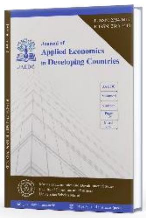

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HOW IS THE BLUE ECONOMY IMPLEMENTED IN FISHERIES MANAGEMENT WITHIN THE RIAU ISLANDS?

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ABSTRACT

This study aims to examine fisheries management factors through a blue economy perspective. It is a quantitative study with an explanatory approach, using panel data regression as the analysis method with an observation period from 2020 to 2023 across seven districts in the Riau Islands. Data were obtained from Statistics Indonesia and the Ministry of Maritime Affairs and Fisheries. The results show that the marine resource sustainability index significantly increase the value of fishery production through a blue economy perspective. Theoretically, this study explains the Tragedy of the Commons Theory, by operationalizes the blue economy paradigm into measurable variables aligned with environmental, social, and economic dimensions which is relevant to the classical approach in natural resource economics, where fishery resources are considered public goods vulnerable to overexploitation for personal gain, ultimately harming everyone in the long run. The results provide empirical evidence that ecosystem-based management remains central to sustaining fisheries output in archipelagic regions. The study contributes to applied development economics by offering a provincial-level panel analysis of fisheries sustainability within a small-island and archipelagic context.

1. INTRODUCTION

The introduction is The Riau Islands (Kepri) is an archipelagic province that is highly dependent on marine resources: its territory is estimated to consist of around 2,408 islands and its marine area covers a large proportion of the province's total area, making maritime and fishing activities the backbone of the local economy and the livelihood of coastal communities. This geographical condition, stretching from the Malacca Strait to the Natuna Sea and directly bordering Singapore, Malaysia, and Vietnam, has become a geographical advantage that drives the economic growth of this region, making Riau Islands not only rich in fishery resources but also strategic in terms of maritime trade and logistics (BPS Riau Islands Province, 2025).

The Riau Islands continue to strengthen their contribution as one of the national fish barns through increased catches and marine aquaculture. Programs to modernize fishing equipment, train fishermen, and monitor marine resources also support the sustainability of the fisheries ecosystem.

As a result, the value of fishery production has experienced a consistent upward trend (Nurafiah et al., 2020; Simanjuntak et al., 2025). However, empirically, there are several phenomena that (1) Data shows that fish production and consumption have increased (2021–2024), but ecological indicators such as illegal fishing are directly proportional to fishery production, mangrove degradation, decline in water quality, environmentally unfriendly fishing gear, and climate change (Adellia Adellia et al., 2024; Rekarti et al., 2025; Rizaldi et al., 2020; Rosdatina et al., 2019 (2) Fishermen face economic pressure due to fluctuations in fish prices and operational costs, despite the existence of aquaculture programs and assistance (Winanda et al., 2025) (3) productivity has increased but ecological and social sustainability are not yet balanced (Putri et al., 2024). From a blue economy perspective, coastal and marine resources are viewed as natural capital that not only has economic value, but also important ecological and social functions for the sustainability of community life. Therefore, integrated management is key to ensuring that resource exploitation does not cause environmental degradation that threatens the future sustainability of the fisheries sector.

Quantitatively, data from 2021-2024 shows an upward trend, with per capita fish consumption in the Riau Islands Province increasing from 64.70 kg/capita/year (2021) to 66.18 kg (2022), then 67.80 kg (2023) and 69.64 kg (2024), indicating a shift in consumption patterns and/or a relative increase in the availability of local fishery products during this period. On the production side, official provincial data recorded an increase in volume in the aquaculture sub-sector. For example, the first semester report of 2024 recorded aquaculture production of around 17,483.95 tons (an increase of ~10.6% compared to the previous semester), and the provincial BPS statistical table shows data on capture and aquaculture production dominating several coastal districts such as Natuna, Karimun, and Anambas in 2022–2024. This quantitative trend provides empirical evidence that the Riau Islands fisheries sector is experiencing a dynamic increase in production and consumption that needs to be evaluated from a sustainability perspective. Fisheries management cannot be separated from a sustainable economic approach, especially in the context of coastal areas and archipelagic countries such as Indonesia. Theoretically, the classical approach in natural resource economics places fishery resources as public goods that are vulnerable to overexploitation for personal gain, even though this will ultimately harm everyone in the long run (Hardin, 1968).

This condition is relevant to discuss in the coastal areas of the Riau Islands, given the pressure of fishing, coastal habitat degradation, and the need for diversification of fishermen's income, which must remain in line with efforts to maintain stocks and ecosystem functions. Hardin (1968) *Tragedy of the Commons* explains that fisheries, as open-access resources, are vulnerable to overexploitation when individual economic incentives override collective sustainability. While this classical framework emphasizes the risk of resource depletion, it does not explicitly integrate broader development objectives. The contemporary blue economy paradigm extends this perspective by aligning fisheries governance with the Triple Bottom Line framework, which balances environmental sustainability (planet), economic viability (profit), and social inclusion (people). Within this structure, fish stock sustainability represents the environmental dimension, fishery production value reflects economic performance, and variables such as fishermen's education and business group participation capture the social dimension of capacity and collective action. Fisheries infrastructure further supports the productive-economic pillar while interacting with governance mechanisms. By structuring these variables according to the Triple Bottom Line logic, this study transforms the tragedy of the commons from a purely theoretical concern into a measurable and empirically testable blue economy model using panel data regression.

Based on these conditions, this study was motivated by the limited number of comprehensive studies that integrate the blue economy perspective with fisheries sustainability analysis at the provincial level in island regions. This is particularly relevant in the Riau Islands, which have a complex geography and different levels of resource pressure compared to other coastal regions in Indonesia. The novelty of this study lies in its attempt to examine fisheries management factors that can balance ecological, social, and economic dimensions through a blue economy approach tailored to the local context of the Riau Islands. In line with this, the objective of this study is to analyze fisheries factors from a blue economy perspective in the Riau Islands and formulate strategies for optimizing sustainable management that supports the improvement of fishermen's welfare without sacrificing the sustainability of marine ecosystems.

The theoretical framework of this study is grounded in natural resource economics and blue economy theory, from which six hypotheses are derived. First, it is hypothesized that lagged fish stock, as a proxy for marine resource sustainability, positively affects fishery production value (H1). Second, rainfall is expected to significantly influence fishery production value (H2). Third, the number of fishermen is posited to have a positive effect on fishery production value (H3). Fourth, the educational attainment of fishermen is hypothesized to positively affect production value (H4). Fifth, fisheries infrastructure operationalized through the number of vessels under 5 gross tonnage is expected to positively influence production value (H5). Lastly, participation in fishery business groups is hypothesized to positively affect fishery production value (H6).

2. RESEARCH METHODS

This study is a quantitative study with an explanatory approach that aims to analyze the factors that influence fishery production value in the perspective of the blue economy in the Riau Islands Province. The study location covers seven districts/cities in the Riau Islands region, namely Batam, Tanjung Pinang, Bintan, Karimun, Lingga, Natuna, and the Anambas Islands. The selection of locations was based on the characteristics of the archipelago, which has varying levels of pressure on fishery resources and a significant contribution to the regional economy.

The type of data used in this study is secondary data obtained from official publications of the Central Statistics Agency (BPS) and the Ministry of Maritime Affairs and Fisheries (KKP) in the period 2020–2023. The data collected includes variables related to fishery production, socio-economic indicators of fishermen, and aquatic environmental conditions.

The analysis method used is panel data regression, as it is able to combine time series and cross-sectional dimensions to produce more robust estimates. The dependent variable in this study is the value of fishery production (Y), while the independent variables include: (X1) marine resource sustainability index, (X2) rainfall, (X3) number of fishermen, (X4) fishermen's education level, (X5) fishery infrastructure, and (X6) participation in fishery business groups.

The use of fish stock as a proxy for the marine resource sustainability index is based on the global standard of Sustainable Development Goal (SDG) Indicator 14.4.1, which establishes the proportion of fish stocks within biologically sustainable levels as the standard metric to measure marine resource sustainability (FAO, 2024). Furthermore, this approach is supported by empirical evidence from Mance et al. (2025), who utilized fish stock status as the primary indicator to evaluate ecological performance and assess the sustainability of a country's marine resource utilization practices. Additionally, a *lag transformation* was applied to the fish stock variable to minimize endogeneity issues, particularly the bias caused by two-way causality (*simultaneity bias*) with the dependent variable. Employing a lagged explanatory variable (from a previous period) serves as a standard instrument to resolve simultaneity, as past values logically precede the dependent variable temporally and remain unaffected by error shocks in the current period (Reed, 2015).

For the fisheries infrastructure variable, the number of vessels is utilized as a proxy because it represents the primary physical capital that determines the production capacity of marine resources (Nøstbakken, Thébaud, & Sørensen, 2011). Furthermore, the specific vessel size limit of < 5 GT serves as the most functional and proportional metric to accurately represent the true infrastructure demographics of small-scale coastal communities (Halim, 2020). The application of this specific measurement is highly suitable for the context of an archipelagic country like Indonesia, particularly in the waters of the Riau Islands, which are predominantly operated by small-scale fishers.

Mathematically, the panel data regression model in this study can be formulated as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1i,t-1} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + \beta_6 X_{6it} + \varepsilon_{it} \quad (1)$$

Description :

Y_{it} : Fisheries production value (Rp. Million)
$X_{1i,t-1}$: Marine resource sustainability index (lagged fish stocks in tons)
X_{2it} : Rainfall (mm)
X_{3it} : Number of fisherman (persons)
X_{4it} : Fishermen's education level (average length of schooling in years)
X_{5it} : Fisheries infrastructure (number of vessels < 5 GT)
X_{6it} : Business group participation (number of Kusuka Fishing)
β_0 : Contant
$\beta_{1,2,3,4,5}$: Regression coefficient for each independent variable
ε_{it} : Error term

This model will be estimated using the common effect model (CEM), fixed effect model (FEM), and random effect model (REM) approaches, with the best model selected based on the Chow test, Hausman test, and Lagrange Multiplier test.

Table 1. Results of Panel Data Model Selection Tests

Variable	*p*-value	Decision
Chow Test	0.0019	FEM Prefered
Hausman Test	0.5246	REM Prefered

Based on Table 1, the Chow test results show a p-value of 0.0019 (< 0.05), indicating that the Fixed Effect model is more appropriate than the Common Effect Model. Subsequently, the Hausman test yields a p-value of 0.5246 (> 0.05), meaning the Random Effect Model (REM) is more efficient and consistent than the Fixed Effect model. Following the panel data model selection procedure outlined by Ratnasari et al. (2023), the REM is therefore selected as the final model and no Lagrange Multiplier test is required.

3. RESULTS AND DISCUSSION

Random Effect GLS Regression

The REM is estimated using Generalized Least Squares (GLS), which accounts for heteroskedasticity and serial correlation within panel structures. Therefore, classical assumption tests required in Ordinary Least Squares (OLS) estimation are not mandatory when REM is applied (Baltagi, 2021). This approach allows for a more accurate analysis of the simultaneous effects of economic, social, and environmental factors in the context of panel data.

Table 2. Random Effect GLS Regression Estimation

Variable	Coefficient	Std. Error	z	*p*-value	Significant	95% Cl (Lower)	95% Cl (Upper)
Lagged Fish Stock (X_1)	17.645	3.31555	5.32	0.000	***	11.14698	24.14373
Raindrops (X_2)	88.780	254.8566	0.35	0.728		-410.7294	588.2902
Number of Fishermen (X_3)	25.328	18.79319	1.35	0.178		-11.50563	62.16234
Fishermen's Education Level (X_4)	-73359.93	66159.94	-1.11	0.268		-203031	56311.17
Fisheries Infrastructure (X_5)	9.951	71.13978	0.14	0.889		-129.4798	149.383
Participation of Business Groups (X_6)	-100.645	309.7704	-0.32	0.745		-707.7844	506.4931
Constants (_cons)	578584.3	971031.3	0.60	0.551		-1324602	2481771

Source: Analyzed data (2024)

Notes: Overall R-squared = 0.7485; Significance = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

As shown in Table 2, the results of the Panel Data Regression estimation with the Random Effect (RE) model show that the R-squared value is 0.7485, meaning that the environmental and social variables used in the model are able to explain approximately 74.85% of the variation in fishery production values in the Riau Islands Province. The simultaneous Wald chi-square test of 0.000 confirms that all independent variables collectively have a significant effect on the dependent variable. The regression equation obtained is as follows:

$$Y_{it} = 578584.3 + 17.645X_{1i,t-1} + 88.78X_{2it} + 25.32X_{3it} - 73359.93X_{4it} + 9.951X_{5it} - 100.645X_{6it} + \varepsilon_{it} \qquad (2)$$

Marine Resource Sustainable Index (X_1)

Fish stocks in this study were used as a proxy for marine resource sustainability indices, as they reflect the ecological conditions and availability of fishery resources that can be exploited sustainably. The estimation results show a coefficient of 17.64 with p = 0.000. This means that every 1-ton increase in fish stocks will increase the value of fishery production by IDR 17,64 million. So, H1 is accepted, indicating that marine resource sustainability has a positive and statistically significant effect on fishery production value in the Riau Islands.

Empirically, the availability of fish stocks has a direct effect on the value of fishery production in the Riau Islands because this region is highly dependent on fishery resources scattered across coastal waters and the open sea. When fish stocks are abundant, fishermen can increase their catch volume with relatively the same effort, thereby increasing production value; conversely, a decline in stocks due to overfishing or environmental degradation will reduce catches and their economic value. These findings are in line with Hammill & Stenson (2007), who asserts that a decline in fish stocks directly reduces the production capacity and economic value of the fisheries sector, while effective stock management increases the stability of fishermen's incomes. Similarly, Hamaguchi & Thakur (2024) shows that ecology-based fisheries policies, such as catch quotas and habitat protection, are important instruments in ensuring the sustainability of the blue economy. Thus, the results of this study reinforce the argument that the success of fisheries development in the Riau Islands does not only depend on socio-economic factors, but is largely determined by the effectiveness of fish stock management.

Raindrops (X_2)

Rainfall has a coefficient of 88.78 with a probability value of 0.728, which is not significant so that H2 is not empirically confirmed. Although theoretically rainfall can affect aquatic ecosystem conditions and fishing intensity, in this model its effect on fishery production values has not been statistically proven. Empirically, rainfall does not significantly affect fishery production value in the Riau Islands possibly because fishing activities in this region are more influenced by oceanographic factors such as ocean currents, water surface temperature, and wind seasons (monsoons) than rainfall intensity. In addition, the waters of the Riau Islands, which are located in open sea areas, have relatively stable salinity and primary productivity despite variations in rainfall, so that rainfall fluctuations do not directly affect the quantity or value of fishermen's catches. In line with research on marine fisheries in East Java, although climate variables as a whole affect fishery production, further analysis shows that rainfall individually does not have a significant effect (Illahi et al., 2023). Meanwhile, research at Paotere Port, Makassar, found that rainfall and wind patterns play an important role in influencing fish production during the observation period (Manapa et al., 2023). These differing findings indicate that the impact of rainfall on fish production is highly dependent on local ecological conditions, the characteristics of the fishing area, and the methodological approach used in the research.

Number of Fishermen (X_3)

The number of fishermen variable shows a coefficient of 25.32 with p = 0.178, indicating a positive but insignificant effect and leads to the rejection of H3. This means that an increase in the number of fishermen does not affect an increase in fishery production value. Empirically, the number of fishermen is not always directly proportional to the value of fishery production because an increase in the number of fishermen without accompanying modernization of fishing gear and business efficiency can actually lead to overfishing and a decline in catch per individual. The Riau Islands, with their scattered geographical conditions and dominance of small-scale fishermen, tend to have low productivity per individual, so factors such as modernization of fishing equipment, fisheries management, and market access are more decisive in increasing the value of fishery production in this region. Fishermen's productivity is highly dependent on the availability of capital, technology, and managerial skills. Thus, the presence of fishermen alone is not enough to drive an increase in production without the support of factors such as technological capacity, fishing season, and the quality of fisheries resource management. This is in line with the research by Sulistianto et al. (2025), which shows that the number of fishermen does not significantly affect fishery production in East Kutai Regency, because productivity is more influenced by technology, vessel quality, and human resource skills.

Fishermen's Education Level (X_4)

The findings do not validate H4, as fishermen's education variable (X4) exhibits a negative coefficient of –73,359.93 with a p-value of 0.268, indicating that it does not have a statistically significant effect on fishery production value. This suggests that variations in formal schooling among fishermen do not systematically explain differences in production outcomes across districts. The negative sign should not be overinterpreted, as it may reflect structural characteristics of small-scale fisheries in which production depends more heavily on fishing experience, capital access, and resource availability rather than formal educational attainment. In other words, success in increasing production is determined more by field experience and mastery of fishing techniques than by formal educational background alone.

Fisheries Infrastructure (X_5)

The number of vessels < 5GT in this study was used as a proxy for fisheries infrastructure, as it is one of the main components of production facilities that reflects the capacity and level of facilities available to small-scale fishers in carrying out their fishing activities (Todaro & Smith, 2015). In regions such as the Riau Islands, the dominance of vessels < 5 GT also reflects the limitations of basic fisheries infrastructure, such as port access, fishing technology, and post-harvest facilities, thereby indirectly representing infrastructure conditions in empirical analysis. Empirical evidence does not substantiate H5; the infrastructure proxy presents an insignificant coefficient (p = 0.889), suggesting limited production impact from small-scale fleet expansion alone. Empirically, the number of vessels smaller than 5 GT does not have a significant effect on fishery production value in the Riau Islands because these small vessels have limited range and depend on coastal waters that are increasingly under pressure from intensive fishing activities. In addition, limitations in transport capacity, fishing technology, and the operational resilience of small vessels result in low productivity, preventing them from making a significant contribution to increasing regional fishery production value. According to research by Sulistianto et al. (2025), even though the number of vessels has increased, this does not necessarily lead to an increase in fishery production volume.

The effectiveness of the fleet is more determined by the quality of the vessels, the fishing technology used, and the fishermen's ability to operate them. In other words, simply increasing the number of vessels, especially small ones, is not enough to significantly increase production. Vessels with limited capacity are unable to reach wider fishing areas or utilize more efficient modern technology. Fisheries sector development policies should focus on modernizing the fleet and improving the technical capacity of fishermen, not just on the quantity of vessels.

Participation of Business Groups (X_6)

The number of Kusuka Pengakapan Ikan (fishing cooperatives) in this study was used as a proxy for business group participation. The statistical test provides insufficient evidence to uphold H6, as participation in business groups does not significantly affect fishery production value ($p = 0.745$). Empirically, the number of joint business groups (kusuka) in the fishing industry in the Riau Islands does not always have a significant effect on fishery production value because illegal fishing practices are still high, which significantly reduces fish stocks, making it difficult for kusuka collective efforts to optimally increase catches. In addition, limited supervision and coordination within kusuka groups make them less effective in addressing the challenges of illegal fishing, thereby limiting their positive impact on fisheries productivity and economic value. Many business groups still face limitations in leadership, management, and accountability mechanisms, so that collective benefits, such as joint procurement or price negotiations, are not optimally realized (Wiranthi et al., 2024). In addition, limited access to credit, information, and value-added value chains means that the benefits of group membership tend to be heterogeneous and vulnerable to free-riding issues and high costs to meet market certification standards (Ankrah Twumasi et al., 2021). Other studies also confirm that the social capital possessed by groups, particularly linking social capital with the government, financial institutions, and large-scale market actors, is a crucial factor in enabling groups to have a real impact on competitiveness and productivity (Manlosa et al., 2023).

Optimal Strategy for Sustainable Fisheries Management in the Riau Islands

The based on the results of the study, fish stocks were found to have a significant effect on increasing fishery production value, while the number of fishermen, education, number of boats, and number of fishing permits had no effect. These findings indicate that the quality of resource management and quality of the environment are more important than simply increasing the fleet or labor force (number of fishermen).

The SWOT analysis presented in Table 3 identifies the internal and external factors that influence sustainable fisheries management from a blue economy perspective in the Riau Islands. The SWOT analysis shows that sustainable fisheries management in the Riau Islands has great potential to improve the welfare of fishermen while preserving the marine ecosystem. Therefore, the direction of fisheries management optimization in the Riau Islands should focus on ecosystem-based fish stock management, improving the education and skills of fishermen, and diversifying the economy based on the blue economy. This approach not only supports the improvement of fishermen's welfare but also ensures the sustainability of the marine ecosystem as the main foundation for regional maritime economic development.

Table 3. SWOT Analysis

Internal / External	**Strengths (S)** • Abundant and diverse fish resources as empirical evidence shows that fish stock sustainability significantly drives fishery production value. • Strategic location near international trade routes. • Existence of national policies related to the blue economy. • Local wisdom of fishermen in marine management.	**Weaknesses (W)** • Fishermen have low levels of education and economic literacy. • Storage infrastructure and market access are limited. • There is still minimal innovation in fishing technology. • Based on result, Institutional and human capital factors have not yet translated into measurable short-term economic output.
Opportunities (O) • Support from national and international programs related to sustainability. • The global market for environmentally friendly fishery products is growing. • Potential for business diversification (aquaculture, marine ecotourism). • Digital technology for marketing and monitoring.	**SO Strategy** • Optimizing fish resource potential with environmentally friendly technology and catch quota systems. • Branding and exporting sustainable fishery products to meet global market demand. • Utilization of digital technology	**WO Strategy** • Improving the capacity of fishing communities through education, training, and digital literacy. • Developing cold chain infrastructure, cold storage, and market access with government program support. • Providing institutional assistance to fishing communities so they can participate in blue economy programs.
Threats (T) • Overfishing & IUU fishing practices. • Marineecosystem degradation (pollution, industrial exploitation). • Global fish price fluctuations. • Impact of climate change (extreme weather, decline in fish stocks).	**ST Strategy** • Strengthening community- based marine surveillance to prevent IUU fishing. • Zoning fishing areas to protect ecosystems from degradation. • Utilizing the strategic position of Riau Islands as a center for sustainable fisheries logistics and distribution.	**WT Strategy** • Marine ecosystem rehabilitation programs (mangroves, coral reefs, seagrass beds) to maintain fish stocks. • Economic diversification for fishermen (marine aquaculture, marine ecotourism) to reduce dependence on catches. • Insurance and social protection schemes for fishermen facing climate risks and price fluctuations.

Source: Processed Data (2025)

4. CONCLUSION

The results of this study examines fisheries management in the Riau Islands through a blue economy perspective grounded in the Triple Bottom Line framework. The empirical findings indicate that marine resource sustainability, proxied by lagged fish stock, is the only variable that has a positive and statistically significant effect on fishery production value. This result confirms H1 and highlights the central role of ecological capital in sustaining fisheries-based economic performance in archipelagic regions. In contrast, rainfall, the number of fishermen, fishermen's education level, fisheries infrastructure (vessels < 5 GT), and participation in business groups do not exhibit statistically significant effects. Therefore, H2 through H6 are not empirically supported within the observed period. These findings suggest that increases in labor, small-scale fleet capacity, or institutional participation alone are insufficient to generate measurable production gains without strong ecological foundation.

From a Triple Bottom Line perspective, the results imply that the "planet" dimension (environmental sustainability) currently plays a more decisive role than the "people" and "profit-supporting" institutional dimensions in explaining variations in fishery production value in the Riau

Islands. This does not necessarily mean that social and institutional factors are unimportant, but rather that their measurable economic impact may require longer time horizons, stronger governance integration, or alternative indicators, in order to more thoroughly assess the implementation of the blue economy in small island regions.

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