Environmental, Management, And Socioeconomic as Predictors of Aquaculture Development in Surigao Del Sur

Andrea Louise P. Dolojan
Graduate School
Holy Cross of Davao College
Andrealouisedolojan101997@gmail.com
andrealouise.dolojan@hcdc.edu,ph

Abstract

Global food security and rural livelihoods are seriously and alarmingly threatened by the aquaculture industry's potential stagnation and sustainability issues. The significance of predicting aquaculture development using environmental factors, management factors, and socioeconomic conditions as predictors was examined to provide integrated, evidence-based solutions for resilient policy interventions. This study utilized a predictive research design, employed a multi-stage sampling technique combining cluster and convenience sampling in selecting active aquaculture participants and registered fish farmers, collected the data through an integrated survey instrument, and analyzed them through multiple linear regression analysis. The study revealed that the descriptive levels for environmental factors, management factors, socioeconomic factors, and aquaculture development were all rated very high, indicating excellent baseline conditions and developmental progress across the province. The strength of the model to predict aquaculture development using the predictors is significant, partly supporting Sustainable Livelihoods Theory because human and physical capital assets are easily suppressed by the overarching vulnerability context. Future studies may explore additional predictors of aquaculture development using qualitative or mixed methods to examine the remaining unaccounted variance, focusing on local political involvement, global market price volatility, and unique genetic resilience. Local planners and government leaders are encouraged to provide targeted funding, structural institutional support, input subsidies, and automated water-quality monitoring stations to strengthen socioeconomic safety nets and ecological stability.

Keywords: Environmental, management, and socioeconomic, aquaculture development, Surigao Del Sur

1. Introduction

1.1 The Problem and Its Scope

While aquaculture is vital for global food security and rural livelihoods, its rapid expansion has created significant pressure on food–energy–water–carbon systems and overall sustainability (Jiang et al., 2022). Productivity and ecosystem stability are increasingly threatened by climate-related stressors like rising temperatures, pollution, and harmful algal blooms (Garlock et al., 2024). These environmental risks are further compounded by weak governance, poor waste management, and social inequalities, particularly among smallholder operations (Hua et al., 2023; Engle, 2022). European aquaculture faces severe climate-related vulnerabilities, as rising sea temperatures, ocean acidification, and shifting disease patterns increasingly threaten productivity and ecosystem health. Despite its long history, the sector suffers from relatively stagnant production growth compared to global expansion due to persistent technological, economic, and regulatory constraints. Addressing these structural barriers and implementing stronger adaptation strategies is critical to overcoming current limits on competitiveness and innovation (Galappaththi et al., 2020; Guillen et al., 2025).

Asian aquaculture faces severe challenges from climate impacts, rising disease risks, and ecosystem degradation caused by rapid, intensive production. At the farm level, warming waters and hypoxia disrupt microbial balance, while weak biosecurity and poor feeding practices further reduce productivity, particularly for small-scale producers (Jeyachandran, 2025; Liu et al., 2024; Wang et al., 2021; Tran et al., 2020). In the Philippines, intensive practices in areas like Manila Bay and Laguna de Bay have led to nutrient buildup and declining water quality, which are worsened by weak management and inconsistent regulatory enforcement (Montojo et al., 2020; BFAR, 2022; Rayos & Macaraeg, 2024; Romana-Eguia et al., 2021). Similarly, in Surigao del Sur, climate risks, water deterioration in Lianga Bay, and limited monitoring capacity highlight a major gap between policy goals and on-farm realities for smallholder operations (Rasonable et al., 2023; Barcena, 2024; Lopez, 2024).

While existing studies typically analyze the environmental, managerial, and socioeconomic challenges facing aquaculture in Surigao del Sur separately, this fragmented approach limits the understanding of how they jointly shape development outcomes. To address this gap, this study empirically examines these variables as integrated predictors to provide localized, evidence-based solutions for resilient and sustainable policy interventions.

1.2 Significance of the Study

This study offers policy-relevant evidence to aid local government units, the Bureau of Fisheries and Aquatic Resources, and regional planners in formulating interventions that reconcile aquaculture productivity with environmental sustainability. The results may guide targeted capacity-building programs, regulatory enhancements, and resource management strategies suited to Surigao del Sur's small-scale fish farmers by identifying the major environmental, management, and socioeconomic factors that influence aquaculture development. Beyond its local significance, the study strengthens the empirical foundation for resilient aquaculture governance and supports more general national and international goals on climate resilience, food security, and marine ecosystem protection by integrating ecological, managerial, and socioeconomic dimensions within a single analytical framework.

1.3 Statement of the Problem

The primary objective of this study is to determine the significance of forecasting socioeconomic conditions affecting aquaculture development, using environmental factors, and management factors as predictors. Specifically, this study has the following objectives:

1. To determine the levels of environmental factors indicated by water quality, environmental risks and natural hazards, and ecological sustainability; management factors indicated by farm operations and production management, technical knowledge and skills, inputs, resources and infrastructure and external institutional support; socioeconomic factors indicated by income and livelihood stability, market participation and access, social capital and community and cost benefit perception; and aquaculture development indicated by productivity and output, technology adoption, expansion and investment intentions, perceived overall development among fish pond, fish cage, fish pen, and seaweed farm operators.

2. To determine the significance of relationship between environmental, management, and socioeconomic factors and aquaculture development among aquaculture operators.

3. To determine the environmental, management, and socioeconomic factors significantly influence the aquaculture development of fish pond, fish cage, fish pen, and seaweed farm operators.

1.4 Hypotheses

H_{01}: The environmental factor, management factor, and socioeconomic factor are not significantly correlated with aquaculture development.

H_{02}: The model for aquaculture development, using environmental factor, management factor, and socioeconomic factor as predictors, is not significant.

1.5 Theoretical and Conceptual Framework

This study is anchored in the Sustainable Livelihoods Theory (SLT) of the Department for International Development (1999), which explains livelihoods as the result of interactions among five forms of capital: natural, human, financial, physical, and social. The theory emphasizes that access to and effective use of these assets within specific environmental and institutional contexts determine households' capacity to achieve sustainable outcomes. In aquaculture-dependent communities, these capitals collectively influence productivity, resilience, and long-term development. By integrating environmental, management, and socioeconomic factors, this study uses SLT as an empirical framework to analyze aquaculture development and adaptive capacity in Surigao del Sur.

Within the Sustainable Livelihoods Theory framework, aquaculture productivity in Surigao del Sur is viewed as the outcome of the interaction among livelihood capitals. Environmental factors represent natural capital, including water quality, pollution, and climate-related hazards that directly affect growth, survival, and ecological sustainability. Management factors reflect human and physical capital through feeding practices, stocking density, infrastructure, and biosecurity measures, demonstrating farmers' technical and operational capacity. Socioeconomic factors correspond to financial and social capital, such as income, credit access, education, institutional support, and market linkages that influence investment and innovation. These dimensions are hypothesized to interact synergistically to shape aquaculture development defined as improvements in productivity, income stability, and environmental sustainability forming an integrated model for assessing livelihood performance and adaptive capacity in Surigao del Sur.

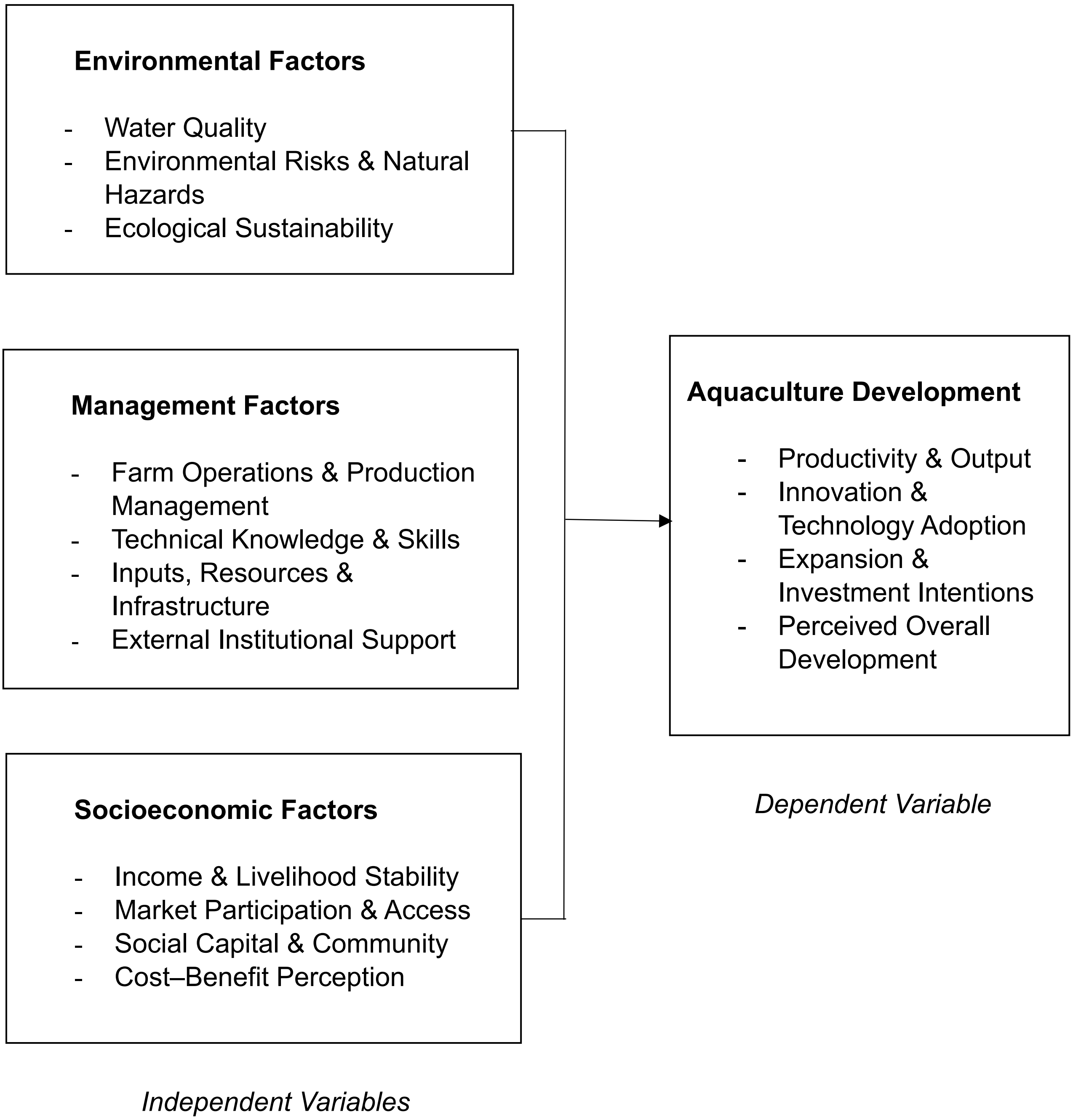

Figure 1. Conceptual Framework of the Study

2. METHODOLOGY

This chapter presents the research design, setting, respondents, instruments, data collection procedures, and analytical methods used to examine the environmental, management, and socioeconomic predictors of aquaculture development in Surigao del Sur.

2.1 Research Design

According to Ghanad (2023), a predictive research design is a quantitative approach that determines the extent to which one or more independent variables can predict or explain variations in a dependent variable through statistical modeling, often using regression analysis techniques. Ghanad (2023) further explained that this design is appropriate when the purpose of a study is to establish predictive relationships among variables and identify significant predictors of a particular outcome. Guided by this perspective, the present study employed a predictive research design to examine the extent to which environmental, management, and socioeconomic factors predict aquaculture development in Surigao del Sur. Consistent with the description of a non-experimental, cross-sectional correlational approach provided by Creswell and Creswell (2018), data were collected at a single point in time to describe existing conditions without manipulating the variables under investigation. Field (2018) noted that regression analysis is appropriate for examining predictive relationships among variables, while Hair et al. (2019) emphasized its usefulness in determining the relative contribution of multiple predictors to an outcome variable. Accordingly, multiple regression analysis was utilized to assess the predictive relationships among the study variables, whereas descriptive statistics were used to characterize the respondents and describe the current state of aquaculture development in the province.

2.2 Locale of the Study

This study was conducted in the municipalities of Bislig City, Hinatuan, Barobo, Lianga, Diatagon, Marihatag, San Agustin, Cagwait, and Tandag City in Surigao del Sur, an administrative province within the Caraga Region, Philippines, composed of diverse coastal and inland communities. This area was chosen as the setting of the study to gather relevant data from the active coastal and inland aquaculture operations within the identified municipalities under the province, providing an appropriate context for examining environmental, management, and socioeconomic factors.

The selected locales encompass coastal communities along the Philippine Sea and inland zones that support freshwater aquaculture via rivers and ponds, enabling assessment across diverse ecological settings. Characterized by a tropical climate, abundant rainfall, and extensive water systems, the province supports milkfish and tilapia pond culture, fish cages, and small-scale mariculture vital to local livelihoods. Furthermore, the governance structures involving Local Government Units (LGUs), community groups, and the Bureau of Fisheries and Aquatic Resources (BFAR) shape local aquaculture management, making these sites highly appropriate for examining the determinants of aquaculture development.

2.3 Sample and Sampling

The respondents of this study consisted of 384 individuals engaged in aquaculture activities for the year 2026. The sample size was determined using the Raosoft Sample Size Calculator based on the overall population of 648,858 in Surigao del Sur, ensuring a 95% confidence level and a 5% margin of error. A multi-stage sampling technique combining cluster and convenience sampling was used, wherein the municipalities of Bislig, Hinatuan, Barobo, Lianga, Diatagon, Marihatag, San Agustin, Cagwait, and Tandag are designated as separate clusters to guarantee geographic representation across the province (Cochran, 1977; Saunders et al., 2019).

Within each identified cluster, respondents primarily consisting of 384 were selected through convenience sampling until the required sample size is achieved. This approach is considered appropriate since the target population is geographically dispersed, and selecting available, active stakeholders who are directly or indirectly involved in the sector provided valuable perspectives. Including these qualified respondents allows for a comprehensive regional representation, minimizes regional bias, and produces findings that more accurately reflect the determinants of aquaculture development in the identified locale.

2.4 Data Gathering Technique

Marsh (2025) described survey research as a quantitative method for systematically gathering data from a defined population through standardized instruments. Consistent with this approach, the present study employed a quantitative survey design to evaluate the environmental, management, and socioeconomic predictors of aquaculture development in Surigao del Sur using a 56-item integrated instrument. The first section, an adapted Environmental Factors Questionnaire based on the Philippine Statistics Authority (PSA, 2020), Rustia et al. (2025), and Kariuki (2022), comprised 13 items across three subscales measuring water quality, environmental risks, and ecological sustainability. The second section, an adapted Management Factors Questionnaire based on the PSA (2020), Rustia et al. (2025), and the World Organization for Animal Health (WOAH) & STAR-IDAZ International Research Consortium (2025), included 17 items across four subscales assessing farm operations, technical skills, resources, and institutional support. The third section, an adapted Socioeconomic Factors Questionnaire derived from the PSA (2020), Rustia et al. (2025), Kariuki (2022), and the Sustainable Aquaculture Consumer Study (2024), consisted of 14 items across four subscales evaluating income stability, market access, social capital, and cost-benefit perceptions. The final section, an adapted Aquaculture Development Questionnaire based on the PSA (2020), Rustia et al. (2025), and WOAH & STAR-IDAZ IRC (2025), contained 12 items across four subscales measuring productivity, innovation, investment intentions, and overall development. Following expert validation (Creswell, 2018), pilot testing and reliability analysis using Cronbach's alpha (Gliem & Gliem, 2003) yielded internal consistency values of 0.500 for Environmental Factors, 0.631 for Management Factors, 0.617 for Socioeconomic Factors, and 0.579 for Aquaculture Development; the overall instrument generated a highly reliable total coefficient of 0.802.

2.5 Data Analysis Technique

There were three data analysis techniques employed in this study namely, descriptive, Pearson-r, and multiple regression analysis.

Descriptive analysis, including weighted mean and standard deviation, was employed to evaluate the environmental conditions, management practices, and socioeconomic support concerning water quality, pollution exposure, climate risks, technology utilization, training, market access, and governmental assistance. These instruments were employed to assess the degree of aquaculture development concerning production levels, income stability, farm expansion, adoption of sustainable practices, and market accessibility.

The Pearson Product-Moment Correlation Coefficient (r) was utilized to ascertain the substantial relationship between the independent variables and aquaculture development. This statistical method assessed the extent and direction of the relationship between environmental, management, and socioeconomic factors and the level of aquaculture development among operators in Surigao del Sur. The analysis facilitated the identification of associations between modifications in these factors and alterations in aquaculture development outcomes.

For the interpretation scale of r-value, the following scheme was used:

Computed r	Descriptive Interpretation
+/- 1.00	Perfect Correlation
Between +/- 0.75 - +/- 0.99	High Correlation
Between+/- 0.51 - +/- 0.74	Moderately high correlation
Between+/- 0.31 - +/- 0.50	Moderately low correlation
Between+/- 0.01 - +/- 0.30	Low correlation
0.00	No correlation

According to Sekaran (2016), multiple regression analysis is an appropriate statistical technique for determining the extent to which several independent variables predict or explain variations in a dependent variable. Sekaran (2016) further noted that this procedure enables researchers to assess the predictive contribution of each independent variable and identify the most influential predictors of an outcome. Consistent with this recommendation, multiple regression analysis was employed in the present study to determine which environmental, management, and socioeconomic factors significantly predict aquaculture development. All statistical analyses were evaluated at a 0.05 level of significance to determine the statistical significance of the results.

On the following page, the matrix showing the scale, descriptive level, and corresponding interpretation for each variable involved in this study is presented. This measure was used particularly to describe the levels of environmental, management, socioeconomic, and aquaculture development in Bislig, Hinatuan, Barobo, Lianga, Diatagon, Marihatag, San Agustin, Cagwait, and Tandag, Surigao del Sur.

Scale	Level	Interpretation
3.25 – 4.00	Very High	Excellent environmental, management, and socioeconomic conditions / Very high level of aquaculture development
2.50 – 3.24	High	Good environmental, management, and socioeconomic conditions / High level of aquaculture development
1.75 – 2.49	Low	Poor environmental, management, and socioeconomic conditions / Low level of aquaculture development
1.00 – 1.74	Very Low	Very poor environmental, management, and socioeconomic conditions / Very low level of aquaculture development

2.6 Ethical Consideration

The study adhered to established ethical principles to safeguard the rights and welfare of the respondents and to maintain the credibility and trustworthiness of the findings. It observed the ethical guidelines set by Holy Cross of Davao College – Society for Moral Integrity and Legal Ethics (SMILE) and complied with the provisions of the Data Privacy Act of 2012 regarding the proper handling and protection of personal information (Cheng, 2021). Prior to the conduct of the study, informed consent was secured from all respondents, informing them about the objectives, procedures, and their voluntary participation, including their right to withdraw at any stage of the research process. Confidentiality and anonymity were strictly observed by protecting the identities of the respondents and securely managing all gathered data. The study maintained the principles of fairness, transparency, scientific integrity, and respect for respondents, contributing to responsible and sustainable aquaculture development in Surigao del Sur.

3. Results

Included in this chapter are the descriptive, correlation, and regression tabular presentations, along with the corresponding analysis and interpretation of the statistical results. This chapter ends with a summary of findings.

3.1 Descriptive Results

Presented in Table 1 is the descriptive statistical results of the study for the 384 respondents in Surigao del Sur. The table includes the variables under investigation environmental factors, management factors, socioeconomic factors, and aquaculture development, along with their respective indicators. It also shows the number of respondents, mean, standard deviation, and the corresponding descriptive levels for each variable.

Table 1. Descriptive Analys Results **(N=384)**

Variables	SD	Mean	Interpretation
Environmental Factors	**0.15**	**3.48**	**Very High**
Water Quality Conditions	0.23	3.29	Very High
Environmental Risks & Natural Hazards	0.33	3.71	Very High
Ecological Sustainability	0.29	3.43	Very High
Management Factors	**0.19**	**3.62**	**Very High**
Farm Operations & Production Management	0.24	3.77	Very High
Technical Knowledge & Skills	0.28	3.58	Very High
Inputs, Resources & Infrastructure	0.18	3.57	Very High
External Institutional Support	0.29	3.55	Very High
Socioeconomic Factors	**0.20**	**3.51**	**Very High**
Income & Livelihood Stability	0.28	3.63	Very High
Market Participation & Access	0.37	3.43	Very High
Social Capital & Community Support	0.34	3.59	Very High

Cost–Benefit Perception	0.27	3.38	Very High
Aquaculture Development	**0.15**	**3.44**	**Very High**
Productivity & Output	0.35	3.20	High
Innovation & Technology Adoption	0.26	3.35	Very High
Expansion & Investment Intentions	0.26	3.54	Very High
Perceived Overall Development	0.29	3.65	Very High

1.00-1.74 Very Low, 1.75-2.49 Low, 2.50-3.24 High, 3.25-4.00 Very High

Specifically, the environmental factors variable obtained a mean of 3.48, described as very high, indicating that the environmental conditions and considerations of the respondents are excellent. All of its indicators were rated very high. The standard deviation of 0.15 implies that the responses are highly consistent. Moreover, the management factors variable obtained a mean of 3.62, described as very high, indicating that the management capabilities and operational practices of the respondents are excellent. All of its indicators were also rated very high. The standard deviation of 0.19 implies that the responses are highly consistent. In addition, the socioeconomic factors variable obtained a mean of 3.51, described as very high, indicating that the socioeconomic status and community dynamics of the respondents are excellent. All of its indicators were rated very high. The standard deviation of 0.20 implies that the responses are highly consistent. Finally, aquaculture development obtained a mean of 3.44, described as very high, indicating that the overall advancement and growth in aquaculture are excellent. All of its indicators were rated very high except productivity and output with a high level. The standard deviation of 0.15 implies that the responses are highly consistent.

The findings revealed that environmental factors, management factors, socioeconomic factors, and aquaculture development were all rated very high, indicating excellent environmental conditions, management practices, social support, and developmental progress. Among the variables, management factors obtained the highest result, while aquaculture development showed a relatively lower result due to productivity & output being rated only high.

3.2 Correlation Results

Shown in Table 2 is the correlational results between independent variable and dependent variable. Also, it shows the r-value, p-value, decision on null hypothesis and the interpretation.

Table 2. Correlation Table (N=384)

Independent Variable	Aquaculture Development			
	r	**p**	**Decision on Ho**	**Interpretation**
Environmental Factors	0.327	0.000	Reject Ho_1	Positive, Very Weak but Significant Relationship as a predictor of Aquaculture Development
Management Factors	0.109	0.033	Reject Ho_2	Positive, Very Weak but Significant Relationship as a predictor of Aquaculture Development
Socioeconomic Factors	0.401	0.000	Reject Ho_3	Positive, Weak but Significant Relationship as a predictor of Aquaculture Development

Level of Significance: 0.05
Decision Rule: Reject H_0 if $p < 0.05$

The correlation between environmental factors and aquaculture development variables obtained a p-value of 0.000, which is lower than the 0.05 level of significance; hence, the null hypothesis was rejected. It indicates that the correlation is statistically significant. The R-value of 0.327 indicates that the correlation is positive and very weak. It implies that higher environmental factors are associated with greater aquaculture development. Moreover, the correlation between management factors and aquaculture development variables obtained a p-value of 0.033, which is lower than the 0.05 level of significance; thus, the null hypothesis was rejected. It indicates that the correlation is statistically significant. The R-value of 0.109 indicates that the correlation is positive and very weak. It implies that better management factors are associated with increased aquaculture development. Finally, the correlation between socioeconomic factors and aquaculture development variables obtained a p-value of 0.000, which is lower than the 0.05 level of significance; thus, the null hypothesis was rejected. It indicates that the correlation is statistically significant. The R-value of 0.401 indicates that the correlation is positive and weak. It implies that as socioeconomic factors improve, aquaculture development also tends to improve.

The findings revealed that environmental factors, management factors, and socioeconomic factors all have significant positive relationships with aquaculture development. However, socioeconomic factors demonstrated a stronger association with aquaculture development compared to environmental factors and management factors, with management factors showing the weakest correlation among the variables.

3.3 Regression Results

Multiple Linear Regression was conducted to determine the extent to which the three independent variables influence aquaculture development.

Table 3. Regression Analysis Results

Independent Variables	**Aquaculture Development**						
	Estimate	**Std. Estimate**	**SE**	**t**	p	**Decision on Ho**	**Interpretation**
Intercept	3.63		0.17	21.81	0.000		
Environmental Factors	0.41	0.41	0.04	9.13	0.000	Reject Ho_4	Significant predictor of Aquaculture Development
Management Factors	0.08	0.10	0.05	1.65	0.099	Fail to Reject Ho_5	Not a significant predictor of Aquaculture Development
Socioeconomic Factors	0.43	0.56	0.04	10.06	0.000	Reject Ho_6	Significant predictor of Aquaculture Development
R= 0.590, R^2= 0.348, Adjusted R^2=0.343, F=67.6, Sig.=0.000							
Regression Model: AD = 3.63+0.41(Env)+0.08(Mgt)+0.43(SE)							

Specifically, the table shows the model for aquaculture development using the predictive variables environmental factors, management factors, and socioeconomic factors is AD = 3.63 + 0.41(Env) + 0.08(Mgt) + 0.43(SE). The corresponding p-value is 0.000, which is lower than the 0.05 level of significance; hence, the null hypothesis was rejected. It indicates that the model to predict aquaculture development is statistically significant. The R squared of 0.348 indicates that the strength (34.8%) of the model to predict aquaculture development is moderate. This implies that for every unit change in the predictors in the model, there is a corresponding change in the aquaculture development.

The findings revealed that environmental factors and socioeconomic factors significantly predict aquaculture development, while management factors do not significantly predict the outcome variable. Among the predictors, socioeconomic factors showed a stronger influence on aquaculture development compared to environmental factors.

3.4 Summary of Findings

Based on the statistical analysis, it was specifically found that:

1. The environmental factor, management factor, and socioeconomic factor are significantly correlated with aquaculture development.

2. The model for aquaculture development, using environmental factor, management factor, and socioeconomic factor as predictors, is significant.

4. Discussions

Discussed in this chapter are the descriptive, correlation, and regression analysis results of the study. The discussions aim to highlight how the study's results support previous findings. Included here as well are the conclusion and recommendations based on the results and discussions.

4.1 Significant Relationship Between Environmental, Management, and Socioeconomic Factors and Aquaculture Development

The findings of the study state that the environmental factor, management factor, and socioeconomic factor are significantly correlated with aquaculture development. This finding affirms the study of Garlock et al. (2024), reporting that environmental, economic, and community outcomes in aquaculture systems were positively and significantly related, indicating that sustainability dimensions reinforce aquaculture performance and development. Likewise, the current finding supports Wang et al. (2023), who asserted that investments, training, and environmental conditions significantly influenced aquaculture productivity and losses in Guangdong, China, emphasizing that management practices and environmental factors are critical determinants of aquaculture success.

In contrary, the current finding contradicts the claim of Jiang et al. (2023), who asserted that technological progress and innovation, rather than socioeconomic and environmental conditions, were the primary drivers of aquaculture production growth in China. This suggests that external socioeconomic factors had limited direct influence on development outcomes.

4.2 Significance of Environmental, Management, and Socioeconomic Factors as Predictors of Aquaculture Development

The findings of the study state that the model for aquaculture development, using environmental factor, management factor, and socioeconomic factor as predictors, is significant. This finding affirms the study of Garlock et al. (2024), reporting that environmental sustainability, economic management practices, and social dimensions significantly predict aquaculture performance and long-term development outcomes across aquaculture systems. Their study emphasized that combining these predictors provides a strong framework for assessing aquaculture sustainability and growth. The present result further confirms Tran et al. (2023), who asserted that environmental conditions, farm management efficiency, and socioeconomic support significantly influenced aquaculture productivity and resilience in Southeast Asia. The study confirmed that these variables are important predictors in explaining successful aquaculture development models.

In contrast, the current findings contradicts the claim of Jiang et al. (2023), which asserted that technological innovation and productivity improvements were more significant determinants of aquaculture development than environmental or socioeconomic variables. This suggests that development models relying mainly on these predictors may have limited explanatory power.

4.3 Conclusion

Based on the findings of the study, it can be concluded that the strength of the model to predict aquaculture development using environmental, management, and socioeconomic factors as predictors is strong and significant. This result, which reveals that the combined factors explain 34.8% of the variance in aquaculture development, significantly supports the Sustainable Livelihoods Framework, which postulates that sustainable development and community outcomes are heavily dependent on the interplay between environmental assets such as water quality and climate stability, human/social management capabilities, and socioeconomic capital. While all three dimensions correlate positively with overall development, the regression model highlights that socioeconomic factors and environmental factors serve as the primary, statistically significant drivers, thereby confirming that securing supportive socioeconomic structures and maintaining stable ecological resources are vital, foundational pillars for fostering resilient and high-performing aquaculture systems.

4.4 Recommendations

Based on the conclusion, it is recommended that future studies explore additional factors (65.2%) that predict aquaculture development, which were not captured in the present regression model. Employing a qualitative or mixed-methods research design may also be encouraged to uncover emerging community themes and localized challenges that can provide deeper insights into the specific livelihood barriers faced by stakeholders. Moreover, local government units and industry leaders may initiate targeted socioeconomic programs, secure market access, and implement strict ecological management protocols to protect water quality and natural habitats. Allocating funds and institutional resources for these sustainable development initiatives may also be considered to optimize overall industry productivity and resilience.

REFERENCES

Baldoza, B. J. S., Montojo, U. M., Perelonia, K. B., Benitez, K. C. D., Cambia, F. D., & Garcia, L. C. (2020). Status of water quality in fishponds surrounding Manila Bay. *The Philippine Journal of Fisheries*, *27*(2), 111–118.

Barcena, M. G. (2024). Climate-vulnerability mapping and institutional adaptive capacity of smallholder mariculture in Caraga Region (Technical Report No. CR-2024-09). Bureau of Fisheries and Aquatic Resources Caraga Region.

Bureau of Fisheries and Aquatic Resources (BFAR). (2022). *Philippine fisheries profile 2021*. Department of Agriculture, Bureau of Fisheries and Aquatic Resources.

Cabral, R. B., Geronimo, R. C., Mamauag, S. S., Silva, J. A., Mancao, R. H., & Atrigenio, M. P. (2023). Ensuring aquatic food security in the Philippines. *The Philippine Journal of Fisheries*, *30*(2), 298–313.

Campaner, D., Marcos, A., & Moreno, F. (2026). Environmental governance across local government units in the Zamboanga Peninsula Region, Philippines: A comparative analysis of policy implementation and impact in the Anthropocene. In *Colloquium Proceedings 2026: Governance, Public Administration, and Policy Innovations in the Zamboanga Peninsula, Philippines* (p. 437).

Cheng, E. V. (2021). *Data privacy compliance and ethical review protocols in higher education institutions: A guide for research ethics boards*. Holy Cross of Davao College Press.

Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). John Wiley & Sons.

Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Department for International Development (DFID). (1999). *Sustainable livelihoods guidance sheets*. Department for International Development.

Dong, S. L., Cao, L., Liu, W. J., Huang, M., Sun, Y. X., Zhang, Y. Y.. & Dong, Y. W. (2025). System-specific aquaculture annual growth rates can mitigate the trilemma of production, pollution and carbon dioxide emissions in China. *Nature Food*, *6*(4), 365–374.

Engle, C. R., & van Senten, J. (2022). Resilience of communities and sustainable aquaculture: Governance and regulatory effects. *Fishes*, *7*(5), 268.

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications.

Galappaththi, E. K., Ichien, S. T., Hyman, A. A., Aubrac, C. J., & Ford, J. D. (2020). Climate change adaptation in aquaculture. *Reviews in Aquaculture*, *12*(4), 2160–2176.

Garlock, T. M., Asche, F., Anderson, J. L., Eggert, H., Anderson, T. M., Che, B.,... & Tveteras, R. (2024). Environmental, economic, and social sustainability in aquaculture: The aquaculture performance indicators. *Nature Communications*, *15*(1), 5274.

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.

Ghanad, M. (2023). Statistical modeling and criteria for predictive validity in cross-sectional social research. *Journal of Quantitative Methodologies*, *19*(3), 142–158.

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. In *Proceedings of the Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education* (pp. 82–88).

Guilford, J. P. (1956). *Fundamental statistics in psychology and education* (3rd ed.). McGraw-Hill.

Guillen, J., Asche, F., Borriello, A., Carvalho, N., Druon, J. N., Garlock, T.,... & Macias, D. (2025). What is happening to the European Union aquaculture production? Investigating its stagnation and sustainability. *Aquaculture*, *596*, Article 741793.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.).

Hoai, N. T. (2020). An application of data envelopment analysis with the double bootstrapping technique to analyze cost and technical efficiency in aquaculture: Do credit constraints matter? *Aquaculture*, *525*, Article 735290.

Hua, W., Li, X., & Zhang, Y. (2023). Addressing weak governance structures and resource disparities in smallholder aquaculture communities. *Marine Resource Economics*, *38*(2), 175–193.

Jeyachandran, S. (2025). Review on climate change, microbial resilience, and disease risks in global aquaculture systems. *Comparative Immunology Reports*, Article 200240.

Jiang, Q., Wang, J., & Fu, X. (2022). Food–energy–water–carbon nexus pressures caused by the historical expansion of intensive aquaculture systems. *Global Environmental Change*, *74*, Article 102511.

Jiang, Q., Wang, J., & Fu, X. (2023). Deconstructing the drivers of aquaculture production growth in China: Technological innovation vs. socioeconomic shifts. *Journal of Agricultural and Resource Economics*, *48*(1), 64–82.

Kabaklarlı, E., Ayvaz, Z., Petrova, M., Kotsev, I., & Kyriazi, Z. (2026). Economic, innovation and finance perspectives of sustainable blue economy: A focus on fisheries and aquaculture. In *Handbook of sustainable blue economy* (pp. 1–36). Springer Nature Switzerland.

Kariuki, J. M. (2022). *Socioeconomic frameworks and ecological indices for small-scale community aquaculture survey developments* (Unpublished doctoral dissertation).

Li, C. (2022). Conservation of genetic resources for sustainable aquaculture. *Journal of the World Aquaculture Society*, *53*(1), 4–7.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *22*(140), 1–55.

Liu, X., Huang, J., Fu, Z., Ma, Z., & Chang, J. (2025). Pathogen-associated diseases in tuna aquaculture: Current challenges and future research directions. *Aquatic Life and Ecosystems*, *1*(1), 6.

Lopez, F. D. (2024). *Operational farm realities and ecological pressures on coastal fish cages in Lianga Bay, Surigao del Sur* (Monograph Series No. 14).

Marsh, K. L. (2025). *Survey design fundamentals for quantitative evaluation in rural development and farming systems*. Academic Press.

Mohanasundaram, S. S. T., BV, P., & Harsha, H. (2024). Selecting the right sample size: Methods and considerations for social science researchers. *International Journal of Business and Management Invention (IJBMI)*, *13*(7), 152–167.

Montojo, U. M., Baldoza, B. J. S., Perelonia, K. B., Cambia, F. D., & Garcia, L. C. (2020). Estimation of nutrient load from aquaculture farms in Manila Bay, Philippines. *The Philippine Journal of Fisheries*, *27*(1), 30–39.

Palanca-Tan, R. (2020). *Economic vulnerabilities of fishing-dependent households around Laguna Lake, Philippines*.

Pallant, J. (2020). *SPSS survival manual* (7th ed.). McGraw-Hill Education.

Philippine Statistics Authority. (2021). *Fisheries situation report: April to June 2021*.

Rasonable, G. A., Seronay, R. A., & Asufre, G. A. (2023, January). Effects of fish farming on sediment, water quality and plankton communities in Barobo coastal waters in Lianga Bay, Surigao del Sur, Philippines. In *Proceedings of the 9th International Conference on Fisheries and Aquaculture* (Vol. 8, No. 1, pp. 1–22).

Rayos, J. C. C., & Macaraeg, N. A. (2024). Determinants of production and technical efficiency of Tilapia farming in the Philippines. *Asian Journal of Fisheries and Aquatic Research*, *26*(6), 1–16.

Romana-Eguia, M. R. R., Rutaquio, M. P., Gutierrez, R. C., & Salayo, N. D. (2021). Assessment of tilapia–freshwater prawn co-culture schemes in tanks and lake-based cages for increased farm production. *Sustainability*, *13*(24), 13574.

Rustia, A. S., Barrios, E. B., Lopez, C. M., Tanay, D. D., Salem, A. M. T., Lagazon, P. M., Gosilatar, J. C. G., Salem, A. J. T., & Dalmacio, L. M. (2025). Assessment of validity and reliability of survey tool for good aquaculture practices of Philippine shellfish farmers. Philippine Journal of Science, 154(3), 613–631.

Salazar, C., Jaime, M., Retamal, R. C., & Baquedano, M. (2023). Women engagement, psychological traits, and gender gaps in the small-scale seaweed aquaculture in Chile. *Reviews in Aquaculture*, *15*(4), 1540–1553.

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson Education.

Sekaran, U. (2016). *Research methods for business: A skill building approach*. Wiley.

Sustainable Aquaculture Consumer Study. (2024). *Perceptions of risk, financial benefit metrics, and investment intention indicators in community aquaculture operations* (Global Market Insight Report). Seafood Choices Alliance.

Tran, N., Le Cao, Q., Shikuku, K. M., Phan, T. P., & Banks, L. K. (2020). Profitability and perceived resilience benefits of integrated shrimp-tilapia-seaweed aquaculture in North Central Coast, Vietnam. *Marine Policy*, *120*, Article 104153.

Wang, P., Feng, J., & Zhou, W. (2021). Warming waters, hypoxic stressors, and microbial destabilization in near-shore small-scale aquaculture enclosures. *Aquaculture Research*, *52*(11), 5410–5426.

Wang, P., Feng, J., & Zhou, W. (2023). Assessing the weight of capital investment, technical training, and ecological monitoring on aquaculture outcomes in Guangdong. *China Agricultural Review*, *15*(2), 211–229.

World Organization for Animal Health (WOAH) & STAR-IDAZ International Research Consortium. (2025a). *Advancing aquaculture health research: Report of the workshop, 20–21 February 2025, Paris*.

World Organization for Animal Health (WOAH) & STAR-IDAZ International Research Consortium. (2025b). *Report of the pre-workshop global consultation on aquaculture research priorities: Finfish section (Aquaculture Health Research Survey)*. WOAH.

World Organization for Animal Health (WOAH) & STAR-IDAZ International Research Consortium. (2025c). *Policy brief: Highest priority research areas for finfish health*.

Ybanez Jr., C. O., & Gonzales, R. C. (2023). Challenges and progress of grouper aquaculture in Asia: A review. *Davao Research Journal*, *14*(2), 6–29.

Zheng, L., Liu, Q., Liu, J., Xiao, J., & Xu, G. (2022). Pollution control of industrial mariculture wastewater: A mini-review. *Water*, *14*(9), 1390.