Determinants of Export Readiness of Mangrove Crab Fishermen at Tahura Ngurah Rai After Ecosystem Disruption: A Blue Economy-Based Structural Analysis

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Abstract. This study examines the determinants of export readiness among mangrove crab (Scylla spp.) fishers in the Tahura Ngurah Rai conservation area, Southern Bali, following an ecosystem disturbance caused by a fuel pipeline leak in the Benoa area in 2025–2026. Grounded in Blue Economy theory, the Resource-Based View (RBV), and Legal Effectiveness Theory, this explanatory quantitative study uses Partial Least Squares-Structural Equation Modeling (PLS-SEM) with the assistance of SmartPLS software. Data were collected from 100 respondents through purposive sampling of active fishers in the traditional fishing centers of Pesanggaran, Suwung, and Serangan. Three latent variables were tested: Blue Economy Principles (X), Sustainable Fisheries Development (M), and Export Readiness (Y). The results show that Blue Economy Principles have a significant positive effect on Sustainable Fisheries Development (β = 0.854, T = 45.163, $p < 0.001$), and Sustainable Fisheries Development has a significant effect on Export Readiness (β = 0.793, T = 10.276, $p < 0.001$). However, the direct effect of Blue Economy Principles on Export Readiness is not significant (β = 0.081, p = 0.322). Full mediation is confirmed, with Sustainable Fisheries Development as the primary pathway linking Blue Economy Principles to Export Readiness (indirect effect = 0.677, T = 9.770, $p < 0.001$). This structural model explains 74.5% of the variation in Export Readiness (R^2 = 0.745). These findings indicate that improving export readiness in micro-scale fisheries requires translating blue economy principles into concrete sustainable fisheries practices, supported by regulatory compliance, institutional integration, and technical capacity strengthening.

Keywords: Blue Economy, Export Readiness, Mangrove Crab, PLS-SEM, Sustainable Fisherie.

1 Introduction

The global economic development paradigm has fundamentally shifted toward recognizing the ocean as the last economic frontier. The Blue Economy is defined as the sustainable use of ocean resources for economic growth, improved livelihoods, and employment, while preserving the health of marine ecosystems (Vierros & De Fontaubert, 2017). Globally, the maritime economy is a strategic sector, with the value

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of ocean-derived goods and services reaching USD 2.2 trillion in 2023, sustaining more than 100 million jobs worldwide (UNCTAD, 2025).

One commodity highly sought after in East Asian markets, particularly China and Singapore, is the mangrove crab (Scylla spp.). The value of world crab imports grew at an average of 11.13% per year during 2017–2022 (Kementerian Kelautan dan Perikanan Republik Indonesia, 2023). As a leading producer, with Scylla serrata production reaching 18,232 tons (14.0% of global production), Indonesia has substantial potential to dominate the premium market. Regionally, Bali Province plays a strategic role in exports, with the fisheries and marine sector among the main contributors to the region's export performance. However, Bali's export performance declined by 21.65% year-on-year in July 2025 (Badan Pusat Statistik Bali, 2025), indicating supply-stability disruption and declining production capacity among traditional fishers.

In September 2025, a fuel pipeline leak was reported in the Benoa area, suspected to be linked to damage to the mangrove ecosystem in Tahura Ngurah Rai. Mangrove die-off began to be observed in February 2026, with approximately 200–300 trees affected across an area of ±600 m² on the west side of the Bali Mandara Toll Road. Gas Chromatography–Mass Spectrometry (GC-MS) testing on 24–26 February 2026 showed a dominance of C15–C24 hydrocarbons consistent with diesel/solar fuel characteristics. However, quantitative concentrations in mg/kg and the extent of contamination reaching fishers' catch areas are not yet available in public reports (detikBali, 2026). This situation has heightened challenges to fisheries sustainability and crab export readiness, particularly in meeting the requirements of Ministerial Regulation (Permen KP) No. 7 of 2024, including minimum size/weight requirements for crabs for consumption and the prohibition on releasing egg-bearing crabs for sale.

Traditional fishers in Tahura Ngurah Rai are now caught in a development paradox: they are required to meet high export quality standards, while the natural capital that sustains the crabs' physical growth has been damaged by industrial pollution. The identified research gap is that most blue economy studies in Bali still focus on marine tourism (Chin & Hampton, 2020; Rihhadatul'aisy et al., 2024), while empirical studies examining traditional fishers' export readiness through a structural model following a real ecosystem disturbance remain very limited. This study fills that gap by developing a resilient export-readiness model for micro-scale fisheries in the face of environmental shocks.

2 Methodology

2.1 Research Design and Location

These three areas served as the research locations because they are centers of traditional fishing activity around Tahura Ngurah Rai and fall within the context of the 2025–2026 Benoa ecosystem disturbance.

2.2 Conceptual Framework and Hypothesis

The conceptual framework tests the structural relationship between sustainability values and their impact on fishers' export performance, integrating three theoretical foundations: Blue Economy theory (Pauli, 2017) as the primary predictor; Sustainable Fisheries Development as the mediating bridge influenced by regulatory compliance; and the Resource-Based View to explain export readiness as a competitive achievement. The research framework and hypotheses are presented in Figure 1.

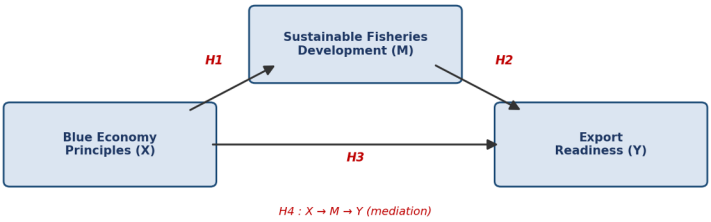


Figure 1. Conceptual Framework and Hypotheses.

The hypotheses tested are: H1: Blue Economy Principles have a significant positive effect on Sustainable Fisheries Development; H2: Sustainable Fisheries Development has a significant positive effect on Export Readiness; H3: Blue Economy Principles have a significant positive effect on Export Readiness; H4: Sustainable Fisheries Development significantly mediates the effect of Blue Economy Principles on Export Readiness.

2.3 Population, Sample and Variables

The unknown exact population size of mangrove crab fishers was considered when determining the minimum adequate sample size. The Lemeshow approach was used as the reference for determining the minimum number of respondents with conservative assumptions ($p = 0.50$), ($Z = 1.96$), and a precision level of 10%, a value of ($n = 96.04$) was obtained, so the minimum sample size was rounded up to 97 respondents. Subsequently, purposive sampling was used to select respondents based on predetermined criteria: fishers still actively catching mangrove crab at the research location and having at least two years of experience as a fisher. This experience criterion refers to the length of time engaged in fishing activity, not the duration of activity in the area affected by oil contamination. Based on these criteria, 100 respondents met the research criteria, so the actual sample size met the established minimum.

2.4 Analysis and Technique

Environmental contamination data provided the empirical context for the study but were not included as a variable in the PLS-SEM model. This study also did not conduct direct laboratory testing of crab tissue. The biosecurity aspect within the Sustainable Fisheries construct was measured based on survey indicators representing respondents' perceptions. The findings are therefore not intended to conclude about the laboratory-confirmed safety of crab consumption.

In addition to the questionnaire survey, the study was supplemented with field observations during the data-collection process to obtain contextual information on fishing practices, environmental conditions, and forms of economic adaptation among fishers at the research locations. Information on cultivation practices, including the use of holding containers, as well as economic diversification through mangrove ecotourism, was used as contextual findings to enrich the interpretation of the results, rather than as variables analyzed quantitatively in the PLS-SEM model.

The study used Partial Least Squares Structural Equation Modeling (PLS-SEM) with the aid of SmartPLS software. The analysis was conducted in two stages: evaluation of the outer model, covering convergent validity via outer loading and AVE, discriminant validity via the Fornell–Larcker criterion and the HTMT ratio, and construct reliability via Cronbach's Alpha and Composite Reliability; and evaluation of the inner model, covering R^2, path coefficients, f^2, and hypothesis testing via bootstrapping. The mediation effect was tested via specific indirect effects.

3 Result and Discussion

3.1 Respondent and Characteristics

Respondent characteristics by length of work show that most have fairly extensive experience as mangrove crab fishers. The largest group has 6–10 years of experience (31%), followed by more than 15 years (27%), 11–15 years (21%), and 1–5 years (19%). Only 2% have less than one year of experience, indicating that the research sample is dominated by experienced fishers with an in-depth understanding of ecosystem conditions and catching patterns. Based on research location, respondents were distributed across Pesanggaran (35%), Suwung (35%), and Serangan (30%). This distribution indicates representative coverage of respondents from all three research areas.

3.2 Measurment Model (Outer Model)

Table 1 presents the outer loadings for convergent validity. All indicators across the three variables are above the 0.70 threshold, ranging from 0.797–0.963 for Blue Economy Principles, 0.833–0.941 for Sustainable Fisheries, and 0.964–0.975 for Export Readiness. These results indicate that all indicators meet the convergent validity criterion, meaning each indicator adequately represents its latent variable.

Table 1. Outer loading – Convergent Validity.

Indicator	Blue Economy (X)	Sustainable Fisheries (M)	Export Readiness (Y)
M1.1		0.941	
M1.2		0.916	
M1.3		0.924	
M2.1		0.927	
M2.2		0.933	
M3.1		0.838	
M3.2		0.833	
X1.1	0.955		
X1.2	0.963		
X1.3	0.955		
X2.1	0.962		
X2.2	0.957		
X3.1	0.957		
X3.2	0.797		
Y1.1			0.968
Y1.2			0.975
Y1.3			0.964
Y2.1			0.975
Y2.2			0.964
Y3.1			0.968
Y3.2			0.975

The discriminant validity test results based on the Fornell-Larcker criterion (Table 2) show that the square root of the AVE for each construct is greater than its correlation with other constructs, namely Export Readiness = 0.970, Blue Economy = 0.937, and Sustainable Fisheries = 0.903. These findings indicate that each construct has good discriminant validity and can be conceptually distinguished from the other constructs, so there is no indication of excessive measurement overlap between constructs.

Table 2. Discriminant Validity (Fornell-Larcker criterion).

	Export Readiness (Y)	Blue Economy (X)	Sustainable Fisheries (M)
Export Readiness (Y)	0.970		
Blue Economy Principles (X)	0.758	0.937	
Sustainable Fisheries (M)	0.862	0.854	0.903

The test results in Table 3 show an HTMT value of 0.769 between Blue Economy Principles (X) and Export Readiness (Y), 0.874 between Blue Economy Principles (X) and Sustainable Fisheries (M), and 0.872 between Export Readiness (Y) and Sustainable Fisheries (M). All values are below the 0.90 threshold, so discriminant validity between constructs is acceptable. These results are also consistent with the Fornell-Larcker criterion, which shows that the square root of the AVE for each construct is greater than its correlation with other constructs. Discriminant validity is therefore supported by two testing approaches.

Table 3. Discriminant Validity – HTMT.

	Blue Economy (X)	Export Readiness (Y)	Sustainable Fisheries (M)
Blue Economy (X)			
Export Readiness (Y)	0.769		
Sustainable Fisheries (M)	0.874	0.872	

The construct reliability results (Table 4) show that Cronbach's Alpha, rho_a, and Composite Reliability all exceed 0.96 for each construct, with AVE values of 0.877 (X), 0.815 (M), and 0.941 (Y). All constructs have reliability coefficients above 0.70, indicating good internal consistency of the indicators for each variable.

Table 4. Construct Reliability and Convergent Validity.

Construct	Cronbach's Alpha	rho_a	rho_c	AVE
Blue Economy Principles (X)	0.976	0.976	0.980	0.877
Sustainable Fisheries (M)	0.962	0.962	0.968	0.815
Export Readiness (Y)	0.990	0.990	0.991	0.941

Next, Table 5, the collinearity test on the structural model, shows that the Variance Inflation Factor (VIF) values range from 1.000–3.688.

Table 5. Collinearity Statistics.

Construct	Blue Economy (X)	Export Readiness (Y)	Sustainable Fisheries (M)
Blue Economy (X)		3.688	1.000
Export Readiness (Y)			
Sustainable Fisheries (M)		3.688	

The VIF value between Blue Economy Principles (X) and Export Readiness (Y) is 3.688, while the VIF value between Sustainable Fisheries (M) and Export Readiness (Y) is also 3.688. Meanwhile, the relationship between Blue Economy Principles (X)

and Sustainable Fisheries (M) has a VIF value of 1.000. All VIF values are below the 5.00 threshold, so there is no indication of high multicollinearity in the structural model. These results indicate that the predictor constructs do not experience collinearity problems that could disrupt the estimation of relationships between variables in the model.

3.3 Structural Model (Inner Model) and Hypothesis Testing

The R-Square value for Sustainable Fisheries Development (M) is 0.729, indicating that Blue Economy Principles explain 72.9% of its variation. The R-Square value for Export Readiness (Y) is 0.745, indicating that Blue Economy Principles and Sustainable Fisheries Development jointly explain 74.5% of its variation. The structural model is shown in Figure 2, and the path coefficients are presented in Table 6.

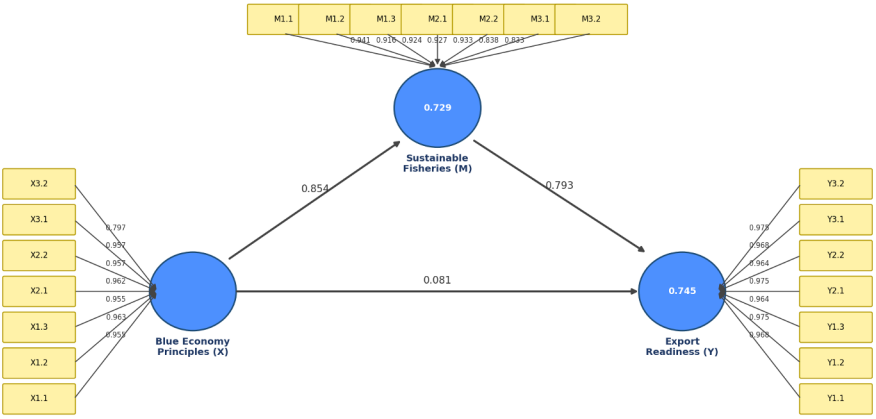


Figure 2. Structural model with outer loadings and path coefficients (PLS-SEM).

Table 6. Path Coefficients and Hypothesis Testing Results

Path Relationship	β	Mean	STDEV	T-stat	p-value
X → M (H1)	0.854	0.854	0.019	45.163	0.000
M → Y (H2)	0.793	0.794	0.077	10.276	0.000
X → Y (H3)	0.081	0.079	0.082	0.991	0.322
X → M → Y (H4)	0.677	0.679	0.069	9.770	0.000

The hypothesis testing results in Table 6 show that Blue Economy Principles (X) have a positive and significant effect on Sustainable Fisheries (M) ($\beta = 0.854$; $t = 45.163$; $p < 0.001$), and Sustainable Fisheries (M) has a positive and significant effect on Export Readiness (Y) ($\beta = 0.793$; $t = 10.276$; $p < 0.001$). Meanwhile, Blue Economy Principles (X) do not have a significant direct effect on Export Readiness (Y) ($\beta = 0.081$; $t = 0.991$; $p = 0.322$). Furthermore, the indirect effect of Blue Economy Principles on Export Readiness through Sustainable Fisheries shows a positive and significant result ($\beta =$

0.677; t = 9.770; p < 0.001), indicating a mediating effect of Sustainable Fisheries in this relationship.

3.4 Discussion

H1 (Supported): Blue Economy Principles have a positive and significant effect on Sustainable Fisheries Development (β = 0.854, T = 45.163, p < 0.001), with a very large effect size (f^2 = 2.688). Fishers' involvement in mangrove conservation, zero-waste practices, and the use of environmentally friendly fishing gear strengthens their commitment to sustainable resource management. This finding is consistent with Efani et al., 2025 and Trenggono et al., 2025, who confirmed that blue economy adoption drives sustainable fisheries practices in Indonesian coastal communities.

H2 (Supported): Sustainable Fisheries Development has a significant effect on Export Readiness (β = 0.793, T = 10.276, p < 0.001), with a large effect size (f^2 = 0.668). This finding indicates that the sustainability indicators measured in the study, including compliance with regulatory standards, institutional integration, and biosecurity aspects, are closely related to the technical and administrative foundations of export readiness. This interpretation is limited to the relationships between constructs measured through the survey and is not intended as causal evidence regarding the biological condition or safety of the product.

H3 (Not Supported): The direct effect of Blue Economy Principles on Export Readiness is not significant (β = 0.081, T = 0.991, p = 0.322). This result indicates that the application of blue economy principles, as perceived and measured in the study, has not yet been directly translated into export readiness. Export readiness encompasses legal documentation, technical readiness, and logistics and quality, so a strengthening process through sustainable fisheries practices is required before blue economy principles can contribute to this achievement (Gerschewski et al., 2020).

H4 (Supported – Full Mediation): Sustainable Fisheries Development fully mediates the relationship between Blue Economy Principles and Export Readiness (indirect effect = 0.677, T = 9.770, p < 0.001). Because the direct effect is not significant while the mediated effect is significant, this condition constitutes full mediation, indicating that blue economy principles must first be translated into concrete sustainable fisheries practices before they can improve export readiness. The dominant pathway is: Blue Economy → Sustainable Fisheries → Export Readiness.

3.5 Research Limitation

Several limitations need to be considered when interpreting the research results. First, the constructs were measured using self-report questionnaires from the same respondents during the same data-collection period, so the potential for common method bias and social-desirability bias still needs to be considered. Second, several dimensions, particularly M3, are represented by only two indicators. Although both show adequate loadings, developing more diverse indicators in future research could provide a more comprehensive representation of the construct. Third, the study focuses on fishers who were still actively working at the time of the survey, so the perspectives of fishers who had stopped working due to the ecosystem disturbance are not fully captured. Fourth, environmental contamination data and post-incident recovery

information were used as empirical context but have not yet been integrated as quantitative variables in the PLS-SEM model. Future research could therefore extend the model by integrating environmental quality data, contamination test results, ecosystem conditions, and information on post-incident cleanup, remediation, and monitoring to provide a more comprehensive picture of the linkages between ecosystem recovery, fisheries sustainability, and the economic readiness of coastal communities.

4 Conclusion

This study confirms that the export readiness of mangrove crab fishers in Tahura Ngurah Rai is not built directly through Blue Economy Principles, but through Sustainable Fisheries Development as a full mediator. The structural model (R^2 = 0.745) shows the effective pathway: Blue Economy Principles → Sustainable Fisheries Development → Export Readiness. Practically, policy needs to translate blue economy principles into strengthened sustainable fisheries capacity, fisher institutions, compliance with Permen KP 7/2024, and export capabilities such as cold-chain, health certification, and traceability. The limited information on post-incident recovery and monitoring also underscores the need for recovery efforts that are not only oriented toward ecosystem rehabilitation but also toward fisheries sustainability and the economic readiness of coastal communities.

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