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Technology and Policy Strategies for Enhancing Freshwater Fish Seed Production Capacity at the Regional Fish Hatchery (UPTD BBI) of Bontang City

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ABSTRACT

The production capacity of freshwater fish seeds at the Regional Fish Hatchery (UPTD BBI) of Bontang City has not met regional demand. This study aims to formulate technology and policy strategies to enhance freshwater fish seed production capacity. This study uses primary and secondary data to provide a comprehensive overview of freshwater fish seed production capacity at the Bontang City BBI Technical Implementation Unit. The research sample was selected using purposive sampling, comprising 30 internal respondents BBI and 7 relevant academic experts. A mixed-methods approach was applied, including SWOT analysis, IFE–EFE and IE matrices, and the Analytical Hierarchy Process (AHP). Results indicate that actual production of 173,840 seeds per year satisfies only approximately 14.5% of regional demand (±1,200,000 seeds/year), resulting in an 85.5% supply deficit. IFE (±2.40) and EFE (±2.00) scores place the organization in IE Quadrant V (*hold and maintain*). AHP results identify technology and production systems as the top priority (weight 0.30), followed by human resources and infrastructure (each 0.20). The integrated SWOT–AHP analysis prioritizes the WO strategy (global weight 0.38). Strengthening production systems, improving human resource capacity, and gradually upgrading infrastructure are recommended to increase seed production capacity and support regional food security.

INTRODUCTION

Regional food security is determined not only by the availability of food for consumption, but also by the sustainability of upstream production systems, including the availability of high-quality and sustainable freshwater fish fry. In aquaculture systems, fry are a key factor determining the survival rate, production efficiency, and productivity of fish for consumption (Boyd & Tucker, 2019; FAO, 2020). Increasing fish consumption and population growth are driving the demand for freshwater fish fry in various regions, making hatchery capacity a strategic issue in supporting aquaculture-based food security.

Bontang City is one of the regions with the highest fish consumption rates in East Kalimantan Province. Data from the Central Statistics Agency (BPS, 2024) shows that fish consumption among Bontang residents reaches more than 60 kg per capita per year, with a significant proportion of freshwater fish consumption. However, meeting the demand for freshwater fish and its seeds remains highly dependent on supplies from outside the region, such as East Kutai and Berau Regencies, as well as Kutai Kartanegara Regency. This dependence indicates weak local production capacity and has the potential to increase the vulnerability of the regional food system to distribution disruptions and price fluctuations.

The Bontang City Fish Seed Center Technical Implementation Unit (UPTD BBI) is the only local government-owned freshwater fish hatchery unit responsible for providing seeds to local farmers. However, the UPTD BBI's actual production capacity still falls short of regional needs. Based on UPTD BBI performance data, freshwater fish seed production in 2025 will only reach approximately 173,400 per year, while seed demand in 2027 is projected to reach approximately 1.2 million per year. This situation indicates a seed supply deficit of approximately 85.5%, which has the potential to hamper aquaculture development and weaken regional food security.

The low production capacity of freshwater fish fry is not only caused by limited facilities and infrastructure, but also by the low adoption rate of modern hatchery technology, limited human resource (HR) competency, and suboptimal institutional policy support (Martins et al., 2010; Badiola et al., 2012; KKP, 2020). Several previous studies have shown that the application of technologies such as recirculating aquaculture systems (RAS) and Internet of Things (IoT)-based water quality monitoring systems can increase production efficiency and reduce fry mortality rates (Chang et al., 2015; De Graaf & Janssen, 2019). However, the implementation of these technologies in public hatchery units at the regional level still faces obstacles in infrastructure, financing, and human resource capacity.

On the other hand, most studies related to seed production unit development still focus only on technical or financial aspects, without integrating the technological, institutional, and policy dimensions into a coherent strategic framework (Bula et al., 2019; Putri et al., 2022; Dewanti et al., 2020; Timsina et al., 2023). However, strengthening seed production capacity requires a techno-policy approach that can bridge technical needs in the field with regional development policy directions.

Based on these problems, this study aims to formulate technological and policy strategies to increase the production capacity of freshwater fish seeds at the Bontang City Fish Seed Center Technical Implementation Unit (UPTD). The approach used integrates Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and the Analytical Hierarchy Process (AHP) with validation through Focus Group Discussions (FGD). The resulting strategy is expected to be measurable, contextual, and applicable, and can serve as a basis for formulating regional policies to support freshwater fish seed independence and sustainable food security.

METHOD

Research Design and Approach

This study used a mixed methods approach, a combination of qualitative and quantitative methods, to gain a comprehensive understanding of the freshwater fish seed production capacity at the Bontang City Fish Seed Center (BBI) Technical Implementation Unit (UPTD). This approach was chosen because it integrates analysis of existing technical conditions with the formulation of data-driven policy strategies and stakeholder preferences (Creswell, 2014).

Strategic analysis was conducted using the Strengths, Weaknesses, Opportunities, and Threats (SWOT) approach to identify internal and external factors affecting seed production capacity. Furthermore, the Analytical Hierarchy Process (AHP) was used to quantitatively prioritize strategies based on the relative importance of each factor and strategic alternative (Saaty, 2008; Gurel & Tat, 2017).

Location and Time of Research

The research was conducted at the Bontang City Fish Seed Center (BBI) Technical Implementation Unit (UPTD), East Kalimantan Province, which is the only local government-owned freshwater fish hatchery in the city. This location was selected purposively due to its strategic role in providing freshwater fish seeds for local farmers and supporting regional food security. The research was conducted from September 2025 to February 2026, encompassing data collection, analysis, and strategy formulation.

Data Types and Sources

This study used primary and secondary data. Primary data were obtained through direct observation of hatchery facilities, in-depth interviews with managers and technicians of the BBI Technical Implementation Unit (UPTD BBI), and questionnaires completed by relevant stakeholders. Furthermore, focus group discussions (FGDs) were conducted involving representatives from the Department of Food Security, Fisheries and Agriculture of Bontang City, UPTD BBI management, academics and researchers in aquaculture, as well as fisheries practitioners and hatchery business actors, to obtain agreement and validate the weighting of criteria and alternative strategies in the AHP analysis. Secondary data included UPTD BBI performance reports, seed production data, regional planning and policy documents, as well as scientific publications and institutional reports related to aquaculture and food security.

Data collection technique

Data collection techniques in this study included field observations to identify the condition of facilities and infrastructure and the level of utilization of production facilities, semi-structured interviews with key informants to explore technical and institutional issues, and the distribution of a SWOT questionnaire to identify internal and external factors affecting seed production capacity. The research sample was determined using purposive sampling, involving a minimum of 30 respondents for the SWOT analysis (hatchery technicians, production staff, and partner farmers) and 5–7 experts for the AHP analysis, consisting of the Head of UPTD, fisheries academics, officials from the Department of Food Security, Fisheries and Agriculture (DKP3), and hatchery practitioners. Furthermore, Focus Group Discussions (FGDs) were conducted to agree on the weighting of criteria and alternative strategies in the Analytical Hierarchy Process (AHP) analysis. The use of various data collection techniques aims to increase the validity and reliability of data through triangulation of sources and methods (Creswell, 2014).

Data Analysis Techniques

Data analysis was conducted in several stages. First, a SWOT analysis was used to identify and classify strengths, weaknesses, opportunities, and threats affecting freshwater fish seed production capacity. These factors were then compiled into Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrices to determine the strategic position of the UPTD BBI.

Second, the SWOT strategy formulation results (SO, WO, ST, and WT) were analyzed using the AHP method to determine strategic priorities. AHP was conducted through pairwise comparisons of criteria and strategic alternatives, with the level of assessment consistency tested using the Consistency Ratio ($CR \leq 0.1$) as recommended by Saaty (2008). The AHP results produced strategic priority weights that became the basis for policy recommendations for increasing freshwater fish seed production capacity.

RESULT AND DISCUSSION

Geographical Location and Conditions

Bontang City is geographically located at coordinates 117°23'–117°38' East Longitude and 0°01'–0°12' North Latitude, with a coastline of approximately 24.4 km directly facing the Makassar Strait as part of the Indonesian Archipelago Sea Lane (ALKI) II. Administratively, Bontang City has an area of 497.57 km^2 dominated by waters covering 347.77 km^2 (69.9%), while the land area only reaches 149.80 km^2 (29.7%) (BPS Bontang City, 2022). Bontang City is divided into three sub-districts: South Bontang, North Bontang, and West Bontang, with a total of 15 villages. The region's predominantly water and coastal characteristics demonstrate significant potential for developing the fisheries sector, both in capture fisheries and aquaculture. This situation aligns with the FAO (2020) perspective, which states that coastal areas dominated by water play a strategic role in supporting fisheries production systems and food security based on aquatic resources.

Bontang City's administrative boundaries include Teluk Pandan District, East Kutai Regency, to the west and north, the Makassar Strait to the east, and Marangkayu District, Kutai Kartanegara Regency, to the south. These geographic and administrative conditions reinforce

Bontang City's position as a coastal region with a close relationship between land and water activities.

Table 1. Number of Sub-districts and Land Area per District in Bontang City

No	Subdistrict	Number of Sub-districts	Land Area (km^2)	Percentage (%)
1	South Bontang	6	111.59	68.94
2	North Bontang	6	32.33	19.97
3	West Bontang	3	17.94	11.08

Source: Bontang in Figures BPS, 2022

Freshwater Fish Farming Production in East Kalimantan Province

Freshwater fish farming is a strategic subsector supporting food security and the regional economy in East Kalimantan Province. The performance of this subsector is influenced by the availability of water and land resources, the quality of production inputs (seed and feed), infrastructure support, and institutional and human resource capacity. Production data for 2023 shows that freshwater fish production distribution across regencies/cities in East Kalimantan remains uneven. The highest production was recorded in Kutai Kartanegara Regency (6,210 tons) and East Kutai Regency (5,940 tons), while the lowest production was in Mahakam Ulu Regency (750 tons). Total provincial freshwater fish production reached 23,650 tons, with the main contributions coming from tilapia, catfish, patin, and gourami (BPS, 2023).

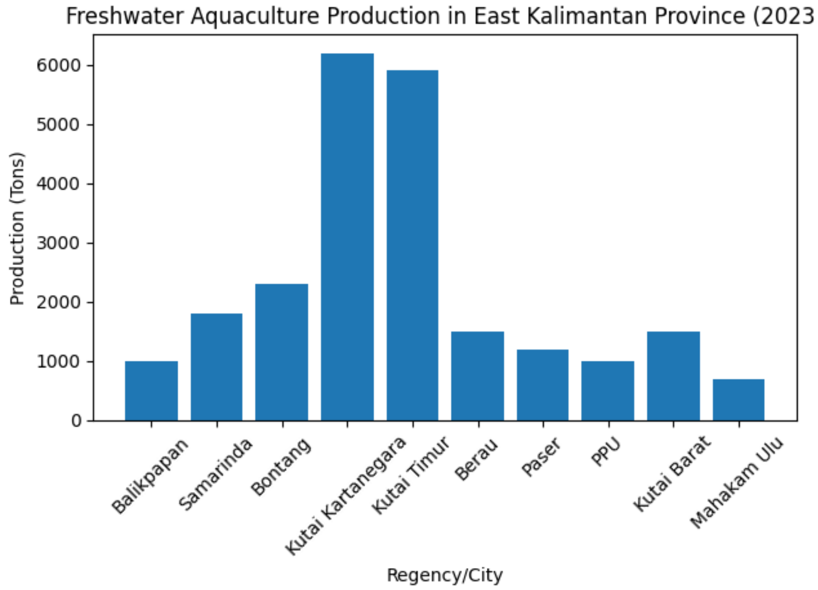

Figure 1. Graph of Aquaculture Production in East Kalimantan
Source: BPS (2023) reprocessed

In the context of increasing demand for fish consumption in East Kalimantan, strengthening hatchery systems is a key factor in the sustainability of freshwater aquaculture. The FAO (2020) emphasized that a robust and integrated hatchery system is a key prerequisite for sustainable aquaculture development. Therefore, the Bontang City Fish Seed Center (BBI) is strategically positioned as a regional seed supply hub, a center for seed technology transfer, and an instrument for improving the quality of production inputs through the implementation of quality and biosecurity standards.

Gap in Freshwater Fish Seed Production Capacity

The analysis shows that the freshwater fish seed production capacity at the Bontang City Fish Seed Center (BBI) is very low compared to the region's actual needs. Existing seed production is recorded at approximately 173,840 per year, while the demand for freshwater fish seeds in 2027 is projected to reach approximately 1.2 million per year. Therefore, local production capacity is only able to meet approximately 14.5% of total demand, resulting in a supply deficit of approximately 85.5%.

Table 2. Gaps in Production and Demand for Freshwater Fish Seeds in Bontang City

Parameter	Mark
Actual production of UPTD BBI (head/year)	173,840
Regional seed requirements (heads/year)	1,200,000
Fulfillment rate (%)	14.5
Supply deficit (%)	85.5

Source: Data from the Bontang City BBI UPTD (processed)

This significant deficit indicates that the problem of seed production capacity is not marginal, but structural in nature. In the context of regional food security, this condition directly increases dependence on external seed supply, raises production costs for farmers, and weakens the competitiveness of local aquaculture systems. The FAO (2020) emphasizes that seed independence is a key prerequisite for sustainable aquaculture, particularly in regions with high fish consumption.

From a policy perspective, these findings imply the need for a more targeted regional development strategy that prioritizes strengthening local hatchery systems as part of food security and economic diversification agendas. This includes increasing public investment through regional budgets (APBD) for hatchery infrastructure modernization, facilitating access to financing schemes or public–private partnerships, and reforming institutional arrangements to enhance the operational flexibility of UPTD BBI. In addition, policy support in the form of technical training programs, innovation adoption incentives, and integrated supply chain planning is essential to ensure that improvements in seed production capacity can be sustained and effectively contribute to regional economic resilience.

SWOT Analysis through IFE and EFE Matrix

Internal factor analysis of the Bontang City Fish Seed Center (BBI) UPTD was conducted using the Internal Factor Evaluation (IFE) Matrix to systematically assess the organization's strengths and weaknesses. Each internal strategic factor was weighted based on its importance and rated based on the actual condition of BBI. The results of the IFE Matrix calculation are presented in Table 3.

Table 3. Results of the IFE Matrix calculation of the Bontang City Fish Seed Center UPTD

No	Internal Strategic Factors	Weight	Rating	Weighted Score
Strengths				
S1	The seeding facilities and infrastructure are relatively complete	0.047	3	0.141
S2	Strategic location and easy to access	0.035	3	0.106
S3	Seeds adaptive to local conditions	0.047	4	0.188
S4	Availability of certified broodstock	0.047	3	0.141
S5	CPIB certification of the entire production process	0.059	4	0.235
S6	Technical guidance and regular training	0.035	3	0.106
S7	Active water quality testing laboratory	0.035	3	0.106
S8	CPIB compliant biosecurity system	0.047	3	0.141
S9	Multi-commodity production (catfish, tilapia, gourami)	0.035	3	0.106
S10	High market confidence (repeat orders)	0.047	4	0.188
	Subtotal Strength	0.434		1.45

No	Internal Strategic Factors	Weight	Rating	Weighted Score
Weaknesses				
W1	Seeding infrastructure has not been optimally retrofitted	0.059	1	0.059
W2	Operational costs and limited electrical power	0.059	1	0.059
W3	Limitations and inequalities in human resource competencies	0.059	1	0.059
W4	No automatic monitoring system is available yet	0.047	2	0.094
W5	Limited capacity of parent and nursery tanks	0.059	1	0.059
W6	Production documentation is not yet digitally integrated	0.035	2	0.071
W7	Research and university collaboration is not yet optimal	0.047	2	0.094
W8	The survival rate of certain commodities is still low	0.059	1	0.059
Subtotal Weaknesses		0.424		0.55
Total IFE Score	1,000			±2.40

Source: IFE Analysis (processed)

The total IFE Matrix score of ±2.40 indicates that the internal conditions of the Bontang City Fish Seed Center UPTD are in the moderate category. Similar studies in shrimp aquaculture reported an IFE score of 2.658, indicating a relatively strong internal condition that still requires improvement in technical and environmental aspects (Purwanto et al., 2023). Internal strengths are relatively able to offset weaknesses, particularly in CPIB certification, locally adapted seed quality, and market confidence. However, limited hatchery facilities, technical human resources, and low adoption of modern technology remain major obstacles requiring a structured internal strengthening strategy. External factor analysis of the Bontang City Fish Seed Center (BBI) UPTD was conducted using the External Factor Evaluation (EFE) Matrix to assess the organization's ability to respond to opportunities and anticipate external environmental threats. Each external strategic factor was weighted based on its relative importance to the organization's success and a rating that reflects the quality of BBI's response to that factor. A weighted score was obtained from the multiplication of the weight and rating, which was then used to determine the organization's external strategic position. The EFE Matrix was compiled based on David's (2017) strategic management framework.

Table 4. External Factor Evaluation (EFE) Matrix of the Bontang City Fish Seed Center UPTD

No	External Strategic Factors	Weight	Rating	Weighted Score
Opportunities				
O1	Regional authority after Law No. 23/2014	0.047	3	0.141
O2	Reputation for quality seeds opens up inter-regional markets	0.059	2	0.118
O3	PAD potential from seeds, training, and certification	0.059	2	0.118
O4	BBI as a center for education and learning of cultivation	0.047	4	0.188

No	External Strategic Factors	Weight	Rating	Weighted Score
O5	Seed quality standardization opportunities (CPIB)	0.035	3	0.106
Subtotal Opportunities		0.247		1.09
Threats				
T1	Dependence on APBD	0.059	1	0.059
T2	Fluctuations in feed prices and production inputs	0.047	2	0.094
T3	Risk of disease and parasites in the larval phase	0.059	2	0.118
T4	Climate change and water temperature variability	0.047	2	0.094
T5	The entry of seeds from outside the region at cheaper prices	0.047	2	0.094
Threat Subtotal		0.259		0.91
Total EFE Score	1,000			±2.00

Source: EFE Analysis (processed)

The results of the strategic position mapping of the UPTD Fish Seed Center (BBI) of Bontang City in the IE Matrix are presented in Table 5 below.

Table 5 Strategic Positions in the IE Matrix

Matrix	Mark	Position
IFE	2.40	Internal – Medium
EFE	2.00	External – Medium
IE Matrix Position	Cell V (Hold & Maintain)	Consolidation & Capacity Building Strategy

Source: IFE–EFE analysis (processed)

The hold and maintain position indicate that the UPTD BBI is not in a state of institutional crisis, but is experiencing stagnant production performance. In this context, the relevant strategy is not aggressive expansion, but rather strengthening core capacity through increased operational efficiency and modernization of production technology (David & David, 2017). This finding indicates that well-targeted policy interventions have the potential to generate significant increases in production capacity without requiring massive institutional investments.

SWOT-Based Techno-Policy Strategy Formulation

Based on the SWOT matrix, four main strategy groups were formulated (SO, WO, ST, and WT). However, the analysis showed that the Weakness–Opportunity (WO) strategy was the most relevant to the existing conditions of the Bontang City BBI UPTD.

Table 6. Techno-Policy Strategy Formulation

Strategy	**Main Focus**
SO	Optimizing institutional roles to meet seed demand
WO	Modernization of seed technology and increasing human resource capacity
ST	Strengthening biosecurity and mitigating production risks
WT	Cost efficiency and operational risk control

Source: SWOT analysis (processed)

The dominance of WO strategies indicates that external opportunities in the form of policy support and increasing seed demand can only be exploited if internal weaknesses, particularly in technology and human resources, can be addressed. This finding aligns with

Gürel and Tat (2017), who stated that public organizations with significant external opportunities should prioritize internal transformation strategies. Opportunities such as policy support, subsidies, and increasing seed demand do not necessarily improve performance if internal weaknesses, particularly in production technology and human resource quality, remain unaddressed (Harlianingtyas et al., 2024; Kurniawati et al., 2025).

Strategic Priorities Based on AHP Analysis

The determination of development strategy priorities for the Bontang City Fish Seed Center (BBI) UPTD was carried out using the Analytical Hierarchy Process (AHP) method to support objective and measurable multi-criteria decision-making. The main criteria analyzed include: (1) Technology and Production Systems, (2) Human Resources (HR), (3) Facilities and Infrastructure, (4) Financing and Operations, and (5) Policies and Institutions. The assessment was carried out through pairwise comparisons between criteria to obtain priority weights and ensure consistency of assessment (Saaty, 2008).

Table 7. Pairwise Comparison Matrix of Criteria (AHP)

Criteria	Technology & Production Systems	HR	infrastructure	Financing & Operations	Policies & Institutions
Technology & Production Systems	1.00	1.50	1.50	2.00	2.00
HR	0.67	1.00	1.00	1.33	1.33
Facilities and infrastructure	0.67	1.00	1.00	1.33	1.33
Financing & Operations	0.50	0.75	0.75	1.00	1.00
Policies & Institutions	0.50	0.75	0.75	1.00	1.00

Source: AHP analysis (processed)

The analysis results show that the Technology and Production Systems criteria have the highest level of importance compared to other criteria. This confirms that increasing the capacity and performance of BBI is largely determined by the effectiveness of the production system, the implementation of seeding technology, water quality management, biosecurity, and production monitoring systems. This finding aligns with Saaty (2008) and Badiola et al. (2012) who position the production system as the core driver in aquaculture-based technical units.

Table 8. Priority Weighting of BBI Development Criteria

No	Criteria	Priority Weight	Ranking
1	Technology & Production Systems	0.30	1
2	Human Resources (HR)	0.20	2–3
3	Facilities and infrastructure	0.20	2–3
4	Financing & Operations	0.15	4–5
5	Policies & Institutions	0.15	4–5
	Total	1.00	

Source: AHP analysis (processed)

The Human Resources and Facilities and Infrastructure criteria occupy medium priority with balanced weighting, indicating that improving the competency of technical personnel must go hand in hand with the availability of adequate production facilities. Meanwhile, Financing and Operations, as well as Policies and Institutions, serve as enabling factors that ensure the sustainability of the technical strategy implementation, including the direction of BBI's transformation towards a Regional Public Service Agency (BLUD) management model to increase management flexibility and efficiency (Mahmudi, 2019; OECD, 2020; Fatihawati & Handajani, 2022; Tito et al., 2023).

Alternative Priorities for BBI Development Strategy

Based on the weighted criteria obtained, an assessment of the alternative strategies resulting from the SWOT analysis is conducted, namely the SO, WO, ST, and WT strategies. This assessment produces a global weight that reflects the priority level of each strategy in the development of the Bontang City BBI.

Table 9 Alternative Strategy Priority Weights (AHP–SWOT)

Code	Strategy Group	Global Weight	Ranking
WO	Reducing internal weaknesses by exploiting external opportunities	0.38	1
SO	Maximizing internal strengths to capture opportunities	0.32	2
ST	Using force to minimize threats	0.18	3
WT	Defensive strategies minimize weaknesses and threats	0.12	4
	Total	1.00	

Source: AHP analysis (processed)

The AHP results indicate that the WO (Weakness–Opportunity) strategy is the top priority strategy in the development of the Bontang City UPTD BBI. The dominance of the WO strategy indicates that the current condition of BBI requires more internal strengthening, especially in seeding facilities, technical human resources, and production systems, by leveraging external opportunities such as increased seed demand, the role of education, partnerships, and policy support. This finding aligns with the recommended strategic turnaround approach for public sector organizations with suboptimal internal capacity (David & David, 2017; FAO, 2020).

The SO strategy is ranked second, reflecting that BBI has significant capital strength, but is not yet ready to immediately undertake aggressive expansion without addressing internal structural constraints. However, this position is not yet entirely ideal for aggressive expansion. This is due to the persistence of internal structural constraints, such as technological limitations, suboptimal production efficiency, and uneven human resource capacity (Ulubaeva et al., 2025; Obydiennova & Chernous, 2025). ST and WT strategies serve as buffer and defensive strategies, implemented selectively to maintain operational stability and mitigate risks.

Overall, the AHP analysis confirms that the development of the Bontang City Fish Seed Center (UPTD) should prioritize the WO strategy, as it directly addresses the causal gap between internal weaknesses such as limited technology, low production efficiency, and inadequate human resource capacity and external opportunities, including rising seed demand, institutional support, and partnership potential. By aligning these opportunities to systematically reduce internal constraints, this strategy enables a more effective pathway for capacity improvement. Therefore, it provides a strong analytical basis for formulating targeted policies and action programs focused on technology modernization, capacity building, and infrastructure strengthening, ensuring that BBI development proceeds in a gradual, adaptive, and sustainable manner.

CONCLUSION

The results of the study indicate that the production capacity of freshwater fish seeds at the Bontang City Fish Seed Center (BBI) is still unable to meet regional needs. Actual production of 173,840 fish per year only covers approximately ±14.5% of the regional seed requirement (±1,200,000 fish per year), resulting in a supply deficit of ±85.5%. The results of the IFE analysis (±2.40) and EFE (±2.00) place BBI in Quadrant V of the IE Matrix (hold and maintain), which indicates a fairly stable internal condition but faces significant external pressures.

The results of the Analytical Hierarchy Process (AHP) indicate that Technology and Production Systems are the top priority (weighting 0.30), followed by Human Resources and Infrastructure (each 0.20). The SWOT–AHP integration places the WO strategy as a priority strategy (weighting 0.38), so that BBI development needs to focus on strengthening production systems, increasing human resource capacity, and gradually improving infrastructure to increase seed production capacity and support regional food security.

For future research, it is recommended to incorporate quantitative modeling of production optimization and conduct sensitivity analysis to assess the robustness of strategic priorities under changing conditions. In addition, further studies should explore the feasibility and scalability of advanced technologies such as Recirculating Aquaculture Systems (RAS) and IoT-based monitoring within local constraints, as well as evaluate policy implementation effectiveness and financing mechanisms to ensure sustainable development of hatchery systems.

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