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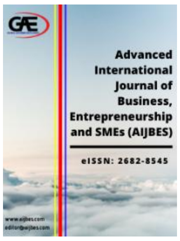

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BROODSTOCKS SELECTION PRACTICES AMONG HATCHERIES IN PENINSULAR MALAYSIA

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Abstract:

The fisheries sector plays a vital role in ensuring protein security in Malaysia. However, heavy dependence on marine capture fisheries has contributed to declining fish stocks, raising concerns over long-term sustainability. Aquaculture has therefore been identified as a key strategy to enhance fish production and meet national food security goals under the National Agro-Food Policy 2 (NAP 2). Despite this, aquaculture production in Malaysia remains below targeted levels, largely due to limitations in the quantity and quality of fish fry supplied to grow-out farms. As fish fry quality is closely linked to broodstock management, effective broodstock selection practices are critical for sustainable aquaculture development. This study examined current broodstock selection practices among hatchery operators in Peninsular Malaysia, as hatcheries serve as the primary source of fish fry for the aquaculture sector. Data were collected from hatchery operators and analysed using descriptive statistics and chi-square analysis. The results indicate that farmers mainly rely on manual selection criteria, particularly broodstock size, physical appearance, and weight. Chi-square analysis further revealed that farm size, labour availability, and production system significantly influence the extent to which farmers evaluate broodstock physical traits, health status, growth rate, and weight. Larger farms and farms with more workers demonstrated a greater capacity to apply multiple broodstock assessment criteria. These findings highlight that broodstock selection practices are shaped not only by farmers' experience and knowledge but also by structural farm capacity. The study provides empirical evidence to support targeted policy interventions, including scale-appropriate broodstock management guidelines and labour-efficient assessment tools. Improving broodstock selection practices at the hatchery level has the potential to enhance fish fry quality, increase aquaculture productivity, and support Malaysia's efforts to meet national fish production targets sustainably.

Keywords:

Broodstock, Hatchery, Aquaculture, Selection Practices, Fish Fry

Introduction

The fisheries sector contributed 11.0% of the total agriculture GDP in Malaysia in 2021 (Department of Statistics Malaysia, DOSM, 2022). The production of fisheries is mainly from the fish capture landing, compared to the aquaculture sector. The fish capture landing contributed about 1,333,603 tonnes, while the aquaculture sector only contributed about 417,188 tonnes in 2021 (Department of Fisheries, DOF, 2022). However, FAO (2020) has alerted that the marine fish in the open sea are estimated to be seriously depleted in 2048 if the capture activities continue as they are today, which will result in severe food security issues in the world as well as in Malaysia. Thus, the government has been encouraging the aquaculture sector and stipulated it as an important economic activity for the country in the National Agro-Food Policy Two 2021 -2030 (NAP 2). The target is to increase the production to around 40% of the total fisheries production in 2030. However, in 2021, the report shows that the aquaculture activities only managed to cater for 23.80% (417,188 tonnes) of the total production (1,750,791 tonnes), which is still far from the target stated in NAP 2.

According to the DOF, there are about 313 hatcheries that produce fish fry in Malaysia. They are mainly involved in breeding activities and nursery care. Hatcheries are places where breeding occurs, while nursery care is where fish eggs are nursed until they hatch. In Malaysia, about 97.7% of the fish fry and seedlings were supplied by private hatcheries, whereas only 2.3% were provided by government hatcheries (DOF, 2022). As mentioned earlier, the report shows that the productivity of aquaculture is still relatively low, which can be for several reasons. DOF (2020) stated that the low quality of the fish fry produced and the low number of fish fry that can be supplied to the fish farmer are among the main issues in the aquaculture industry in Malaysia (DOF, 2020). The production of fish fry has been fluctuating over the years, and Malaysia is facing difficulties in catering to the demand for fish fry. A low number of fish fry can cause the depletion of the operation of fish farms. Fish farms cannot be operated smoothly if the fish fry is not supplied based on their demand. As a result, aquaculture production decreases and directly affects the country's fish production.

Despite national efforts to expand aquaculture, domestic fish fry production remains insufficient to meet industry demand, leading to continued reliance on imports from neighbouring countries such as Thailand and Indonesia (DOF, 2022). Imported fry often fail to meet quality standards due to prolonged transportation times, which induce stress, and the necessity to transport fry in large quantities, resulting in smaller sizes than those preferred by farmers (Ledesma, 2022). This reliance on external sources constrains farmers' ability to select fry that meet operational needs, thereby limiting grow-out performance and undermining national production targets under the National Agro-Food Policy 2021–2030. Furthermore, the

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persistent gap between market demand and domestic fry production highlights the need for improved broodstock management practices. Rising input costs and limited access to high-quality fry further restrict the sector's production potential (Obi et al., 2025; DOF, 2022). These challenges underscore the importance of structural interventions, including targeted policy support, optimized resource allocation, and enhanced broodstock selection processes, to improve fry quality and increase aquaculture output in Malaysia.

In order to ensure that the production of fish fry is sustainable and of good quality, there is a need to carefully select the broodstocks that are being used for breeding. Broodstock is the adult fish used for breeding. Broodstock is a term that refers to a colony of animals kept in captivity as a source of seed and fry replacement or enhancement (Waples and Do, 1994). These are often kept in ponds or tanks with carefully controlled environmental conditions such as photoperiod, temperature, and pH. These populations are frequently subjected to training to maximise fry production. Broodstock can also be taken from wild populations, which are caught and kept in tanks until their eggs are collected and grown to market size or until the juveniles are put back into the sea to help natural populations (Duncan, Sonesson, and Chavanne, 2013). A good broodstock can produce an enormous amount of fry and support the economic demand of the fishing industry. Broodstock, which is good in quality, produces fish fry that can withstand diseases and stress (NAP 2.0, 2021). A fish fry of high quality is defined as fit, 'clean,' evenly proportioned fry and will produce the most profitable harvest in the shortest possible time (National Agricultural Advisory Services (NAADS), 2020).

The ability to fully manage sexual maturity and spawning and to produce vast quantities of high-quality seeds "on demand" throughout the year is essential for the growth of aquaculture (Migaud, Bell, Cabrita, McAndrew, Davie, Bobe,... and Carrillo, 2013). However, poor selection of broodstocks has caused the low quality of fish fry produced (Ingram and Nguyen, 2014). Poor quality of seeds affects the growth rate and the likelihood of disease infection. The productivity of the fish will decrease due to the mortality rate at the early stage of production. Methods to overcome this problem are through better selection of quality broodstock, improving the hatchery development, and enhancing the technology to produce high-quality seed and fingerling production (Ingram and Nguyen, 2014).). Studying hatchery broodstock selection processes and understanding the level of intention in adopting new technology is essential for improving productivity and reducing mortality rates. Since hatcheries are the main source of fish fry for the aquaculture industry, encouraging the adoption of better practices by enhancing farmers' technical skills and providing more support through extension programs is key to the industry's success.

Literature Review

Broodstock selection is widely recognised as a foundational component of hatchery management, as it directly influences reproductive performance, fish fry quality, and survival rates. Broodstock sourcing practices among fish farmers include wild capture, acquisition from commercial broodstock suppliers, and internal broodstock development through on-farm breeding. In Malaysia, broodstock selection is largely based on conventional, experience-driven approaches, reflecting the practical realities of hatchery operations. Farmers commonly apply individual selection techniques that rely on observable characteristics rather than specialised equipment, as these methods are low-cost and easily implemented across different farm scales (Ingram & Nguyen, 2014).

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Several key physical and biological traits, including body size, external appearance, weight, growth performance, and general health condition, typically guide the selection of broodstock. Among these, body size and physical appearance are often used as initial screening criteria. Farmers generally perceive larger fish with well-proportioned bodies and no visible deformities to have better reproductive potential and higher spawning success (Mohamad et al., 2021). The next generation will be more valuable because the fish will develop quicker, increase yields, grow more effectively, lower feed costs and all fish will have a more desirable body colour and increase market value. This practice is consistent with regional hatchery guidelines, which emphasise the importance of selecting broodstock that exhibit normal morphology and appropriate size for reproductive maturity (SEAFDEC, 1996; Mylonas et al., 2010). Malaysian-specific studies, including research on mahseer, (*Tor spp*.), further confirm that body size and physical condition remain central to broodstock evaluation in local aquaculture practices (Faznur & Firdaus, 2018; Jaapar et al., 2024).

However, the literature cautions against excessive reliance on size alone as a selection criterion. While larger broodstock may exhibit higher productivity, rapid bodily growth can be associated with aggressive feeding behaviour or cannibalism. These traits may be transferred to offspring and contribute to increased fry mortality (FAO, 2022). Additionally, some large individuals may allocate more energy toward body growth rather than gonadal development, which can result in reduced breeding efficiency. These findings indicate that size should be considered alongside other biological indicators rather than used as a sole determinant of broodstock quality.

Health status is consistently highlighted as a critical criterion in broodstock selection. Healthy broodstock that are free from injuries, deformities, and infectious diseases are more likely to produce quality eggs. Malaysian hatchery standards require broodstock to be disease-free before breeding, reflecting the well-established link between broodstock health and hatchery performance (Department of Fisheries Malaysia & SIRIM, 2022). Empirical studies further demonstrate that poor broodstock health negatively affects egg quality and larval survival, contributing to high mortality rates during the early life stages (Bobe & Labbé, 2010).

Disease transmission from broodstock to offspring remains a major concern in hatchery operations. Viral pathogens such as Iridovirus and Nervous Necrosis Virus have been identified as significant causes of mortality among fish fry, particularly during the first week after hatching (Ahmad, 2017; Mohamed, 2019). Once introduced into a hatchery system, these pathogens are difficult to eliminate, highlighting the importance of careful broodstock health screening. This challenge is especially pronounced in brackishwater and marine aquaculture systems, where disease outbreaks are more frequent and severe. This makes it crucial to select broodstock that are free of these viruses to increase farm productivity. This understanding helps explain the underperformance of the aquaculture industry in Malaysia, particularly with the high fry mortality during the grow-out phase.

In addition to physical appearance and health, body weight and growth rate are commonly used by farmers to evaluate broodstock performance. These indicators are often viewed as proxies for good nutritional status and overall vitality. Broodstock that demonstrate consistent growth and maintain appropriate body condition are generally preferred for breeding, as these traits are associated with improved reproductive output. Nevertheless, the effective use of weight and growth-based criteria requires repeated observation and monitoring over time, which may not be uniformly practised across all hatcheries.

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Overall, the literature indicates strong consistency in the broodstock selection criteria applied by fish farmers. Physical condition, size, health status, body weight, and growth performance remain central to broodstock evaluation across different aquaculture systems. While these criteria are well established and scientifically supported, their application often depends on farmers' experience, labour availability, and farm management capacity. This variability in practice helps explain differences in broodstock selection intensity and consistency observed among hatchery operators. Hence, previous studies provide a clear context for examining broodstock selection practices at the hatchery level. Understanding how these commonly used criteria are applied in practice is essential for identifying strengths and gaps in current broodstock management and for improving the quality and survival of fish fry in aquaculture production systems.

Methodology

This study focused on fish farmer that operates hatcheries in Peninsular Malaysia. The data of fish farmers had been obtained from the Department of Fisheries Malaysia. The selection of states is based on the highest number of hatcheries in four different regions. Thus, Perak (Northern region), Terengganu (East Coast region), Selangor (Central region) and Negeri Sembilan (Southern region) had been selected as the location of the study as these states contributing highest number of hatcheries.

Figure 1: Location Of the Study

A field study was conducted with 45 hatchery operators, as the total number of hatcheries based on the four states that represent each region is 198. This study focused on the fish farmers who own broodstocks, as the questions were related to the practices when selecting the broodstocks. Participating fish farmers were recruited with the help of the Department of Fisheries for each state that represents four different regions. Respective officers from each DOF contacted the fish farmers, and the meeting was conducted at designed place on a certain date around March to May 2023.

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A structured questionnaire was used as the research instrument and consisted of three sections with questions developed in the Malay language. The first section was designed to explain the socio-demographic profiles of the respondents, such as gender, age, experience in fish farming and education level. The second section consisted of questions related to the farm profile. The third section was designed to obtain information on the practices of fish farmers in selecting the broodstocks. The fish farmer was given six practices in the third section, and a 5-point Likert scale was used, ranging from 1 (Not a Priority) to 5 (Essential) for farmers to select based on their broodstock selection practices. The estimated time for each of the questionnaires to be answered was around 10 to 15 minutes.

The statistical analyses applied in this study were Descriptive analysis and Chi-square analysis. Descriptive analysis was used to analyse and summarise the fish farmer's personal characteristics (such as age and gender) and farm profile (such as the size of the farm and types of fish reared). Chi-square analysis was employed to examine the association between socio-demographic variables (age, education, and farming experience), farm-level characteristics (farm size, number of workers, farm income, and type of aquaculture), and broodstock selection practices (evaluation of size, origin, physical condition, health, weight, and growth rate).

Results and Discussion

Fish Farmers' and Farm Profile

Table 1 shows the sociodemographic profile of the fish farmer. Based on the table, 86.7% of fish farmers were male. Mostly fish farmers (31.1%) aged between 37 to 46 years old were operating the hatcheries. They usually have experience in fish farming ranging between 1 to 5 years, with 31.1% followed by 6 to 10 years' experience in fish farming, with 22.2%. The level of education for most fish farmer that operating the broodstocks is finishing their secondary school with 60.0%. Even though the compulsory education in Malaysia is six years, which is finishing primary school based on the Educational Act 1996 (Ministry of Education (MOE), 2003), the majority of fish farmer that involved in this study had finished their studies until form five.

Table 1: Socio-Demographic Profile of Respondents

Item	Profile	Frequency (n)	Percentage (%)
Gender	Male	39	86.7
	Female	6	13.3
Age	17 – 26	1	2.2
	27 – 36	10	22.2
	37 – 46	14	31.1
	47 – 56	11	24.4
	57 years and above	9	20.0
Fish farming experience (years)	1 – 5	14	31.1
	6 – 10	10	22.2
	11 – 15	9	20.0
	16 – 20	8	17.8
	21 and above	4	8.9
Educational level	Primary school	1	2.2
	Secondary school	27	60.0
	Tertiary School	17	37.8

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Table 2 shows the farm profile of the fish farmers that operating the hatcheries. From the table, the farm size that being operated as the hatcheries mostly ranging between 3.01 acre and above with total 17 fish farmer (37.8%). It is then followed by the farm size ranging between 0.5 acre and below with 11 fish farmer (24.4%). The farm income per month mostly ranging between RM6501 and above with 37.8% out of the total number of fish farmer. It can be seen that the income of fish farmers operating the hatcheries is quite high. The farm size corresponds with the monthly income of the fish farmer. There are about 17 fish farmer that have more than 3.00 acres of farm size and their farm income is also large, which is more than RM6500. It is possible that the bigger the farm size, the higher the possibility for fish farmers to have a high income, as they can produce more fish fry and sell to other fish farmers.

Besides that, mostly the ownership of the farm is sole proprietorship with 23 are owns by the fish farmer (51.1%). A total of 34 fish farmers (75.6%) and the ownership of the farm is sole proprietorship, with 23 fish farmers (51.1%). Usually, farmers will hire workers to help them operate the hatchery. Most of the farms (19 farms) have 1 to 3 workers, and there are only 9 farms that operate by themselves without any workers. A total of 34 fish farmers (75.5%) operate the hatcheries, mostly operating freshwater broodstocks and the remaining 11 fish farmers (24.4%) operate brackishwater broodstocks. For the freshwater broodstocks, fish farmers mostly breed the red Tilapia (12 fish farmers), catfish (10 fish farmers) and silver catfish (6 fish farmers). Meanwhile, seabass and grouper are the only types of brackishwater that are bred by the fish farmers in the studied hatcheries. A total of 31 fish farmer use ponds (ground) in their hatchery operations. It is mainly due to the fish that they breed need natural like environment for the fish to breed successfully, such as Tilapia, catfish and silver catfish.

Table 2: Farm Profile

Item		Frequency (n)	Percentages (%)
Farm size (acre)	0.5 and below	11	24.4
	0.51 – 1.0	5	11.1
	1.01 – 1.5	3	6.7
	1.51 – 2.0	3	6.7
	2.01 – 2.5	0	0
	2.51 – 3.0	6	13.3
	3.01 and above	17	37.8
Farm ownership	Owner/Family	34	75.6
	Rent	8	17.8
	Lease	3	6.7
Types of ownership	Corporation	22	48.9
	Sole Proprietorship	23	51.1
No of workers	None	9	20.0
	1 – 3	19	42.2
	4 – 6	12	26.7
	7 – 9	2	4.4
	10 and above	3	6.7
Types of aquacultures	Brackishwater	11	24.4
	Freshwater	34	75.6
Types of fish reared	Grouper	4	8.9
	Seabass	7	15.6
	Catfish	10	22.2
	Silver catfish	6	13.3

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	Red Tilapia	12	26.7
	Black Tilapia	2	4.4
	Mahseer	4	8.9
Types of fish farming System	Cage system	1	2.22
	Fiber Tank	7	15.6
	Cement Tank	8	17.8
	Pond (Ground)	31	68.9
	Pond (Cement)	11	24.4
	Canvas	5	11.1
Farm income per month (RM)	1,500 and below	5	11.1
	1501 – 2500	7	15.6
	2501 – 3500	5	11.1
	3501 – 4500	5	11.1
	4501 – 5500	4	8.9
	5501 – 6500	2	4.4
	6501 and above	17	37.8

Broodstock Selection Practices

Table 3 below shows sources of broodstock used by fish farmers. Fish farmers can choose more than one answer for this question. Most of the fish farmers (31 fish farmers) are likely purchasing broodstock from external suppliers. External suppliers may provide and offer the broodstock that has desirable traits in genetics. They are likely to purchase from the external supplier due to the easy access and lack of resources to maintain their broodstocks. Besides that, fish farmers (23 fish farmers) also rely on the broodstocks that they breed at their farms. This option gives the farmers better control over the genetics and quality of broodstock, and it is more cost-effective. Broodstock that breeds at their farm is important to ensure the broodstock supply is enough when needed (Ahmad, 2016). Wild-caught is the least preferred by the farmer. Maybe this is due to the regulation on wild fish capture and the unpredictable wild stock's genetics and health. Fish farmers might turn to wild-caught for genetic diversity or if another option is not available. Fish farmers might use more than one source to acquire broodstock due to the availability and cost.

Table 3: Source of broodstock

Sources of brood fish	
	Frequency (n)
Purchased from others	31
Breed from own farm	23
Wild caught	4

Mortality can occur in the hatchery operation, as shown in Table 4 below. The mortality that is being analysed in this study is the mortality of the fish seed and fish fry before they are distributed to the fish farmers who operate the grow-out farm. There are about 15 hatcheries out of 45 hatcheries that have mortality rates ranges 10 to 19. This shows that many hatcheries experience relatively low mortality rates of fish seed or fish fry. A relatively large proportion (13 hatcheries) experience mortality rates of 50% and higher. It is signalling that nearly one-third of hatcheries face challenges with high mortality. This situation requires immediate intervention to identify and address the root cause of the loss. The mean mortality rate of 28.56 implies that while many hatcheries maintain lower mortality rates of fish seed and fish fry, there is still a presence of hatcheries experiencing high losses.

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Table 4: The Mortality Rate That Occurs in The Hatchery

Item	Percentages (%)	Frequency (n)	Percentages (%)
Mortality rate (%)	10 – 19	15	33.3
	20 – 29	9	20.0
(Mean: 28.56%)	30 – 39	6	13.3
	40 – 49	2	4.4
	50 and above	13	28.9
	Total	45	100.0

The practices of fish farmers use in the selection of broodstocks have been identified. Table 5 shows the current practices of fish farmers in selecting broodstocks. Based on the answers that were given, the **size** of the broodstock is the most important attribute that the fish farmer looks into when selecting the broodstocks, with a total of 33 fish farmers (73.3%). It is then followed by the **weight** when selecting the broodstock with a total 29 fish farmers (64.4%) and the **physical** attributes of the broodstocks with 27 fish farmers (60.0%). These three practices are the practices that can be conducted manually by the fish farmer at their farm. Basically, fish farmers select the broodstocks based on their experience in fish farming over the years. The productivity of fish fry differs based on the size of the broodstocks, especially the size of the female. The bigger the size of the female fish, the more eggs it will produce compared to the small female fish (Ahmad, 2016).

Moreover, approximately 20 fish farmers emphasise the importance of considering the **health** of broodstocks when selecting them for breeding purposes. Broodstock **health** can be gauged by observing their activity levels in the tank or pond. However, accurately assessing the exact health status of broodstocks solely through visual inspection is challenging. Manual detection methods are susceptible to human error. The healthiness of the broodstock can be diagnosed in the laboratory by looking into their haematological and biochemical parameters in the blood of the broodstock (Long, Polinski, Call, & Cain, 2012), also by using an automatic detection system (Yasruddin, Ismail, Husin, & Tan, 2022). Despite outward appearances of good health, broodstocks may harbour diseases that can be transmitted to the fish fry during breeding (Swain, & Nayak, 2009).

Adding to that, the **growth rate** of the broodstocks is important to look into for breeding purposes. Fish that have a high **growth rate** can grow faster and have better spawning quality (Ferosekhan et al., 2022). There are about 18 fish farmers (40.0%) who stated it is a high priority to look into the **growth rate,** and 16 fish farmers (35.6%) who stated it is essential to look into the growth rate of broodstocks before it can be selected for breeding purposes.

Last but not least, the **origin** of the broodstocks is perceived as the least essential criterion among fish farmers when selecting broodstock. Only 13 fish farmers (28.9%) consider it necessary to examine the **origin** when selecting broodstocks. However, the **origin** of the broodstock is a vital characteristic to consider to prevent inbreeding within the farm (Loughnan et al., 2016), which can produce low-quality fish fry. In summary, the characteristics of the selected broodstocks will be passed on to the fish fry. Therefore, the process of choosing broodstocks is crucial in hatchery operations.

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Table 5: Fish Farmer Practices in Selecting Broodstocks

No	Practices	n (%)				
		1	2	3	4	5
1.	Look into size of the broodstock	1 (2.2%)	3 (6.7%)	2 (4.4%)	6 (13.3%)	33 (73.3%)
2.	Look into the origin of the broodstock	5 (11.1%)	1 (2.2%)	18 (40.0%)	8 (17.8%)	13 (28.9%)
3.	Look into the physical appearance of the broodstocks	1 (2.2%)	1 (2.2%)	3 (6.7%)	13 (28.9%)	27 (60.0%)
4.	Look into the health of the broodstocks	2 (4.4%)	2 (4.4%)	5 (11.1%)	16 (35.6%)	20 (44.4%)
5.	Look into the weight of the broodstocks	0	0	5 (11.1%)	11 (24.4%)	29 (64.4%)
6.	Look into the growth rate of the broodstocks	1 (2.2%)	0	10 (22.2%)	18 (40.0%)	16 (35.6%)

Note: 1=Not a priority; 2=Low priority; 3=Medium Priority; 4=High Priority; 5=Essential

Association between Fish Farmers and Farm Profile with Broodstock Selection Process

Chi-square analysis was used to analyse the association between **socio-demographic profiles, farm profiles** and **broodstock selection practices**. This non-parametric test is appropriate for analysing relationships between categorical variables and determining whether observed patterns differ significantly from expected distributions. To investigate these associations, the scale of broodstock selection practices was combined and characterised into two categories: "practices that are important to look into" and "practices that are not important to look into" when selecting broodstocks. Practices that are not important to consider when selecting broodstocks include the combination of "Not a priority", "Low priority", and "Medium priority". Meanwhile, practices that are important to consider are the combination of "High priority" and "Essential". The null and alternative hypotheses were developed as follows:

H_0: There are no associations between socio-demographic profiles (age, educational level, experience), farm profiles (farm income, farm size, no of workers, types of aquacultures) and broodstock selection practices (size, origin, physical, health, weight, growth rate) among fish farmers.

H_1: There are association between socio-demographic profiles (age, educational level, experience), farm profiles (farm income, farm size, no of workers, types of aquacultures) and the broodstock selection practices (size, origin, physical, health, weight, growth rate) among fish farmers.

Table 4 is a summary of the chi-square result between demographic profile, farm profile and broodstocks selection practices that farmers do when selecting the broodstocks for breeding purposes. The first practice that the researcher wants to look into is the **size of the broodstocks**. Table 4 indicates that the age of the farmer has a significant association with the practices of looking into the size of broodstocks for the selection process, with a p-value of 0.053. Farmers aged between 37 to 46 years old have a high tendency to look into the size of the broodstocks when selecting them for breeding purposes. This age group may rely more strongly on experiential and visually assessed indicators of reproductive suitability. This may reflect greater accumulated practical experience in recognising phenotypic indicators associated with

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reproductive potential, such as body size, which is widely recognised as a key criterion in broodstock management (Ingram & Nguyen, 2014; FAO, 2022). Besides that, the number of workers (p-value = 0.012) also has a significant association with the practices that look into the size of broodstocks when selecting it. Hatcheries employing one to three workers were more likely to systematically evaluate broodstock size compared to farms operated solely by the owner. This finding highlights the role of labour capacity in enabling routine broodstock assessment activities, particularly those that require repeated handling and observation before spawning (Migaud et al., 2013; Duncan et al., 2013).

As for the second practice, which is look into the **origin of broodstock**. Four profiles have shown significant associations with it. The level of education among farmers (p-value = 0.016) greatly affects their focus on broodstock origin. Farmers with a secondary education are more attentive to the source of broodstock compared to those with only primary education, likely due to their greater ability to adapt and assimilate new knowledge (Hlad'o et al., 2020). Furthermore, the number of workers and the type of aquaculture practised show significant associations with this attention to broodstock origin, with p-values of 0.090 and 0.079, respectively. Farms employing 1 to 3 workers and those involved in freshwater aquaculture are especially inclined to prioritise the origin of broodstock when making breeding decisions. This may reflect differences in management intensity and breeding practices between production systems. Freshwater hatcheries often rely more heavily on controlled breeding cycles and on-farm broodstock development. Hence, making source identification particularly important for avoiding inbreeding and maintaining stock quality.

Next are the results on the association between demographic profile and farm profiles with the physical characteristics of broodstocks. Based on the table, farm size and number of workers have a significant association with the practices by looking into the physical characteristics of the broodstocks when selecting them for breeding purposes. Based on the table, farm size (p-value=0.048) has a significant association with the practices by looking into the physical characteristics of the broodstocks when selecting them for breeding purposes. It shows that farmers that operating the farm size 3.01 acre and above demonstrated a higher tendency to look into the physical characteristics of the broodstocks, such as body condition, symmetry, and the absence of visible deformities, compared to the farmer that operating the farm size smaller than 3.01 acre. These traits are widely recognised in broodstock management literature as essential indicators of reproductive suitability and overall broodstock quality (Ingram & Nguyen, 2014; FAO, 2022).

Similarly, the number of workers employed on the farm exhibited a strong association with physical assessment practices (p-value = 0.001). Farms employing four to six workers were more likely to routinely evaluate broodstock physical characteristics compared to farms with fewer or no workers. Previous studies on broodstock management emphasise that effective physical assessment requires repeated handling, observation, and monitoring, which are inherently labour-intensive processes (Migaud et al., 2013; Duncan et al., 2013). Consequently, hatcheries with greater labour capacity are better positioned to implement systematic broodstock inspection protocols. These findings suggest that the application of recommended broodstock selection practices is strongly influenced by structural farm capacity rather than technical awareness alone.

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The assessment of broodstock health was found to be significantly associated with several farm profile characteristics, namely farm size, labour availability, and type of aquaculture system. For the farm size (p-value = 0.005), the result suggested that farmers that operating the farm size range 3.01 acres and above have a high tendency to look into the health of the broodstocks when selecting it for breeding purposes. This finding aligns with broodstock management principles, which emphasise that healthy broodstock are less likely to transmit pathogens and are more capable of producing high-quality eggs and larvae, thereby improving fry survival and overall hatchery performance (FAO, 2022). Labour availability also exhibited a significant association with the practice of assessing broodstock health (p-value = 0.004). Farms employing one to three workers demonstrated a higher tendency to monitor broodstock health compared to farms operated without hired labour. Health assessment often involves repeated observation of behaviour, feeding response, and external condition, as well as occasional handling for closer inspection, all of which are labour-intensive activities (Migaud et al., 2013). Consequently, hatcheries with additional workers are better positioned to implement routine health monitoring as part of broodstock management. In addition, the type of aquaculture system practised was significantly associated with attention to broodstock health (p-value = 0.019), with freshwater hatcheries showing a greater tendency to prioritise broodstock health than brackishwater operations. This may reflect differences in disease management strategies and production cycles, as freshwater hatcheries often rely on closed or semi-controlled systems where broodstock health directly influences spawning success and fry output (Ingram & Nguyen, 2014).

Besides that, Table 4 also shows the result summary for practices that look into the weight of broodstocks before it can be chosen for breeding purposes. The results indicated that three out of eight variables have a statistical association with the practices that look into the weight when selecting the broodstocks. These variables are age (p-value = 0.041), educational level (p-value = 0.036) and farm size (p-value = 0.006). Farmers aged between 37 and 46 years demonstrated a significantly higher tendency to prioritise broodstock weight during selection, suggesting that experience accumulated during mid-career stages may enhance awareness of growth-related performance indicators. In addition, farmers who had completed secondary education were more likely to use broodstock weight as a key selection criterion, reflecting the role of formal education in improving technical decision-making and adoption of scientifically informed practices (Obiero et al., 2019). In addition, farmers managing smaller farms (≤ 0.5 acres) relied more on broodstock weight when selecting broodstocks. This likely reflects the need to make more efficient and targeted choices in limited farm space, ensuring better growth performance and feed efficiency (Joffre et al., 2014). These results suggest that both human capital and structural farm limitations shape the degree to which farmers apply quantitative traits, such as body weight, in broodstock selection decisions.

Additionally, Table 4 also shows that there are significant associations of the number of workers and types of aquacultures with the practices that affect the growth rate of the broodstocks before they can be used for breeding purposes. Farms employing 1 to 3 workers (p-value=0.001) have a high tendency to check the growth rate of the broodstocks when selecting them, compared to a farm that has no workers. It shows that having workers in the farm is important to carry out the broodstock selection practices. Growth rate assessment typically requires repeated observation and record-keeping, which may be challenging for farms without hired labour. This reinforces the role of manpower as an enabling factor for implementing more advanced broodstock selection practices. Moreover, farmers operating freshwater systems (p = 0.083) were more likely to consider growth rate when selecting broodstock than those managing

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brackish water farms, suggesting that production system influences selection priorities. Freshwater farmers also showed a higher tendency to assess growth rate compared to brackishwater farmers, possibly due to shorter production cycles and easier handling conditions in freshwater systems.

Table 4: Summary of the Chi-square Analysis

Profile	Practices					
	Size	Origin	Physical	Health	Weight	Growth Rate
Age	0.053***	0.309	0.481	0.163	0.041**	0.506
Educational level	0.290	0.016**	0.545	0.323	0.036**	0.167
Experience	0.747	0.912	0.515	0.942	0.376	0.572
Farm income	0.932	0.562	0.418	0.712	0.852	0.135
Farm Size	0.142	0.393	0.048**	0.005***	0.006***	0.120
No of workers	0.012**	0.090*	0.001***	0.004***	0.223	0.001***
Types of aquacultures	0.115	0.079*	0.156	0.019**	0.105	0.083*

*Notes: *Significant at 1% level of significance, **Significant at 5% level of significance, ***Significant at 10% level of significance*

Conclusion

Fish farming in Malaysia is primarily conducted through two operational systems which are hatchery and grow-out operations. Hatcheries play a vital role in producing high-quality fish fry, which directly influence productivity and performance during the grow-out phase. High-quality fish fry demonstrates greater tolerance to environmental stressors and increased resistance to infectious diseases, contributing to improved survival rates and production efficiency. In current practices, broodstock selection is mostly conducted manually. Farmers rely on visual assessment of traits such as body size, external appearance, and weight. The decisions are guided by experiential knowledge rather than the use of technological support. While this practice remains common, the integration of technology could enhance the accuracy and consistency of broodstock quality evaluation.

Chi-square analysis revealed that the number of workers on a farm influences a farmer's ability to assess key broodstock traits, including body size, origin, health, and growth rate. Farms with a larger workforce demonstrated a greater capacity to apply multiple selection criteria, thereby improving the overall quality of broodstock chosen for spawning. In contrast, smaller operations often face financial constraints that limit their ability to employ additional labour. These farms are predominantly owner-managed, and the costs associated with hiring workers tend to further reduce already narrow profit margins. Consequently, most small-scale farms operate with only one to three workers. Although empirical studies linking farm labour directly to broodstock selection behaviour are limited, hatchery management literature consistently highlights that effective evaluation of broodstock physical traits and reproductive condition requires time, repeated observation, and adequate labour resources. In freshwater aquaculture systems, broodstock origin, health condition, and growth performance are systematically monitored due to their strong association with farm productivity. Farmers aged 37 to 46 years, possessing secondary level education and managing farms of up to 0.5 acres, were found to prioritise the weight of broodstock as the principal selection criterion.

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The results of this study indicate that while Malaysian fish farmers are generally aware of recommended broodstock selection criteria, the consistent application of these practices is constrained by labour availability and farm capacity. Such structural limitations have important implications for hatchery performance, as inconsistent broodstock evaluation may lead to variability in fish fry quality and survival. Specifically, broodstock selection practices were found to be significantly influenced by farm size, workforce availability, and the type of production system. Larger farms and those with additional workers were better able to evaluate broodstock physical traits, health status, growth rate, and weight, whereas smaller or labour-limited farms faced constraints that hindered the consistent application of these practices. These findings highlight that broodstock management is shaped not only by technical knowledge but also by the structural capacity of the farm.

The structural constraints identified in this study, particularly income limitations and labour costs reflect broader economic realities faced by small-scale aquaculture producers. Small-scale pond aquaculture systems often experience negative net farm income and low returns on investment due to high operational expenses, including labour and feed, which can constitute a substantial portion of total production costs and worsen financial vulnerability (Meliko et al., 2021). Labour costs alone have been reported to account for a significant share of variable expenses in small cage aquaculture systems, highlighting how labour-intensive practices can strain limited farm resources (Meliko et al., 2021). In the Malaysian context, rising production costs such as feed, land, and hatchery expenses disproportionately affect small and medium producers, reducing profitability and constraining farm investment capacity (Obi et al., 2025), Consequently, many farmers tend to operate their farms independently without employing additional workers.

These structural realities have direct implications for broodstock selection and hatchery performance. The persistent gap between domestic fish fry production and national demand can be partly attributed to these economic and operational limitations. The study helps explain the persistent gap between fish fry production capacity and national demand, pointing to structural constraints as key limiting factors. To strengthen broodstock selection processes, interventions should be tailored to the specific needs and capacities of farms. For example, adopting a tiered approach to broodstock management guidelines which is adjusted for farm size and workforce availability. These types of tiered guidelines could improve applicability and effectiveness in selecting the broodstocks. Extension programmes should focus on practical, simplified assessment methods that are feasible for small-scale operators, complemented by the provision of basic assessment tools and targeted training. At the farm level, even modest improvements in human resource capacity can enhance broodstock selection practices, while cooperative labour arrangements or community-based hatchery initiatives may help small farms overcome workforce limitations. Furthermore, the introduction of simple, non-invasive, and affordable assessment technologies aligned with farmers' existing selection criteria could facilitate more systematic and reliable broodstock evaluation.

Future research should explore the causal relationship between broodstock selection practices and fish fry quality, as well as farmers' acceptance and use of assessment tools. Such studies would provide critical evidence to inform the design of effective policies and interventions, ultimately supporting more productive, efficient, and sustainable aquaculture practices in Malaysia. By addressing both structural and technical constraints, these efforts have the

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potential to enhance hatchery efficiency, increase fish fry output, and contribute to the long-term growth and sustainability of the nation's aquaculture sector.

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