapia under the GIFT (genetically enhanced fish tilapia) program with the cooperation of the World Fish Center in 2001 marked the start of the commercial culture of all male or monosexual tilapia with a broad body conformation, resulting in increased productivity. The tropical tilapia fish is a vital culture fish because it can be easily reproduced and does not have feeding problems (Kanya & Canli, 2000).

2.4.2 Tilapia Farming in Malaysia

Approximately 37,600 tonnes of tilapia were produced in Malaysia in 2021, with a wholesale value of RM 361 million, demonstrating the importance of tilapia farming in the nation (DOF, 2021). The production of this fish is also expected to increase in the future due to the sector's industrialisation (Othman et al., 2017). Currently, two large commercial farms in Temenggor and Kenyir Lakes produce tilapia in floating cages. The aquaculture industry contributes to the production of fish in Kenyir Lake, with the main species being red tilapia (Oreochromis hybrid), Patin (Pangasius sp.), and Baung (Hemibagrus sp.) in Como River, with fish production in 2016 and 2017 totaling 204,830 kg and 122,000 kg, respectively (David, 2018).

2.4.3 Benefit of Tilapia

These tilapias have many characteristics that favor the aquaculture industry, including a relatively short period of cultivation (Philippart & Ruwet, 1982). They are classified as fertile fish that matures between 3-4 months of life and is easily paired. The female can reproduce three or four times a year, laying up to 1,000 eggs at a time, making it easy to understand how tilapia breeding can congest a pond (Watanabe et al., 1985).

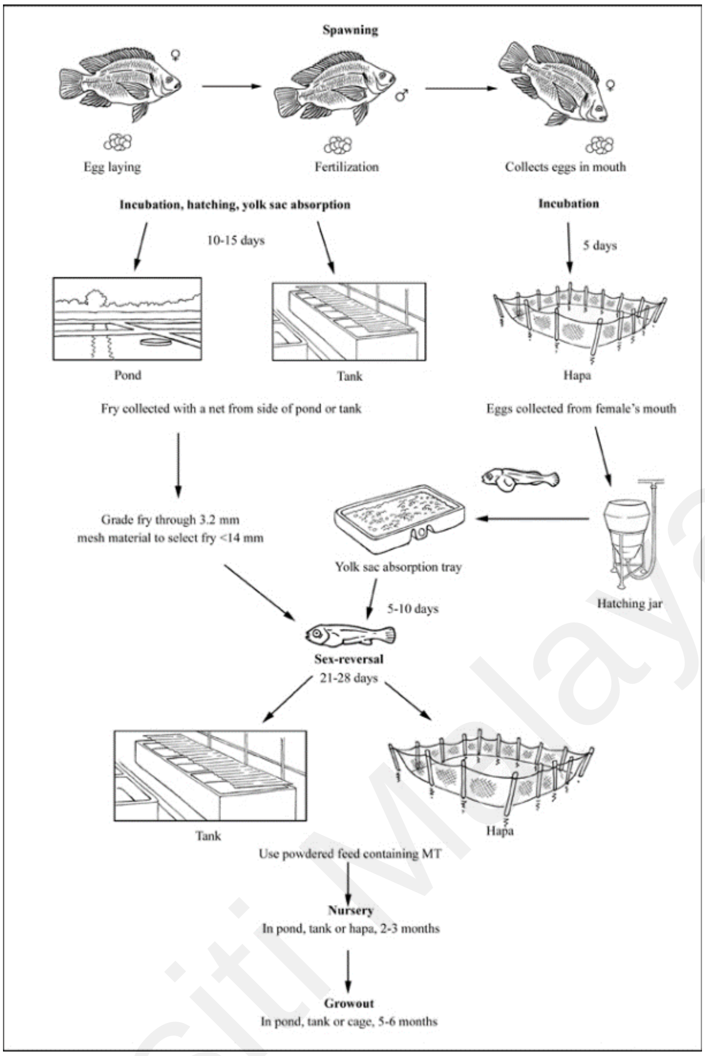

Figure 2.2: General life of Tilapia fish (adapted from FAO, 2022)

Based on Figure 2.2, during the first days and even weeks of their lives, all Oreochromis females perform maternal care, protecting the eggs (and then the larvae) in their mouths (Popma & Lovshin, 1996; Carballo et al., 2008). Many Oreochromis females protect their young actively before they swim quickly for several weeks after the fry. Tilapias can also withstand high densities, adverse environmental conditions, and low oxygen concentrations (Abd El-Hack et al., 2022). They can utilize the food potential of the water they live in and be genetically manipulated. They can feed on plants, vegetables, and meat, while their diet focuses mainly on phytoplankton and a few other zooplankton parts. Tilapia varieties can be produced from commonly known species with better growth, taste, color, and size of fish (Win, 2010).

Tilapia is a popular fish due to its low to moderate fat level and excellent protein quality (Prabu et al., 2019). They have a better ability than other farmed species to feed on unpelleted feeds (Kamruzzaman & Jintasataporm, 2021). The advantage is owing to tilapia's two pharyngeal plates of fine teeth, which aid in the physical grinding of plant tissues, and a stomach pH of 2, which helps break down bacteria and algae cell walls. Tilapia is relatively durable and can endure a wide range of climates. They prefer a warm environment which is not a problem in tropical Africa and Asia.

2.5 Good Aquaculture Practice in ASEAN and Malaysia.

GAqP which was issued in 2007, is the primary reference for aquaculture certification. In 2017, a revised version was produced to ensure that all requirements from the previous approved standard correspond with standard requirements in the ASEAN Good Aquaculture Practices (ASEAN-GAqP) guidelines.

Four essential ASEAN-GAqP primary certification components have been added to the previously stated standards in MS 1998:2017. MS1998:2017 - Good Aquaculture Practices (First Revision) was published and implemented in 2018. The benchmarking of Malaysian standards with ASEAN-GAqP is required to ensure that Malaysian fish and fisheries products traded inside ASEAN member states meet the standard and can freely enter the ASEAN market.

MyGAP is a coherent certification scheme for the crops, aquaculture andlivestock industries. MyGAP is applied in compliance with Malaysian

Requirements (MS). MS 1784: 2005 Crop Commodities — Good agricultural practice for crop sector module and MS 1998: 2007 Good Aquaculture Practice (GaqP) — Aquaculture Farm — Guidelines General.

The norm is specifically intended to educate customers on how food is grown on the farm by minimizing adverse environmental impacts from agricultural activities, limiting the use of chemical inputs and maintaining a responsible approach to the health and safety of employees as well as animal welfare.

2.5.1 GAqP in MyGAP

In 2005, the Malaysian Aquaculture Farm Certification Scheme (SPLAM) protected aquaculture systems for the development of ponds, cages, tanks, orphanages (hatcheries), and seaweeds. It encourages the production of healthy and high-quality products for aquaculture without sacrificing the environment, animal welfare, and compliance with workplace safety and health needs.

The Ministry of Agriculture and Agro-based Industry (MOA) has developed an action plan for large-and small-scale operations to ensure fair and sustainable aquaculture production in Malaysia. Corporate sector involvement is vital to spearhead the growth of industrial aquaculture, but small-scale producers' contributions are also significant.

The benefits of MyGAP to fish farmers are that it will help increase consumer trust in aquaculture products that are clean, healthy, and manufactured without compromising the quality of the environment. The Government guarantees healthy products for aquaculture by sampling activities. Also, it ensures the farm's contribution to producing healthy produce from aquaculture and growing consumer trust. It will expand consumer access to aquaculture products in Malaysia.

2.5.2 GAqP Criteria Used in MyGAP

Some of the primary criteria set by the government are the selection of livestock sites lawfully owned and run (private / rent / temporary ownership/tax). Documentation and current records are kept from the sector. Fish farmers must be prepared to receive feedback, suggestions, and guidance on developing livestock farming practices and have a document on the quality assurance system as evidence.

The five main criteria needed by the fish farmers to apply for the certificate are food safety, fish health needs, occupational safety and health, environmental sustainability, and animal welfare. There are 18 specific benchmarks used to evaluate the fish farmers' ponds to ensure their ponds are safe from pollutants and the fish are safe to eat:

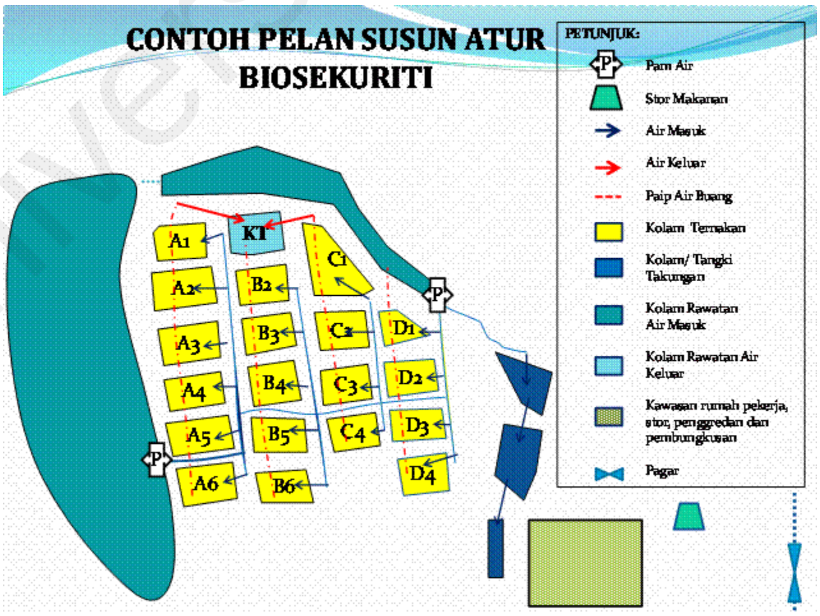

Figure 2.3: Recommended plan for fish farm to apply for MyGAP certificate

Table 0.1: 18 criteria used to evaluate the fish farmers' ponds

Site Selection	Water Management	Wastewater Control
Raw Material Supply (Additives, Seeds)	Farm Hygiene Practices	Labeling, Storage and Use of Hazardous Compounds
Farm Construction	Pool fertilizer	Halal
Cleanliness and surface condition are affected	Social and Welfare of Workers	Control of Predators and Pests
Pool / cage design	Farm Record Keeping	Farm Biosecurity Control
Occupational Health	Harvesting and Handling of Farm Products	Livestock Health Management

2.5.3 GAqP standards for MyGAP Certificate

The certificate issued to the breeder has two (2) years of validity and can be renewed three months before the expiry date.

The following criteria were used to determine the livestock farms had not accepted the MyGAP criteria as well as whether they had violated and failed to comply with all certification recognition standards:

i. The farm has moved to another location.
ii. Changes to the operation and type of farm livestock.
iii. Farm management withdrew voluntarily.

iv. Failure to maintain compliance levels during service activities and surprise inspections performed.

v. The farm produce is unsafe and has been detected to have exceeded the maximum waste level allowed through the official sampling program of the Department of Fisheries Malaysia.

2.6 Challenges in the Aquaculture Industry

A variety of benefits are derived from aquaculture, the main ones being food production for human consumption, creating business opportunities and employment, and increasing exports or substituting local production for imports of fish and fish products. As opposed to 67% in the 1960s, 89% (157 million tonnes) of global production in 2020 (excluding algae) was used directly for human consumption (FAO, 2022e). Nonetheless, this activity has far-reaching consequences, both on a global scale and within the context of Malaysia. Today's global demand for high-quality and abundant aquaculture products requires appropriate aquatic animal health and effective disease management techniques (Hasimuna et al., 2020).

Aquaculture industry participants in Malaysia may work toward sustainable growth, increased productivity, and resilience in the midst of shifting global dynamics by recognizing and resolving both global and Malaysia-specific concerns.

2.6.1 Global Challenges in Aquaculture

Global aquaculture has experienced poor average growth levels in the 1980s and 1990s since 2000 (10.8% and 9.5%, respectively) (FAO, 2018). Based on Figure 2.4, annual growth declined to a modest 5.8% between 2001 and 2016, while double-digit growth continued to occur in a limited number of individual countries, especially in Africa, between 2006 and 2010.

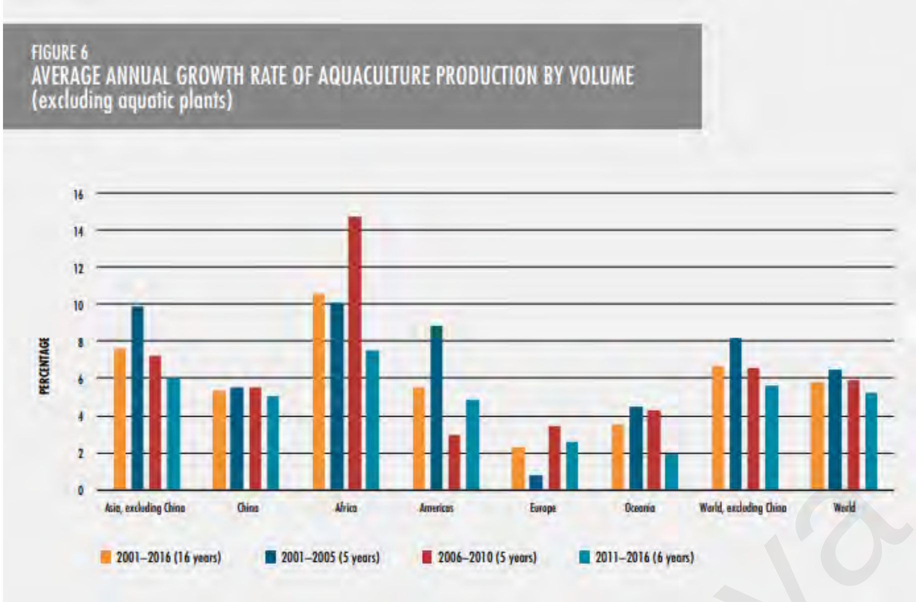

Figure 2.4: Average annual growth rate of aquaculture production by volume (excluding plants) (World Aquaculture, 2022)

Weak returns due to the poor bargaining power of small-scale aquaculture farmers; credit supply and marketing monopolies of intermediaries; insufficient marketing and service facilities and consequent waste, unstable markets and high costs; low demand for less favoured species, and limited support from the government makes it hard for the small-scale fish farmers (Hasan et al., 2020).

The environmental sustainability problems will be one of the limitations for future development. Aquaculture's environmental impact is noted in many respects, including user disputes, ecosystem shifts, water pollution, etc. Water pollution of water resources is the most prevalent complaint of these possible adverse effects and has attracted the most attention across countries (Tookwinas, 1996; Boyd & Tucker, 2000; Cripps & Bergheim, 2000). Not only that, disease outbreaks also have the potential to decimate fish populations are a problem that aquaculture enterprises face very frequently. It is vital to control and prevent disease while using less antibiotics and pesticides.

By decreasing resource demands, minimising environmental effects, and engaging in regulatory coalitions, fish farmers can minimise the effect of future disputes and sustainability problems.

2.6.2 Challenges Specific in Malaysia

In Malaysia, the aquaculture industry faces challenges related to a complex regulatory framework. For a sector to thrive, rules must be streamlined and made clearer while yet maintaining sustainable practices. The primary scarcity in the value chain, however, is the poor interaction between players in aquaculture and fisheries officials. The reasoning is due to the absence of meaningful communication and updated data available to the aquaculture industry (Fathi et al., 2018).

Another obstacle for Malaysia's aquaculture sector is the government's inadequate support for training and skills development. A trained workforce that can meet the changing demands of the industry has been hampered by a lack of educational options and training programs. The adoption of contemporary and environmentally friendly aquaculture practices, which are essential for raising production and competitiveness, is further hindered by the lack of specialist training efforts. In order to overcome this obstacle, the government must make a concerted effort to invest in educational and skill-development initiatives specifically designed for the aquaculture sector. This will give the workforce the knowledge and skills needed to successfully navigate the industry's complexities and support its long-term growth and sustainability.

Supplies of fishmeal are also restricted and unlikely to rise. In 2020, approximately 86% of fishmeal was utilised in aquaculture, with the remaining 9% going to pig farming, 4% going to other uses (mostly pet food), and 1% going to poultry (FAO, 2022e). As a result, fishmeal will increase in price and be less frequently used in meals in favour of other sources of protein (Chamberlain & Rosenthal, 1995). Nutrient content, palatability, solubility, antinutrient factors, availability, and cost are fundamental considerations when looking at substitute proteins for fishmeal (Hodar et al., 2020). Some of the by-products from terrestrial animals utilised in aquaculture diets include fermented feather meal, blood meal, feather meal, meat meal, and bone meal (Mountinho et al., 2017; Ayadi et al., 2012). These alternatives have caused an issue as the fish might not get adequate nutrients. An imbalanced diet may have a negative effect on the growth of fish (Zlaugotne et al., 2022). For aquaculture to be more sustainably produced, constant research is required to develop feeds that use little wild-caught fish while still providing appropriate nutrition (Macaulay et al., 2022).

2.7 Research Gap

In the 1990s and 2000s, as global trade in fisheries and aquaculture increased, there were concerns about food safety and consumer protection. As a result, tighter food laws and regulations, private standards, and market-based requirements emerged to address these concerns by promoting good aquaculture practices and eventually encompassing environmental, social, and animal welfare considerations. The burden on farmers, however, has frequently been disregarded in these developments (for example, the expense of certification, the technical capability of the smaller stakeholders, or the requirement to comply with numerous competing standards). Additionally, they frequently overlook the regional differences in production methods (Mialhe et al., 2018)

There needs to be more research on small-scale fish farmers and how they can survive in this economy. There is also limited research in Malaysia focusing on how efficiently fish feed management can broadly impact the operational business of fish farmers. Most MyGAP research was also mainly related to agriculture, and little data is determining how GAqP in MyGAP can contribute to the sustainability of the business. Furthermore, there needs to be data on small-scale fish farmers complying with the GAqP criteria.

CHAPTER 3 : METHODOLOGY

3.1 Introduction

This chapter presents the details of the research methodology. This chapter also explains and highlights the data collection, and data analysis techniques to meet the objectives of this study.

3.2 Compliances Level and Root Cause of The Non-compliances in GAqP Practices.

This section explained about how data are collected and questionnaires was conducted to evaluate the compliances of GAqP amongst the selected small holders in the tilapia aquaculture industry and determine the root cause of the non-compliances in GAqP practices.

3.2.1 Sampling and Data Collection

The study surveyed smallholder aquaculture farms using a documented list of small-scale aquaculture farm operations (defined by a low asset base and poor production of fewer than 2 tonnes per year) received from the Department of Fisheries. The precise number of aquaculture farms in each region is unknown because some farmers do not register with the department and some of those who do have closed their businesses. As a result, purposive sampling was used. The list was divided between active operational farms and non-operational farms. The list was further divided between responsive fish farmers and non-responsive fish farmers.

To collect primary data from operational aquaculture farms, structured questionnaires with open- and closed-ended questions and interview schedules were employed. The questionnaire attempted to identify difficulties confronting farmers while also allowing them to comment on their methods of operation. Due to time and resource limitations, data was collected from 30 fish farmers with the highest number of respondents in Hulu Langat, Petaling, and Gombak.

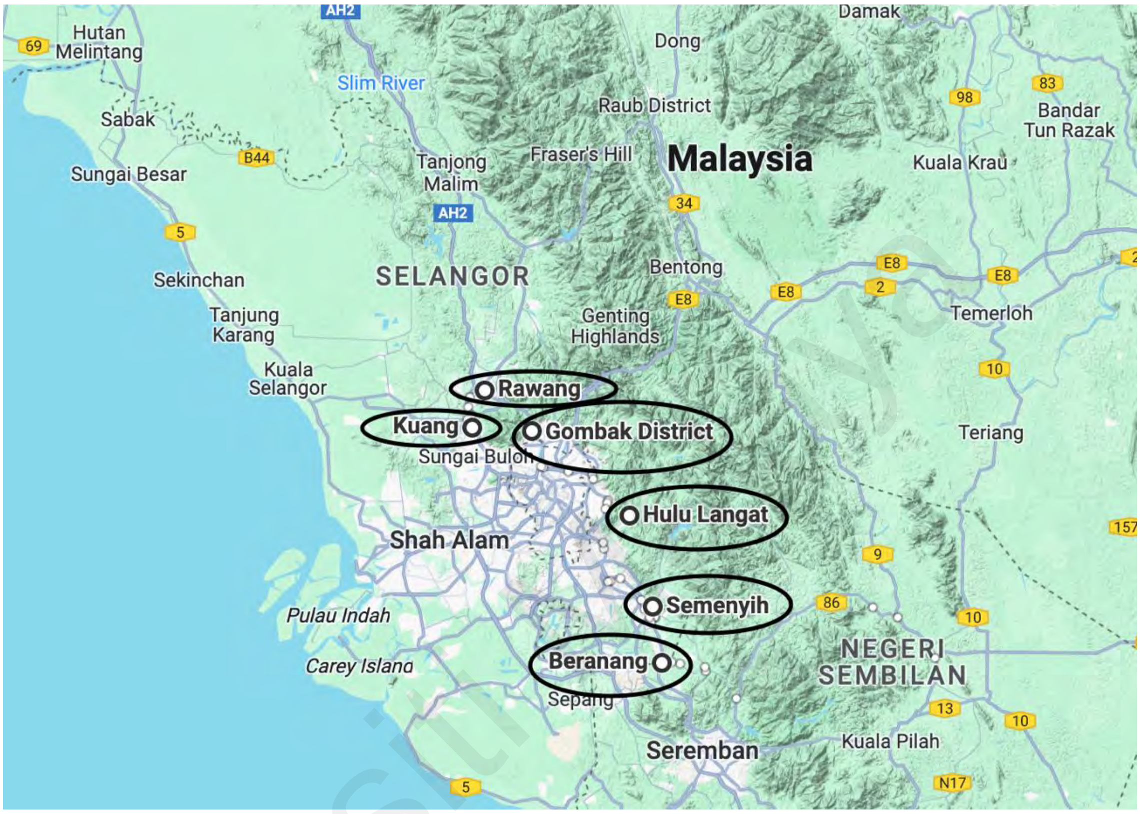

Figure 3.1: Location of interviewed small-scale fish farmers in Selangor

3.2.2 A Structured Questionnaire and Personal Interviews with Small-scale Fish Farmers

A total of 96 questions (59 multiple choices, 18 rating scale questions, and 19 qualitative questions) of the questionnaire were validated and approved by the Fisheries Officer of Department of Fisheries in Putrajaya, Encik Mohd Firdaus bin Ahmad Pauzi. The questionnaire was divided into 12 sections based on Malaysian Standard Good aquaculture practice (GAqP) as shown in Table 3.1. Parameters used in assessing GAqP compliance include site selection, farm design, livestock management, farm management, record management, harvest and post-harvest handling, farm audit, and livestock rotation preparations which is under the MS 1998:2017.

Secondary data reference is used to collect the water quality as part of the physical parameters in meeting the MyGAP requirements. Fish farmers were also asked about their knowledge in terms of water pollution, the quality of water used for the fish, and their perspective on sustainability in general and in the aquaculture industry.

Data was entered and analysed using Microsoft Excel 2016. The results on GAqP criteria were divided between compliance, non-compliance and half compliance. Descriptive analysis was used for the socioeconomic characteristics of respondents and to evaluate the fish farmers' compliance to MyGAP.

In accordance with the outline's breakdown listed in Table 3.1, section L of the questionnaire was designed to capture responses from fish farmers regarding their assessment of the severity of 19 distinct problems. An average rating was calculated for each problem based on the responses, thereby providing a representative measure of the perceived severity of each issue within the aquaculture industry.

Furthermore, fish farmers were also given the opportunity to select the top five problems they commonly encounter from the predefined list provided. Subsequently, a meticulous analysis was conducted to identify the four problems that garnered both the highest average rating and were consistently reported as common issues by the surveyed fish farmers. This dual criterion was utilized to pinpoint and evaluate the most prevalent problems faced by fish farmers in the context of their aquaculture businesses.

Table 3.1: 12 sections of questionnaire

Section	Name	Section	Name
A	Demography	**G**	Record Keeping
B	Benefit-Cost Ratio	**H**	Auditing
C	Site Selection	**I**	Standard of Living
D	Culture Practice	**J**	Farming Activities
E	Trans - Boundary	**K**	General Knowledge
F	Workers, Safety, Health, and Welfare	**L**	Problem in Aquaculture

3.3 Relationship of Cost with The Yield of Fish Harvest

This part focused on the benefit-cost ratio which was employed as a proxy to analyse the profitability of aquaculture farms in their commercial activities, considering all production expenses.

3.3.1 Benefit-Cost Ratio (BCR) Value

This study gathered information on variable and fixed expenses, as well as farm revenue. These data allowed for the estimation of profit margins over a 5-year period. The variable cost data comprised fingerings source and price, feed quantity, and fertiliser formulation, and fertiliser component cost, funding source, and number and salary of employed workers. Net profit will be gained by subtracting total revenue from total cost.

$$BCR = \{\sum_{t=1}^{n}(Bt/(1-r)t\}/\sum_{t=1}^{n}(Ct/(1-r)t\}$$

Figure 3.2: Benefit-Cost ratio formula (Aheto et al., 2019)

BCR value will be calculated based on the formula in figure 3.2 where:

t: current time span of project (years)

Bt: benefits derived from aquaculture farms

Ct: operational costs in time (t)

N: lifespan of project estimated to be 5 years

R: 25% interest rate, which is the average rate at which agricultural loan is given to farmers by financial institutions as reported by the Central Bank of Malaysia.

CHAPTER 4 : RESULTS

4.1 Introduction

This chapter will introduce the expected outcomes from the study to achieve the objective of this research.

4.2 Descriptive Analysis of The Socioeconomic Small-scale Fish Farmers

Descriptive analysis of the socioeconomic characteristics of respondents from Table 4.1 shows that aquaculture is dominated by male fish farmers and the majority is Malay (96.7%) and married (83.3%).

Table 4. 1: Characteristics of smallholder aquaculture farmers and farms surveyed (N = 30)

Characteristics	Frequency	Percentage (%)
Gender		
Male	30	100
Race		
Malay	29	96.7
India	1	3.3
Marital Status		
Married	25	83.3
Single	5	16.7
Education		
Tertiary	26	86.7
Secondary	4	13.3

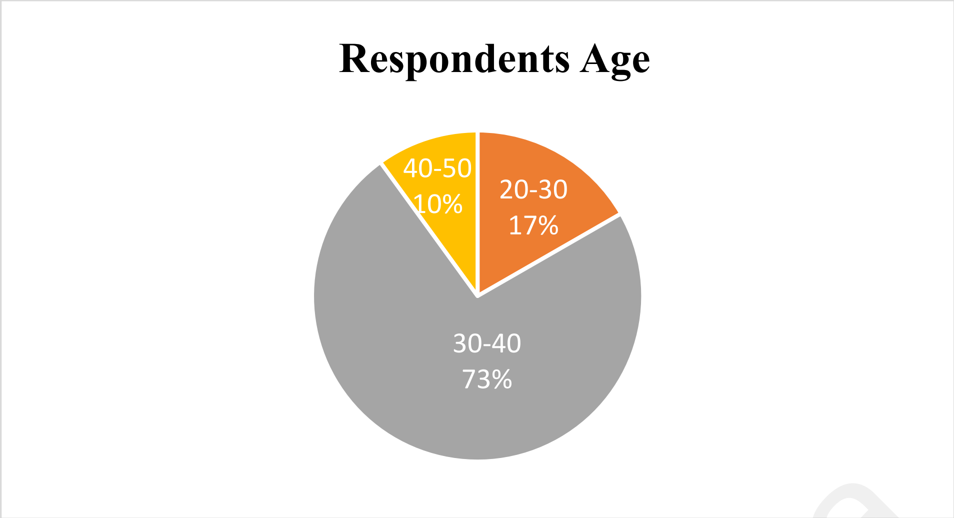

Figure 4.1: Total number of respondents according to age in percentage

Figure 4.1 shows that most of the fish farmers' age range is from 30-40 while 10% of the fish farmers' age is between 40-50. All fish farmers have received formal education in their life and most of them reached tertiary education.

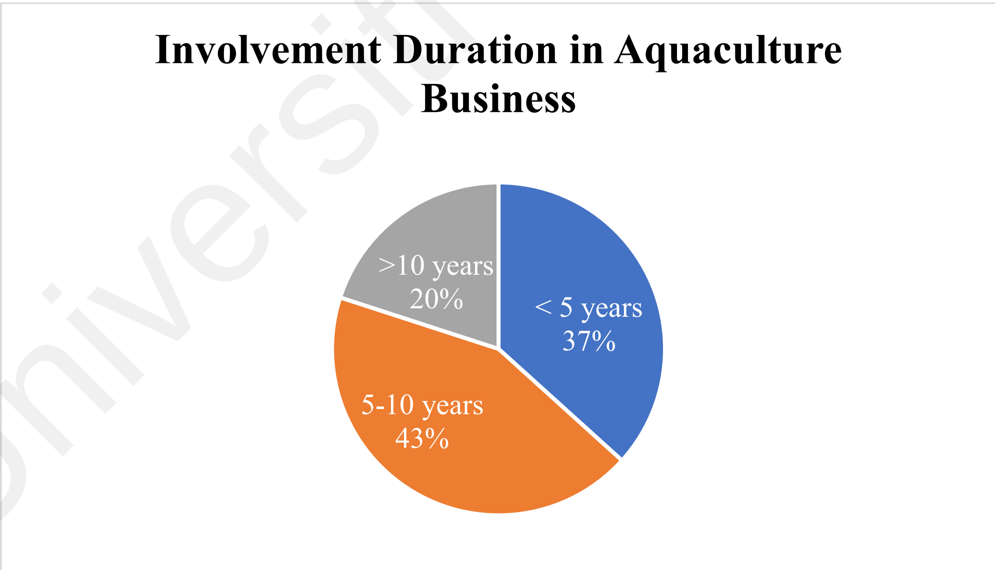

Figure 4.2: Involvement duration in aquaculture business of respondents

Based on figure 4.2, 93.3% of the fish farmers started their aquaculture business by getting exposure to the industry from their friends. Some of the fish farmers have been involved in aquaculture for more than 10 years but the majority of them (43.4%) have aquaculture experience between 5-10 years.

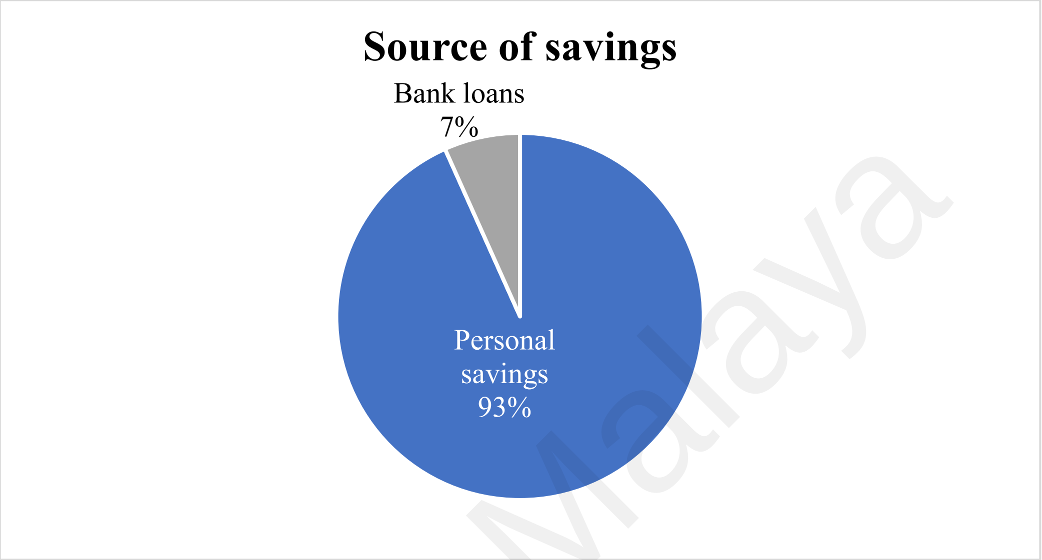

Figure 4.3: Source of savings of respondents in percentage

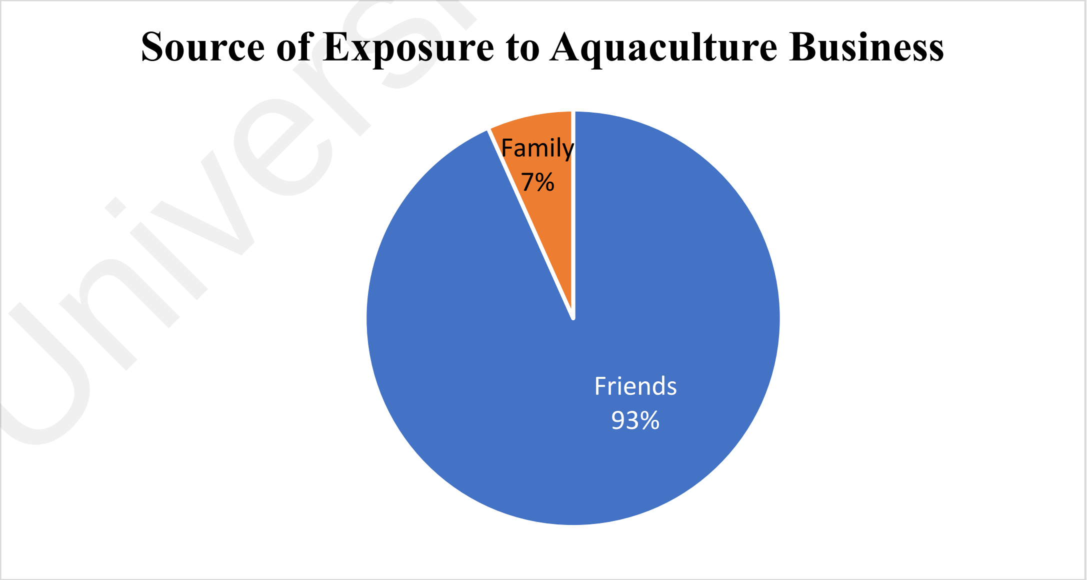

Figure 4.4: Source of exposure to aquaculture business of respondents in percentage

As shown in figure 4.3, the major funding source for the fish farmers is their own personal savings (93.3%) and 6.7% of them requested bank loans to start their aquaculture business. Figure 4.4 shows 93% of the fish farmers have friends as the source of exposure to aquaculture business.

4.3 GAqP Compliance Level

Table 4.2 shows the compliances level of each fish farmers in meeting the MyGAP minimum requirements. Majority of the fish farmers are able to comply in preparing healthy and quality seeds (93.3%) while 80% of the fish farmers comply in meeting harvesting and post-harversting handling, and the disease control criteria. None of the fish farmers comply with the site selection, pest and predator control, and auditing criteria due to lack of experience and knowledge. 53.3% of the fish farmers have prepared a specific location to store their chemical compound but they only meet the partial requirements of chemical storage due to lack of secure location to store the chemical compounds. 13.3% of the fish farmers have received at least one training or guidance from the government related to good aquaculture practices. 64.7% of the GAqP standard complied based on the criteria listed in the GAqP standards. The criteria are considered complied if the majority of fish farmers complied/half-complied with the criteria, which showed 11 out of 17 criteria listed are complied with by the small-scale fish farmers.

Table 4. 2: GAqP Minimum Requirements (N = 30)

Requirements	Frequency	Percentage (%)
Site Selection		
Not complianced	30	100
Construction		
Half-complianced	12	40
Not complianced	18	60
Farm preparation		
Complianced	25	83.3
Half-complianced	2	6.7
Not complianced	3	10
Seed		
Complianced	28	93.3
Half-complianced	2	6.7
Feed		
Complianced	23	76.7
Half-complianced	7	23.3
Chemical storage		
Half-complianced	16	53.3
Not complianced	14	46.7
Water management		
Complianced	3	10
Half-complianced	15	50
Not complianced	12	40
Harvesting and post-harvest handling		
Complianced	24	80
Half-complianced	3	10
Not complianced	3	10

Table 4.2, continued.

Requirements	Frequency	Percentage (%)
Disease control		
Complianced	24	80
Half-complianced	4	13.3
Not complianced	2	6.7
Pest and predator control		
Not complianced	30	100
Trans-boundary		
Complianced	25	83.3
Half-complianced	5	16.7
Workers, safety, health and welfare		
Complianced	24	80
Half-complianced	6	20
Training		
Complianced	4	13.3
Not complianced	26	86.7
Traceability		
Complianced	30	100
Record keeping		
Half-complianced	5	16.7
Not complianced	25	83.3
Auditing		
Not complianced	30	100
Social responsibilities		
Complianced	30	100

4.3.1 Secondary Data of Water Quality

Table 4. 3: Water quality data for 7 sites tested and the overall readings (Rashid et al., 2017)

Variables	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Overall readings (site 1 - site 7)	
	Mean							Mean ± SD	Range
pH (1-14)	6.58	6.39	6.3	6.46	6.42	6.45	6.48	6.44 ± 0.59	5 - 8.45
Temperature (°C)	28.87	28.68	28.68	28.39	28.41	28.37	28.64	28.64 ± 1.93	24.8 - 34.4
DO (mg/L)	7.17	7.04	6.97	6.82	7.1	6.95	6.91	6.99 ± 1.06	4.85 - 9.30

Table 4. 4: The standard acceptable value of water quality parameter for Tilapia Species (Fisheries Research Institute (FRI))

Parameter	Standard Ranges	Unit
pH	6.5-8.5	1-14
Temperature	28-32	°C
DO	>4	ppm

The ideal temperature range for tilapia is between 24°C and 32°C. Below 20°C, the growth rate is rapidly falling, and below 15°C, there is little to no growth visible. The ideal pH ranges between 6 and 9 (Stander, 2000), and based on Table 4.4, standard ranges for pH should between 6.5 - 8.5. Table 4.3 shows that the reading of pH, temperature, and DO for each site tested produced a promising outcome within the ideal range appropriate for the aquaculture business. The overall mean pH is 6.44 which falls under the acceptable value. The mean of temperature is 28.64 and the mean for DO is 6.99. Both parameters meet the standard ranges set by the MOE. Table 4.5 also showed other research has proved that the temperature and pH level taken in their research still fall within the standard range of good water quality and support tilapia life. This shows that tilapia species can be raised in a good water quality environment. Aquaculture can be a profitable business for fish farmers without compromising the quality of water used.

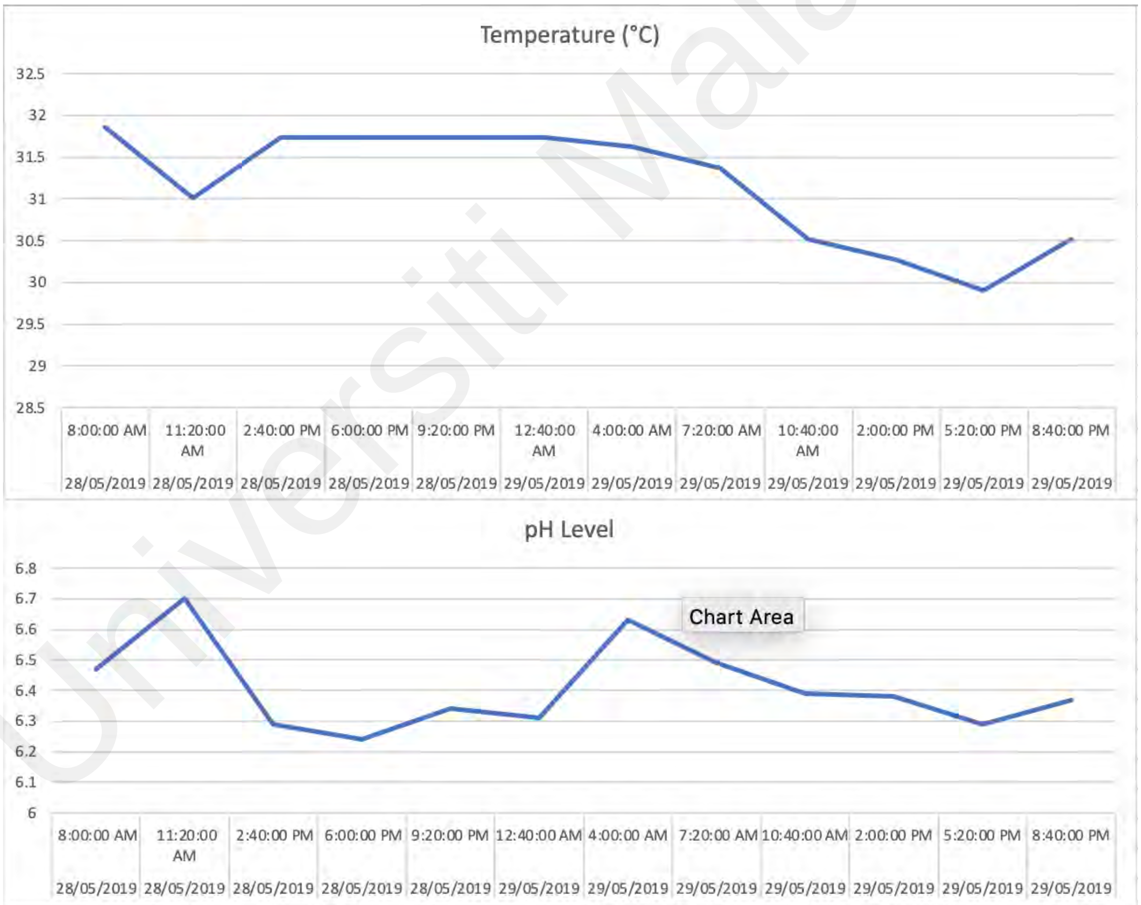

Figure 4.5: Temperature and pH level results according to time (Othman et al., 2020)

4.4 Root Cause of Non-compliances in GAqP Practices.

Based on Table 4.5, fish farmers have experienced a few setbacks including the high cost of fish feeds, lack of support from the government, poor financial management, and deaths of fish. 87% of the fish farmers feel burdened by the high cost of fish feeds. 70% of them felt the lack of support from the government to help grow their small business. 63% acknowledged that they are facing financing challenges due to a lack of financial management experience and 57% have encountered major losses due to sudden deaths of fish.

Table 4. 5: Breakdown of major aquaculture issues faced by the fish farmers (N = 30)

Aquaculture issue	Percentage (%)
High cost of fish feed	87
Lack of support from the government	70
Poor financial management	63
Deaths of fish	57

4.5 Relationship of Cost with The Yield of Fish Harvest

This part is focusing on the Benefit-Cost Ratio Value for 5-year period and individual profits.

4.5.1 Benefit-Cost Ratio (BCR) Value

Table 4.6 shows the Net Profit for each smallholder fish farmers in managing their Tilapia aquaculture business. The amount calculated is based on one year of operations. All fish farmers who have done as part of their source income manage to get profits from this business. Only 2 out of the studied fish farmers do not get any profit as they are only managing it for their own uses and not for business purpose. The results shows that doing aquaculture business can generate income for the fish farmers.

Table 4. 6: Profitability for each of the smallholder farmers (N = 30)

Fish Farmers (No.)	Total Revenue (RM)	Total Cost (RM)	Net Profit (RM)
1	1800	23900	-22100
2	12000	7400	4600
3	72000	51600	20400
4	0	12090	-12090
5	452,200	332,200	120,000
6	5,000,000	3,840,000	1,160,000
7	60000	45000	15,000
8	114000	84000	30,000
9	120450	95450	25,000
10	107600	75800	31,800
11	115000	90000	25,000
12	27400	20000	7,400
13	33000	24500	8,500
14	500540	380000	120,540
15	89000	70000	19,000
16	40350	30350	10000
17	42600	29500	13100
18	56000	40600	15400
19	111000	79000	32000
20	58350	43350	15000
21	45010	35000	10010

22	37950	28950	9000
23	43900	33000	10900
24	52500	40500	12000
25	32040	24000	8040
26	40425	28650	11775
27	39835	31000	8835
28	35420	28000	7420
29	40200	30100	10100
30	38350	29000	9350

Table 4.7 shows the profitability of smallholder aquaculture farms using the benefit-cost ratio (BCR) for small-scale fish farmers. The total number of fish farmers calculated for BCR analysis is 28 as 2 of the fish farmers interviewed are not doing the aquaculture industry as their source of income.

Table 4. 7: Profitability of all smallholder farmers (N = 28)

Year	Total cost of operations (RM)	Net benefit (RM)	Benefit-cost ratio (RM)
1	4983080.17	-3239002.11	-0.65
2	3307838.84	5280578.255	1.59
3	2791425.18	3698975.658	1.33
4	2457060.77	3121498.445	1.27
5	1987876.01	2634175.903	1.32

A BCR is being used to support the efficiency of the capital used to retain the fish farmers in the industry. BCR is an indicator used in a cost-benefit analysis that attempts to summarize a project or proposal's overall value for money. It is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs. The higher the BCR the better the investment. The general rule of thumb is that if the benefit is higher than the cost of the project is a good investment. If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors. If a project's BCR is less than 1.0, the project's costs outweigh the benefits, and it should not be considered.

Based on Table 4.7, the BCR is low in the first year due to the high initial operating costs. During the first year, the fish farmers incur higher costs due to the initial fixed cost such as the acquisition and construction of fish farming facilities and liming, along with variable costs such as the cost of fingerlings, labour, fertilisers, and feed. This caused the income generated to be minimal, and farmers lose money. However, during the second year of the business, the BCR of the small-scale fish farmers is 1.59 which shows a good BCR value. In general, as net benefits rise and production costs fall, the yearly calculated BCR rises. The average BCR for smallholder aquaculture farms for a 5-year period was estimated at 1.23. This shows that aquaculture is a good investment and can deliver positive net value to fish farmers.

The limitation of this result is only 20% of the fish farmers made a proper audit to ensure their expenses are recorded. Since other fish farmers also do a second job to support their lives, they will use the money to cover any cost for their fish farm without properly recording any transaction made. While benefit-cost ratio is a useful metric for assessing profitability, other factors can complicate calculations, such as time, maintenance costs, financing costs, other investment considerations, and the company's overall goals.

CHAPTER 5 : DISCUSSION

5.1 Introduction

The findings from Chapter Four will be covered in further detail in this chapter. In this chapter, GAqP Compliances level, Root Cause of Non-compliances in GAqP practices and Relationship of Cost with The Yield of Harvest will be discussed.

5.2 Socioeconomic Profiles of Small-scale Fish Farmers

This study demonstrates the dominance of men in aquaculture farming. The finding supports the study by Aregu et al. (2017) that confirms men's domination in the aquaculture industry. It has long been believed that men should have larger entitlements to significant household possessions like land and should exercise control over them. Therefore, decisions about how to make a living, like whether to undertake small-scale aquaculture, are primarily made by men (Chow et al., 2017; Aregu et al., 2017). No census or study has effectively documented the full extent of women's economic involvement in the small-scale aquaculture industry. One study by Yahaya (1994) shows that female labour in small-scale aquaculture exists, but they often being classified as "unpaid family workers". In this study, there is no female labour involved as the business is tiny, and the fish farmers mostly do it from A-Z. However, many efforts have recently been made to ensure gender mainstreaming in aquaculture. The Committee on Fisheries (COFI) Declaration acknowledges women's crucial contribution as essential players in the fisheries and aquaculture industries in achieving the SDGs. In it, FAO members make a resolute commitment to "guarantee women's empowerment by promoting women's full access to and equitable opportunities in the fisheries and aquaculture sector through gender-based policies."(FAO, 2022e).

Other than that, the data shows that most fish farmers are between 30-40 years old. The data also shows that the majority of the small-scale fish farmers knew about the aquaculture business from their friends. They were interested in venturing into their business when looking at their friends' businesses, while the remaining fish farmers heard about the aquaculture business from their families. This finding shows the low exposure of aquaculture businesses to large communities and the need for government intervention in attracting young people to start doing aquaculture business. Youth involvement in aquaculture is a crucial component of land and agricultural reform, and it will significantly increase young people's interest in the aquaculture industry (Felsing et al., 2000). A recent study by Amir et al. (2021) shows that nearly 70% of the country's fishermen are of the older generation as the work has long been viewed as an older man's job, and the stereotype has persisted to this day. Due to the restricted possibilities and employment opportunities in the fisheries and aquaculture sectors, young people have not participated as much in these industries in recent decades (Arulingam et al., 2019). Structure and policy inequalities or dysfunction also contributed to the lack of youth engagement and caused them to be reluctant to participate actively in the sector. Labor shortages have also been a problem in the aquaculture industry, as local youths chose to work in factories for better salaries (Vaghefi, 2017). In this study, some fish farmers prefer to hire foreign workers as they can commit to this job thoroughly and even stay in the area to oversee the business overnight. On the other hand, aquaculture requires a certain amount of upfront cash to harvest juveniles, feed them, and buy land and a location to build facilities. This scenario can be one of the biggest obstacles for young people to start a new aquaculture business (Brummet et al., 2004; Azra et al., 2021).

Data also showed that most small-scale fish farmers started their businesses using their savings since it is hard for them to make bank loans. A recent study from Roslina (2018) showed that regarding financial resources, the majority of fish farmers relied on their funds and were more inclined to borrow money from friends and family. This option is risky to the fish farmers as most are already married and need to support their families.

5.3 GAqP Compliances

The study shows that no small-scale fish farmers fully comply with the site selection and construction requirements. As they built the farms with their arrangement and planning, they could not meet the GAqP suggested layout due to the high cost of building the area. The fish farmers are also unable to fully comply with the water management requirement since the effluent from the farm is discharged directly to the municipal water body without proper treatment as they do not have the facility to treat the water. Over 80% of global wastewater production is untreated, with 95% of production in low and lower-middle-income countries discharged directly into streams (Cossio et al., 2020). The reasoning shows that if the fish farmers are not able to comply with the construction criteria, they will not be able to fully comply with the water management requirement.

Meanwhile, the study shows that most fish farmers comply with the farm preparation, seed, and feed criteria. Since the majority of the small-scale fish farmers know about aquaculture from their friends, they will have a similar standard in choosing suitable feed and seeds for their business. Most farms stock between two to four cycles per year and are purchased from private hatcheries, who update their stock via their main Facebook group. Fish farmers can have good access to the fish seeds and feeds as the stocks in Malaysia are readily available in any fish shop. However, some fish farmers cannot comply with the feed requirements due to the high cost of feeds, which makes up around 60-70% of the overall cost. Due to the high worldwide demand, fishmeal prices are predicted to rise by 11% in nominal terms by 2030 (FAO, 2022e). Their main alternative is to use the leftover chicken meats from the markets. The fish farmers know there are better options to grow their tilapia but do not have other options. A study from Ng et al. (2013) shows that due to a lack of cash support and the high cost of formulated feeds, farmers rely heavily on low-quality agricultural by-products and waste as feeds. The uneaten feed can significantly degrade water quality in ponds. These effluents are frequently discharged into larger bodies of water, such as rivers and canals, causing additional pollution issues.

Based on this finding, the fish farmers know what to do to meet the GAqP standards. However, they need help meeting the standards due to the limited support from the government and lack of knowledge in running the business. More significant commitment from the government and fish farmers is needed to overcome the challenges of meeting the GAqP standard. Financial assistance or affordable options for wastewater treatment should be introduced so the level of GAqP compliance among small-scale fish farmers can increase.

5.4 Root Cause of The Non-Compliances in GAqP Practices

This section will discuss in detail why small-scale fish farmers could not fully comply with the GAqP requirements.

5.4.1 High Cost of Fish Feeds

In 2019, the aquaculture industry produced 427,000 tonnes, worth RM 3 billion, and 17,760 breeders in Malaysia (DOF, 2021). It grows in Malaysia, with 90% of fish being exported. Fish food is growing in terms of quality and types of food such as starter and grower. However, some fish farmers mentioned that they have considered retiring from the aquaculture industry due to the high cost of food. Small-scale farmers in Malaysia are hindered by high operating costs, particularly as 60–70% of expenses are related to commercial fish feeds (Jumatli & Ismail, 2021). A study by Craig et al., 2017 also mentioned that fish nutrition is crucial since feed typically accounts for around 50% of the variable production costs. Based on Table 4.2, 87% of the fish farmers are struggling with the high cost of purchasing the feeds for the Tilapia. One standard bag for feed is RM 60, and some fish farmers will use 300 bags per month to feed the fish. Some fish farmers receive 30 kg of fish food aid from the government once they first start registering their farms. This initiative helped kickstart the business, but as the cost of feeds price increased, it was still hard to sustain the business appropriately.

Prices for fishmeal rose due to rising demand (FAO, 2022e). In light of these price rises, farmers are looking increasingly for alternate feed sources such as waste fish, livestock by-products, and grain by-products, or return to single-ingredient supplementary feeding schemes, decreased feeding frequency, and ration. These types of measures to mitigate rising feed costs will compromise fisheries' growth, health, and welfare, and this could reduce the productivity and output of fish. This situation is supported by research made by FAO in 2020, which stated that other alternatives to reduce the fish feed cost would jeopardize fish production, safety, and welfare and can reduce fish productivity. Using plant-based ingredients in aquafeeds to replace fish protein and oil raises the risk of mycotoxin contamination (fungal toxins created by naturally occurring filamentous fungi or molds) (Oliveira, 2020).

The farming of Tilapia produces waste in the form of fecal matter and new feed. These largely nitrogen-based wastes can cause oxygen depletion in coastal environments. These low-quality feeds are damp and unstable in water, and fecal matter and uneaten feeds can significantly degrade pond water quality. However, the fish farmers cannot prepare a proper waste facility. These effluents are frequently discharged into larger bodies of water, such as rivers and canals, causing additional contamination issues (Ahmad et al., 2021). The waste and uneaten feed provide perfect conditions for the growth of various aquatic weeds, including blue-green algae, which, when swallowed by fish, imparts the typical muddy taste of freshwater to the muscle.

5.4.2 Deaths of Fish

Streptococcosis is one of the fish infections mentioned in Intensive Systems of Aquaculture and causes significant economic losses to fish farmers (Maulu et al., 2021). 90% of fish farmers have encountered fish deaths at least once during their care or business. Based on the interviews, there are many reasons which caused the death of the fish. 45% of them mentioned that the fish died due to the common disease that always happened to Tilapia, which is similar to the criteria of Streptococcosis disease. Fish with streptococcosis disease will exhibit either rapid swimming, whirling, eye haemorrhage, cataract, exophthalmia, or skin haemorrhage around the anus or at the base of the fins which the small fish farmers have described the fish disease they have experienced.

A significant environmental factor that can influence fish bacteria's virulence in water pH is Streptococcus iniae in barramundi (Bromage & Owens, 2009) and E. ictaluri in striped catfish (Phuoc et al., 2020). Farmers in Malaysia appear to use erythromycin and oxytetracycline in the treatment of tilapia streptococcosis and prophylactic agents in subclinically stable fish (Mohammad Ridzuan et al., 2020). However, none of the small fish farmers that have been interviewed use that method to prevent the disease infection. One of the reasons is that they are unable to identify the disease as they do not know to identify the name of the disease. Besides that, 30% of the fish farmers will not inform the Department of Fisheries if there is a disease outbreak in their ponds as they will handle it by themselves. Thus, no fish samples were taken to Fisheries Biosecurity Laboratory for further investigation.

One of the ways that they use to ensure the fishes are in good condition is to take the water's pH regularly. They will also observe the fish's movement to detect any abnormality. If there is any odd movement or weird features of the fish, they will quickly separate the fish from the pond to ensure no infection happens. This finding is supported by the study from Laith et al., 2017; strep infection can spread rapidly in a community of fish exposed to bacteria-contaminated water. Thus, if a group of fish was infected with Strep infection, the infected species should be separated from the rest of the population. If necessary, provide special equipment (nets, siphon hoses) for these fish. However, it is usually too late for them to manage the situation as the infection needs only one night to kill all the fish in the pond. In this study, if the fish is still okay to be eaten, they will donate to their neighbours since the fish cannot be sold anymore. If not, they will bury the fish near any tree.

5.4.3 Poor Financial Management

Financial risk in aquaculture refers to the possibility of a loss on an aquaculture investment. Individual farmers, stockholders, farm enterprises, financial organisations, and government agencies may be involved in aquaculture investments, which can be public or private (Van et al., 2018).

Uncertainty in the market and production are frequently considered as causes of risk that result in financial losses (Kahan, 2008). The market price keeps increasing due to high demand from consumers and a low supply of fish. The middleman is making more profit than the fish farmers as many processes between the fish farmers and the consumers keep the price increasing (Aanyu et al., 2020). Even though we cannot deny that their role is essential, the high price of fish does not benefit the fish farmers as they do not get much profit from their selling price, and the consumers need to pay more due to the lengthy process with the mediators.

63% of the fish farmers experienced this challenge, affecting their financial profit in aquaculture. However, they do not have other options as the middleman is the only connection they have to sell their fish. This finding is supported by another study by Ndanga et al., 2013. The economic profitability study was only done for the fish farmers due to data restrictions and input suppliers' reluctance to disclose cost and revenue information for proprietary reasons.

One alternative by LKIM is to create a market for fish farmers to sell their fish (DOF, 2022). This alternative will help the fish farmers get as much profit as possible. However, they prioritise the fishermen that have the fish directly from the sea compared to the fish farmers that conduct aquaculture activity.

A basic understanding of financial analysis methodologies is highly recommended because many of the principles underlying a financial risk assessment are based on financial analysis.

5.4.4 Lack of Support from Government

When there is no coordination to ensure the quality of aquaculture, we have trouble exporting fish to the European Union (EU) countries. Since 2008, the EU has not accepted imported fish from Malaysia as we need to meet the basic standard to import our fish. Implementation is still loose, and Malaysian breeders are free from tight controls and regulations. There needs to be more than the Good Agriculture Practice (GAqP) standard in the MyGAP certificate in Malaysia because there is no strict law to monitor if the fish farmers will follow the guidelines.

Making an effective policy is also limited by a need for more knowledge regarding the current state of aquaculture and its potential to support farmers' livelihoods (Roslina, 2018). Sustainable aquaculture requires good management, and fish farmers require more excellent training and financial assistance to apply best practices.

A change in business practices is crucial in creating new chances for small-scale aquaculture and fisheries-based business operators to interact more directly and closely with clients, allowing them to investigate new markets and goods (FAO & INFOFISH, forthcoming). One of the efforts made in creating an online fish delivery mediator in Malaysia (MyFishman.com), which has assisted small- and medium-sized enterprises (SMEs) in fishing and aquaculture in selling fresh fish through subscription services and delivery services, avoiding wet markets and direct customer contact (IFPRI, 2021).

5.4.5 Resource Constraints in Auditing, Record Keeping and Training

Small-scale fish farmers in Malaysia face a significant barrier to success in the sector and the development of sustainable aquaculture businesses due to a lack of awareness and education. The small-scale fish farmers are not aware of the importance of auditing, record keeping, and training in ensuring good agricultural practices.

Many of these farmers frequently lack access to current knowledge, cutting-edge methods, and critical understanding of best practices in fish farming. Their ability to effectively manage their operations is hindered by this knowledge gap, which also affects their capability to adjust to changing industry norms and environmental issues. They may also lack the necessary resources, both financial and human, to implement and maintain robust auditing, record-keeping systems, and training programs. Therefore, to better optimise production, the industry will need to transition from experience-driven to knowledge-driven approaches in the development of new techniques for fish farming (Fore, et al., 2018).

Targeted educational campaigns and outreach programs created to specifically meet the needs of small-scale fish farmers are required to address this issue. Hence why government support is crucial to expose the small-scale fish farmers on why there is a need for comprehensive education and awareness campaigns to promote these practices. Study made by Mwaijande and Lugendo in 2015 also shows to promote the necessary changes in the fish farming sub-sector, the government must improve the current system or assistance availability towards small-scale fish farmers.

5.4.6 Limited Options for Suitable Sites

Selecting suitable sites and constructing aquaculture facilities are fundamentally influenced by factors like land availability, proximity to water sources, and environmental considerations. When there's a lack of proper infrastructure and few viable site options, it can significantly impede the practice of good agricultural methods.

Therefore, achieving sustainable aquaculture with good site selection and construction requires effective management practices. This is emphasized in a 2018 study by Roslina, which highlights the importance of providing fish farmers with better training and financial support to implement best practices in their operations. Limited access to both technology and funding presents substantial barriers to the success of their small businesses. To help small-scale fish farmers operate efficiently while reducing their environmental impact, it's crucial to adopt innovative approaches for evaluating and managing potential sites, collaborate with local authorities to find suitable locations, and promote responsible land use (Ross et al., 2013).

By comprehensively addressing these challenges, the aquaculture industry can make significant progress toward sustainability while strengthening the resilience of small-scale fish farmers in Malaysia.

5.5 Relationship of Cost with The Yield of Fish Harvest

This part will discuss in detail on profitability analysis of BCR.

5.5.1 Profitability Analysis of Benefit-Cost Ratio (BCR) Value

The profitability analyses indicated that small-scale fish farmers in Selangor's aquaculture industry are financially feasible and profitable, with BCR ratios over one as early as the second year of operation. This finding shows that aquaculture is profitable for them to start their business and improve their living standards. The government has identified aquaculture activities in Malaysia as one of the viable options to improve the standard of living of the communities (Kamaruddin & Baharuddin, 2015). The aquaculture sector is also recognized as one of the significant factors in improving economic activities under the Malaysia National Key Economics Area (NKEA (Jumatli

& Ismail, 2021). However, most fish farmers need help purchasing quality fish feed. This issue caused them to opt for the cheaper option, which is not sustainable for the ecosystem. The feed used in fish farming can significantly impact total productivity, and a profitable business does not always suggest that they are doing well (Aheto et al., 2019).

CHAPTER 6 : CONCLUSION

6.1 Introduction

This chapter will reiterate the key findings from this research and conclusion of this study.

6.2 Key Findings

The finding shows that the average BCR for smallholder aquaculture farms for a 5-year period was estimated at 1.23. Thus, aquaculture fish production is indeed a profitable business. However, small-scale fish farmers are hindered by high operating costs, mainly in purchasing commercial fish feeds, which comprise around 60% of overall expenses.

The study also revealed that 64.7% of the GAqP standard complied. However, not meeting the construction criteria in the GAqP standard caused the fish farmers to be unable to comply with other criteria in GAqP fully. This finding implies that greater commitment from the government and fish farmers is needed to overcome the challenges of meeting the GAqP standard. Better economic return can also be expected when the percentage of compliance increases.

Again, the government's aquaculture for food and jobs agenda should seek to improve yield and boost employment among larger and small-scale fish farmers. Through on-farm research, training, and demonstrations, the government should provide training and technical assistance to small-scale fish farmers in the country. Further research into the locally produced feed from the agricultural product is also necessary to reduce small-scale fish farmers' production costs.

REFERENCES

Aanyu, M., Denis, O., Cassius, A., & Gertrude, A. (2020). Potential for enhancing and sustaining commercial aquaculture in Uganda: Producer organizations, contract farming schemes, and public-private partnerships. *Int. J. Fish. Aquat. Stud*, 8, 258-264.

Abd El-Hack, M. E., El-Saadony, M. T., Nader, M. M., Salem, H. M., El-Tahan, A. M., Soliman, S. M., & Khafaga, A. F. (2022). Effect of environmental factors on growth performance of Nile tilapia (Oreochromis niloticus). *International Journal of Biometeorology*, 66(11), 2183-2194.

Abwao, J., Jung'a, J., Barasa, J.E., Kyule, D., Opiyo, M., Awuor, J.F. & Keya, G.A. (2021). Selective breeding of Nile tilapia, Oreochromisniloticus: a strategy for increased genetic diversity and sustainable development of aquaculture in Kenya. *Journal of Applied Aquaculture*, 1–20.

Adeleke, B., Robertson-Andersson, D., Moodley, G., & Taylor, S. (2020). Aquaculture in Africa: A comparative review of Egypt, Nigeria, and Uganda vis-a-vis South Africa. *Reviews in Fisheries Science & Aquaculture*, 29(2), 167–197.

Aheto, D. W., Acheampong, E., & Odoi, J. O. (2019). Are small-scale freshwater aquaculture farms in coastal areas of Ghana economically profitable? *Aquaculture International*, 27(3), 785–805.

Ahmad, A., Abdullah, S. R. S., Hasan, H. A., Othman, A. R., & Ismail, N. I. (2021). Aquaculture industry: Supply and demand, best practices, effluent, and its current issues and treatment technology. *Journal of environmental management*, 287, Article#112271.

Ahmed, N., & Azra, M. N. (2022). Aquaculture production and value chains in the COVID-19 pandemic. *Current Environmental Health Reports*, 9(3), 423-435.

Amir, H. M., Ahmad, A. A., & Haimid, M. T. (2021). Youth perception and effectiveness of the Stimulate Programme in the Malaysian Fisheries Industry. *Economic and Technology Management Review*, 16, 67–81.

Anusuya, P & Padmavathy, Pandurengan & Aanand, S. & Aruljothi, K. (2017). Review on water quality parameters in freshwater cage fish culture. *International Journal of Applied Research,* 3. 114-120.

Aregu, L., Rajaratnam, S., McDougall, C., Johnstone, G., Wah, Z. Z., Nwe, K. M., ... & Karim, M. (2017). Gender in Myanmar's small-scale aquaculture sector.

Arulingam, I., Nigussie, L., Senaratna Sellamuttu, S., & Debevec, L. (2019). Youth participation in small-scale fisheries, aquaculture, and value chains in Africa and the Asia-Pacific. CGIAR Research Program on Fish Agri-Food Systems.

Ayadi, F.Y.; Muthukumarappan, K.; Rosentrater, K.A. (2012). Alternative protein sources for Aquaculture feeds. *J. Aquac. Feed Sci. Nutr*. 4, 1–26.

Azra, M. N., Kasan, N. A., Othman, R., Noor, G. A. G. R., Mazelan, S., Jamari, Z. B., ... & Ikhwanuddin, M. (2021). Impact of COVID-19 on aquaculture sector in Malaysia: Findings from the first national survey. *Aquaculture Reports*, 19, Article#100568.

Béné, C., & Heck, S. (2005). Fish and food security in Africa.

Blanchard, J. L., Watson, R. A., Fulton, E. A., Cottrell, R. S., Nash, K. L., Bryndum-Buchholz, A., ... & Davidson, L. N. (2017). Linked sustainability challenges and trade-offs among fisheries, aquaculture, and agriculture. *Nature Ecology & Evolution*, 1(9), 1240-1249.

Boyd, C. E. (2003). Guidelines for aquaculture effluent management at farm-level. Measuring Aquaculture Sustainability. Aquaculture, pp. 226, 101–112.Bromage, E., & Owens, L. (2009). Environmental factors affecting the susceptibility of barramundi to Streptococcus iniae. *Aquaculture*, 290(3-4), 224-228.

Brummett, R. E. (2013). Growing Aquaculture in Sustainable Ecosystems. *Agriculture and Environmental Services*, (5), pp. 1–4.

Brummett, R.E., Gockowski, J., Bakwowi, J., Etaba, A.D. (2004). Analysis of aquaculture investments in periurban Yaounde, Cameroon. *Aquac. Econ. Manag*. 8, 319–328.

Carballo, E., Eer, A. V., Chie, T. V., & Hilbrands, A. (2008). Small-scale freshwater fish farming. Agromisa/CTA.

Chamberlain, G., & Rosenthal, H. (1995). By decreasing resource demands, minimizing environmental effects and engaging in regulatory coalitions, aquaculturists can minimize the effect of future disputes and sustainability problems. *World Aquaculture*, 26(1), 21–25.

Chan, C. Y., Tran, N., Dao, D. C., Sulser, T. B., Philips, M. J., Batka, M., ... & Preston, N. (2017). Fish to 2050 in the ASEAN Region. WorldFish Center and Intl Food Policy Res Inst.

Chan, C. Y., Tran, N., Pethiyagoda, S., Crissman, C. C., Sulser, T. B., & Phillips, M. J. (2019). Prospects and challenges of fish for food security in Africa. *Global food security*, pp. 20, 17–25.

Chan, C. Y., Tran, N., Cheong, K. C., Sulser, T. B., Cohen, P. J., Wiebe, K., & Nasr-Allah, A. M. (2021). The future of fish in Africa: Employment and investment opportunities. *PloS one,* 16(12), e0261615.

Chow, M., Egna, H., & West, J. (2017). Towards Assessing Gender Authorship in Aquaculture Publications. Gender in Aquaculture and Fisheries: Engendering Security in Fisheries and Aquaculture, 30, 131-143.

Chua, T. E. (1979). Site selection, structural design, construction, management, and production of floating cage culture system in Malaysia. In Proceedings of the International Workshop on Pen Cage Culture of Fish, p. 11-22 February 1979, Tigbauan, Iloilo, Philippines (pp. 65–80). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

Cossio, C., Norrman, J., McConville, J., Mercado, A., Rauch, S. (2020). Indicators for sustainability assessment of small-scale wastewater treatment plants in low and lower-middle income countries. *Environ. Sustain. Indic*. 6, Article#100028.

Craig, S. R., Helfrich, L. A., Kuhn, D., & Schwarz, M. H. (2017). Understanding fish nutrition, feeds, and feeding.

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S., & Akinwole, A. O. (2019). Waste production in aquaculture: Sources, components and managements in different culture systems. *Aquaculture and Fisheries*, 4(3), 81-88.

David D. (2018). Sg. Como high-impact aquaculture project helps reduce poverty. New Strait Times. Retrieved from https://www.nst.com.my/news/nation/2018/04/352719/sg-como-high-impactaquaculture-project-helps-reduce-poverty.

Dey, M. M., Briones, R. M., Garcia, Y. T., Nissapa, A., Rodriguez, U. P., Taluker, R. K., … & Paraguas, F. J. (2008). Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poorer households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Centre, Penang, Malaysia.

DOF. (2021) Annual Fisheries Statistic. Ministry of Agriculture and Agro-Based Industry, Malaysia.

El-Sayed, A.F.M. (2006). Tilapiaculture. Wallingford, UK: CABI Publishing

Fagun, I. A., Rishan, S. T., Shipra, N. T., & Kunda, M. (2020). Present status of aquaculture and socio-economic condition of fish farmers in a rural setting in Bangladesh. *Research in Agriculture Livestock and Fisheries*, 7(2), 329–339.

FAO. (1997). Report of the expert consultation on small-scale rural aquaculture. FAO Fish. Rep No. 548. FAO, Rome.

FAO. (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome

FAO. (2020) The State of World Fisheries and Aquaculture 2020 – Sustainability in Action. Rome.

FAO. (2022a). Malaysia. Text by Skonhoft, A. Fisheries and Aquaculture Division [online]. Rome. https://www.fao.org/fishery/en/legalframework/nalo_malaysia

FAO. (2022b). The state of world fisheries and aquaculture. Opportunities and challenges. Food and Agriculture Organization of the United Nations.

FAO. (2022c). The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO.

FAO. (2022d). Fishery and Aquaculture Country Profiles. Malaysia. Country Profile Fact Sheets. Fisheries and Aquaculture Division [online]. Rome.

FAO. (2022e). Oreochromis niloticus. Cultured Aquatic Species Information Programme. Text by Rakocy, J. E.. Fisheries and Aquaculture Division [online]. Rome.

FAO & INFOFISH. (forthcoming). Resilience and seizing opportunities: Small-scale fisheries and aquaculture businesses that thrived during the COVID-19 pandemic in South and Southeast Asia. Bangkok, FAO.

FAO & WorldFish. (2021). Aquatic food systems under COVID-19. Rome. www.fao.org/publications/card/en/c/CB5398EN

Fathi, S., Harun, A. N., Rambat, S., & Tukiran, N. A. (2018). Current Issues in Aquaculture: Lessons from Malaysia. *Advanced Science Letters*, 24(1), 503–505.

Felsing, M., C, Brugere, K.Kusakabe and G. Kelkar, (2000). Women for aquaculture or aquaculture for women? *INFOFISH International*, 3, 34-40.

Ferrer, A., Pomeroy, R., Akester, M. J., Muawanah, U., Chumchuen, W., Lee, W., ... & Viswanathan, K. (2021). COVID-19 and Small-Scale Fisheries in Southeast Asia: Impacts and Responses. *Asian Fisheries Science*, 34, 99–113.

Fore, M., Frank, K., Norton, T., Svendsen, E., Alfredsen, J. A., Dempster, T., ... & Berckmans, D. (2018). Precision fish farming: A new framework to improve production in aquaculture. *Biosystems Engineering*, 173, 176-193.

Funge-Smith, S. Phillips, M.J. (2001). Aquaculture systems and species. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand*, 20-25 February 2000. pp. 129–135. NACA, Bangkok, and FAO, Rome.

Garlock, T., Asche, F., Anderson, J., Bjørndal, T., Kumar, G., Lorenzen, K., ... & Tveterås, R. (2020). A global blue revolution: aquaculture growth across regions, species, and countries. *Reviews in Fisheries Science & Aquaculture*, 28(1), 107-116.

Gephart, J. A., Golden, C. D., Asche, F., Belton, B., Brugere, C., Froehlich, H. E., ... & Allison, E. H. (2020). Scenarios for global aquaculture and its role in human nutrition. *Reviews in Fisheries Science & Aquaculture*, 29(1), 122-138.

Guan, C.K. & Hashim, R. (2005). "Diffusing science and technology benefits for rural development," Proceeding of Tun Razak Foundation Forum: New Challenges Facing Rural Development and Poverty Eradication, Kuala Lumpur, 29-30 March.

Gule, T. T., & Geremew, A. (2022). Dietary strategies for better utilization of aquafeeds in Tilapia farming. Aquaculture Nutrition, 2022.

Gupta, M. V., & Acosta, B. O. (2004). A review of global tilapia farming practices. *Aquaculture Asia,* 9(1), 7–12.

Hasan, M. R., Bueno, P. B., & Corner, R. A. (2020). Strengthening, empowering and sustaining small-scale aquaculture farmers' associations. *FAO Fisheries and Aquaculture Technical Paper*, (655), I-181.

Hashim, M. (2008). National Aquaculture Sector Overview. Retrieved from http://www.fao.org/fishery/countrysector/naso_malaysia/en

Hasimuna, O. J., Maulu, S., & Mphande, J. (2020). Aquaculture health management practices in Zambia: status, challenges and proposed biosecurity measures. *Journal of Aquaculture Research and Development*, 11(3), 1-6.

Hodar, A. R., Vasava, R. J., Mahavadiya, D. R., & Joshi, N. H. (2020). Fish meal and fish oil replacement for aqua feed formulation by using alternative sources: A review. *J. Exp. Zool. India*, 23(1), 13-21.

Huaxia. (2020). Construction of smart fish farming ship starts in eastern Chinese city. Retrieved from http://www.xinhuanet.com/english/2020-12/21/c_139607573.htm Qingdao.

IFPRI (International Food Policy Research Institute). (2021). Smallholder and agrifood SME resilience to shocks: Lessons from COVID-19 for the UN Food System Summit. In: IFPRI Blog. Retrieved from www.ifpri.org/blog/smallholder-andagrifood-sme-resilience-shocks-lessons-covid-19-un-foodsystem-summit

Imperatives, S. (1987). Report of the World Commission on Environment and Development: Our common future. Accessed Feb, 10, 1-300.

Isa, S.H., Ramlee, M.N.A., Lola, M.S., Ikhwanuddin, M., Azra, M.N., Abdullah, M.T., Zakaria, S., Ibrahim, Y., 2020. A system dynamics model for analysing the ecoaquaculture system of integrated aquaculture park in Malaysia with policy recommendations. Environ. Dev. Sustain.. https://doi.org/10.1007/s10668-020-00594-4.

Jumatli, A., & Ismail, M. S. (2021). Promotion of sustainable aquaculture in Malaysia. In Proceedings of the International Workshop on the Promotion of Sustainable Aquaculture, Aquatic Animal Health, and Resource Enhancement in Southeast Asia (pp. 31–40). Aquaculture Department, Southeast Asian Fisheries Development Center.

Kaewnuratchadasorn, P., Smithrithee, M., Sato, A., Wanchana, W., Tongdee, N., & Sulit, V. T. (2020). Capturing the impacts of COVID-19 on the fisheries value chain of Southeast Asia. *Fish for the People*, 18(2), 2-8.

Kahan, D. (2008). Managing risk in farming. Food and agriculture organization of the united nations.

Kalay M, & Canli M (2000). Elimination of Essential (Cu, Zn) and NonEssential (Cd, Pb) Metals from Tissues of a Freshwater Fish Tilapia Zilli. Turk. J. Zool. 24(429-436).

Kamaruddin, R., & Baharuddin, A. H. (2015). The importance of good aquaculture practices in improving fish farmer's income: A case of Malaysia. International Journal of Social Economics.

Kamruzzaman, M., & Jintasataporn, O. (2021). Effect of Mash Feed, Sinking Feed and Floating Feed on Growth Performance, Feed Utilization, Hematology and Nutrient Budgets of Nile Tilapia (Oreochromis niloticus) (Doctoral dissertation, Kasetsart University).

Kechik, I. B. A. (1995). Aquaculture in Malaysia. In Towards sustainable aquaculture in Southeast Asia and Japan: Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 26-28 July 1994 (pp. 125-135). Aquaculture Department, Southeast Asian Fisheries Development Center.

Kent, K. (2021). Impacts of COVID-19 on the fisheries and aquaculture food systems with a focus on Europe and the United Kingdom. Paper presented at the XXV Conference of the European Association of Fisheries Economists (EAFE) 5–6 October 2021.

Klinsukhon, S., Tongdee, N., & Sulit, V. T. (2022). Overview of the status and trends of capture fisheries and aquaculture in Southeast Asia. In The Southeast Asian State of Fisheries and Aquaculture 2022 (pp. 1-43). Secretariat, Southeast Asian Fisheries Development Center.

Kurniawan, S. B., Ahmad, A., Rahim, N. F. M., Said, N. S. M., Alnawajha, M. M., Imron, M. F., ... & Hasan, H. A. (2021). Aquaculture in Malaysia: Water-related environmental challenges and opportunities for cleaner production. *Environmental Technology & Innovation*, 24, Article#101913.

Laith, A. A., Ambak, M. A., Hassan, M., Sheriff, S. M., Nadirah, M., Draman, A. S., ... & Najiah, M. (2017). Molecular identification and histopathological study of natural Streptococcus agalactiae infection in hybrid tilapia (Oreochromis niloticus). *Veterinary World*, 10(1), 101.

Liong, P. C., Hanafi, H. B., Merican, Z. O., & Nagaraj, G. (1988). Aquaculture development in Malaysia. In Seminar on Aquaculture Development in Southeast Asia, 8-12 September 1987, Iloilo City, Philippines (pp. 73-90). Aquaculture Department, Southeast Asian Fisheries Development Center.

Liu CF, Qi ZR, He J, Zhang JX (2002): Environmental friendship aquaculture zero discharge integrated recirculating aquaculture systems. *Journal of Dalian Fisheries University* 17, 220–226.

Macaulay, G., Barrett, L. T., & Dempster, T. (2022). Recognising trade-offs between welfare and environmental outcomes in aquaculture will enable good decisions. *Aquaculture Environment Interactions*, 14, 219-227.

Manap, M. G. A., & Pauzi, M. F. A. (2020). myGAP: Malaysia’s gift to seafood world. In IOP Conference Series: Earth and Environmental Science (Vol. 414, No. 1, p. 012012). IOP Publishing.

Massa, F., Demian, S., & Bourdenet, D. (2018). A strategy for the sustainable development of Mediterranean and Black Sea aquaculture. *FAO Aquaculture Newsletter*, (58), 20-22.

Maulu, S., Hasimuna, O. J., Mphande, J., & Munang’andu, H. M. (2021). Prevention and control of streptococcosis in Tilapia culture: A systematic review. *Journal of Aquatic Animal Health,* 33(3), 162-177.

Metian, M., Troell, M., Christensen, V., Steenbeek, J., & Pouil, S. (2020). Mapping diversity of species in global aquaculture. *Reviews in Aquaculture*, 12(2), 1090-1100.

Mialhe, F., Morales, E., Dubuisson-Quellier, S., Vagneron, I., Dabbadie, L. & Little, D.C. (2018). Global standardization and local complexity. A case study of an aquaculture system in Pampanga delta, Philippines. *Aquaculture*, 493, 365–375.

Mohammad Ridzuan, M., MD RADZI, N., Sudirwan, F., Ahmad, K. A. M. I. S. A., Kua, B., Chadag, V., & Nawi, M. (2020). On-farm epidemiological surveillance of genetically improved farmed tilapia (GIFT) cultured at floating net cages in Pahang, Malaysia.

Moldan, B., Janoušková, S., & Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. Ecological Indicators, 17, 4-13.

Mountinho, S.; Martinez-Llores, S.; Tomas-Vidal, A.; Jover-Cerda, M.; Oliva-Teles, A. (2017). Meat and bone meal as partial replacement for fishmeal in diets for gilthead seabream (Sparus aurata) juveniles: Growth, feed utilization, amino acid utilization, and economic efficiency. *Aquaculture,* 468, 271–277.

Muir, J. F., & Young, J. A. (1998). Aquaculture and marine fisheries: will capture fisheries remain competitive?. *Journal of Northwest Atlantic Fishery Science*, 23, 157-174.

Ndanga, L. Z., Quagrainie, K. K., & Dennis, J. H. (2013). Economically feasible options for increased women participation in Kenyan aquaculture value chain. *Aquaculture,* 414, 183-190.

Ng, W. K., Teh, S. W., Chowdhury, K. M., Bureau, D. P., Ng, W. K., Teh, S. W., ... & Bureau, D. P. (2013). On-farm feeding and feed management in tilapia aquaculture in Malaysia. *FAO fisheries and aquaculture technical paper*, 583, 407-431.

Obiero, K., Meulenbroek, P., Drexler, S., Dagne, A., Akoll, P., Odong, R., ... & Waidbacher, H. (2019). The contribution of fish to food and nutrition security in Eastern Africa: Emerging trends and future outlooks. *Sustainability*, 11(6), 1636.

Oliveira, M., & Vasconcelos, V. (2020). Occurrence of mycotoxins in fish feed and its effects: A review. *Toxins,* 12(3), 160.

Osmundsen, T. C., Amundsen, V. S., Alexander, K. A., Asche, F., Bailey, J., Finstad, B., ... & Salgado, H. (2020). The operationalisation of sustainability: Sustainable aquaculture production as defined by certification schemes. *Global Environmental Change*, 60, Article#102025.

Othman, M. F., Hashim, M., Yeo, M. E., Azmai, M. N. A., Iksan, N., Ho, G. C., & Merican, Z. (2017). Transforming the Aquaculture Industry in Malaysia. *World Aquaculture Society*, 15-23.

Othman, N. A., Damanhuri, N. S., Mazalan, M. S., Shamsuddin, S. A., Abbas, M. H., & Meng, B. C. (2020). Automated water quality monitoring system development via LabVIEW for aquaculture industry (Tilapia) in Malaysia. Indones. J. *Electr. Eng. Comput. Sci*, 20(2), 805-812.

Philippart, J.-C.L. and Ruwet, J.-C.L. (1982). Ecology and distribution of tilapias. In: Pullin, R.S.V. and Lowe-McConnell, R.H. (eds) The Biology and Culture of Tilapias. ICLARM Conference Proceedings No. 7, ICLARM, Manila, Philippines, pp. 15–59.

Phiri, F., & Yuan, X. (2018). Economic profitability of tilapia production in Malawi and China. *Journal Aquaculture Research and Development*, 9(535), 1-6.

Popma, T. J., & Lovshin, L. L. (1996). Worldwide prospects for commercial production of tilapia.

Popp, J., Békefi, E., Duleba, S., & Oláh, J. (2019). Multifunctionality of pond fish farms in the opinion of the farm managers: the case of Hungary. *Reviews in Aquaculture*, 11(3), 830-847.

Prabu, E., Rajagopalsamy, C. B. T., Ahilan, B., Jeevagan, I. J. M. A., & Renuhadevi, M. (2019). Tilapia–an excellent candidate species for world aquaculture: a review. Annual Research & Review in Biology, 1-14. Roslina, K. (2018). Contribution of Brackish and Freshwater Aquaculture to Livelihood of Small-Scale Rural Aquaculture Farmers in Kedah, Malaysia. Pertanika Journal of Social Sciences & Humanities, 26(3).

Rashid, Z. A., Amal, M. N. A., & Shohaimi, S. (2018). Water quality influences on fish occurrences in Sungai Pahang, Maran District, Pahang, Malaysia. *Sains Malaysiana*, 47(9), 1941-1951.

Roslina, K. (2018). Contribution of Brackish and Freshwater Aquaculture to Livelihood of Small-Scale Rural Aquaculture Farmers in Kedah, Malaysia. Pertanika Journal of Social Sciences & Humanities, 26(3).

Ross, L. G., Telfer, T., Falconer, L., Soto, D., & Aguilar-Manjarrez, J. (2013). Site Selection and Carrying Capacities for Inland and Coastal Aquaculture: FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6-8 December 2010, Stirling, the United Kingdom of Great Britain and Northern Ireland. Food and Agriculture Organization of the United Nations.

Salayo, N. D., Castel, R. J. G., & Montinola, Q. S. (2022). Issues and challenges in sustainable development of fisheries and aquaculture of the Southeast Asian Region: Aquaculture development: Socioeconomic importance of aquaculture for food security and poverty alleviation. The Southeast Asian State of Fisheries and Aquaculture 2022, 161-166.

Samah, R., Kamaruddin, R., (2015). The influence of socio-demographic factors in adopting good aquaculture practices: Case of aquaculture farmers in Malaysia. J. Sustain. Dev. 8 (97). https://doi.org/10.5539/jsd.v8n9p97.

Saremi, A., Saremi, K., Sadeghi, M., & Sedghi, H. (2013). The effect of aquaculture effluents on water quality parameters of Haraz River. *Iranian Journal of Fisheries Science, 12*(2), 445–453.

Stander, H. (2000). Tilapia in aquaculture. Division of Aquacultue, University of Stellenbosch, South Africa. 2pp.

The WorldFish Center (2008). Using fisheries and aquaculture to reduce poverty and hunger. Brochure; 1893. Penang, Malaysia. 11 p.

Tunde, A. B., Kuton, M. P., Oladipo, A. A., & Olasunkanmi, L. H. (2015). Economic analyze of costs and return of fish farming in Saki-East Local Government Area of Oyo State, Nigeria. Journal of Aquaculture Research & Development, 6(2), 1.

Phuoc, N. N., Linh, N. T. H., Crestani, C., & Zadoks, R. N. (2021). Effect of strain and environmental conditions on the virulence of Streptococcus agalactiae (Group B Streptococcus; GBS) in red tilapia (Oreochromis sp.). Aquaculture, 534, 736256.

Valenti, W.C., Kimpara, J.M., & Preto, B.L. (2011). Measuring Aquaculture Sustainability. *World Aquculture, 42*(3), 26-30.

Valenti, W.C., Kimpara, J.M., Preto, B.L., & Valenti,P.M. (2018). Indicators of Sustainability to Assess Aquaculture Systems. *Ecological Indicators, 88*(1), 402-413.

Vaghefi, N. (2017). Penang's Aquaculture Industry Holds Great Economic Potential By. Penang Institute Issues. https://penanginstitute.org/publications/issues/1005-penang-s-aquaculture-industry-holds-great-economic-potential.

Van Der Heijden, P. G., Shoko, A. P., Van Duijn, A. P., Rurangwa, E., & Bolman, B. (2018). Review and analysis of small-scale aquaculture production in East Africa: Part 3. Tanzania.

Venugopal, V., & Sasidharan, A. (2021). Seafood industry effluents: Environmental hazards, treatment and resource recovery. *Journal of Environmental Chemical Engineering,* 9(2), Article#104758.

Watanabe, W.O., Wicklund, R.I., Olla, B.L. and Head, W.D. (1997). Saltwater culture of the Florida red and other saline tolerant tilapias: a review. In: Costa-Pierce, B.A. and Rakocy, J.E. (eds) *Tilapia Aquaculture in the Americas, Vol. 1. World Aquaculture Society, Baton Rouge, Louisiana,* pp. 54–141.

Wiebe, K., Stads, G. J., Beintema, N., & Brooks, K. (2017). West African Agriculture for Jobs, Nutrition, Growth and Climate Resilience.

Yahaya, J. (1994). Women in small-scale fisheries in Malaysia (p. 99). University of Malaya Press, University of Malaya.

Yanong, R. P., & Francis-Floyd, R. (2002). Streptococcal infections of fish. Florida Cooperative Extension Service. IFAS, University of Florida, 1-5.

Yu, H., Yang, L., Li, D., & Chen, Y. (2021). A hybrid intelligent soft computing method for ammonia nitrogen prediction in aquaculture. *Information Processing in Agriculture*, 8(1), 64-74.

Yue, K., & Shen, Y. (2022). An overview of disruptive technologies for aquaculture. *Aquaculture and Fisheries,* 7(2), 111-120.

Yusoff, A. (2015). Status of resource management and aquaculture in Malaysia. In M. R. R. Romana-Eguia, F. D. Parado-Estepa, N. D. Salayo, & M. J. H. Lebata-Ramos (Eds.), Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia: Challenges in Responsible Production of Aquatic Species: Proceedings of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014 (RESA) (pp. 53-65). Tigbauan, Iloilo, Philippines: Aquaculture Dept., Southeast Asian Fisheries Development Center.

Wang, C., Li, Z., Wang, T., Xu, X., Zhang, X., & Li, D. (2021). Intelligent fish farm—the future of aquaculture. *Aquaculture International,* 29(6), 2681-2711.

Win, T. S. (2010). A Comprehensive Survey and Study of Tilapia Aquaculture in Malaysia with Emphaiss on Production Strategies and Feed Inputs. Universiti Sains Malaysia.

Zhu, M., Zhu, G., Zhao, L., Yao, X., Zhang, Y., Gao, G., & Qin, B. (2013). Influence of algal bloom degradation on nutrient release at the sediment-water interface in Lake Taihu, China. *Environmental Science and Pollution Research,* 20(3), 1803-1811.

Zlaugotne B, Pubule J, Blumberga D. (2022). Advantages and disadvantages of using more sustainable ingredients in fish feed. *Heliyon*. 8(9), e10527.