

Sustainability Of Fishery Ecosystems On Sumatra Island : The Role Of Poverty, Fishing Activities, And Population Pressure

Bima Prasetya Kumara¹, Dina Arini Adipathy²

^{1,2}Faculty of Economics and Business, Universitas Bengkulu, Indonesia

Abstract

Fisheries are important for food security, employment, income, and coastal livelihoods, but increasing pressure on capture fisheries may undermine the long-term sustainability of fishery-dependent economies. This study examines the roles of poverty, fishing activities, and population pressure in explaining the sustainability-oriented structure of fishery production across 65 regencies/cities on Sumatra Island, Indonesia. The study uses panel data for 2020–2024, producing 324 observations. The Fishery Sustainability Indicator (FSI) is measured as the share of aquaculture production in total fishery production and is interpreted as a production-structure proxy rather than a direct ecological measure of ecosystem health. Poverty is measured by the percentage of the population living in poverty, fishing activities by the number of fishermen, and population pressure by population growth. Panel-data estimation is performed using common, fixed, and random effects, with model selection based on the Chow, Hausman, and Breusch–Pagan tests. The results support the Random Effects Model. Fishing activities have a negative and statistically significant effect on FSI, while poverty and population pressure are statistically insignificant. The overall model is statistically significant. The findings indicate that greater participation in capture fishing is associated with a less sustainability-oriented structure of local fishery production. Policy priorities should therefore include fishing-pressure management, livelihood diversification, sustainable aquaculture, and place-based fisheries governance.

Keywords: Fisheries Sustainability, Poverty, Fishing Activities, Population Pressure, Sumatra.

INTRODUCTION

Fisheries are an important component of food systems and coastal economies. They provide aquatic food, employment, income, and livelihood opportunities for communities that depend directly or indirectly on aquatic resources. Yet fisheries are

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based on renewable resources with biological limits. The economic benefits generated by fisheries therefore depend on maintaining the productive capacity of fishery resources over time.

The sustainability of fisheries is consequently both an environmental and an economic issue. Fisheries management research shows that controlling fishing mortality, fishing effort, and access to fishing grounds is central to maintaining fish stocks and balancing ecological objectives with economic and community outcomes (Anderson et al., 2019; Hilborn et al., 2020). Recent evidence also emphasizes that excessive fishing effort can generate declining catches, incomes, and livelihood security when resource pressure becomes persistent (Gnanapragasam et al., 2026).

The issue is particularly important for Indonesia because fisheries are a major component of coastal livelihoods and the national food system. Official statistics from the Ministry of Marine Affairs and Fisheries (KKP) show that Indonesian capture-fisheries production remained at a very large scale during 2020–2024 (KKP, 2024, 2025). This scale illustrates both the economic importance of fisheries and the importance of maintaining the resource base that supports them.

High production, however, does not automatically indicate sustainability. Increasing production through greater fishing pressure may create short-term employment and income while potentially reducing resource productivity in the longer term. This creates an important development question: how can coastal economies maintain livelihoods and fish supply without increasing pressure beyond the productive capacity of fishery resources?

Fishing activities are central to this question. The number of people involved in fishing reflects the socioeconomic importance of fisheries but may also indicate the scale of human dependence on capture-fishery resources. Fisheries effort is multidimensional, and the number of fishermen is therefore only a proxy; actual effort can also depend on fishing days, vessel capacity, gear, and technology. Nevertheless, a larger fishing workforce can indicate stronger dependence on capture fisheries and greater potential pressure on a limited resource base.

The socioeconomic conditions of fishing households further complicate the relationship. The sustainable-livelihoods literature emphasizes that coastal and marine social-ecological systems are characterized by uncertainty, resource dependence, and complex interactions between poverty, institutions, and resource management (Allison & Ellis, 2001; Ferrol-Schulte et al., 2013). Béné (2003) similarly argues that poverty in small-scale fisheries cannot be understood solely through low income or resource depletion because access, institutions, and exclusion mechanisms shape vulnerability.

Evidence from Indonesia reinforces this complexity. Stanford et al. (2013) found that fishing was among the sectors associated with relatively high poverty incidence in



West Sumatra, but high fishing dependency was not significantly correlated with a high proportion of poverty among fishers. Stanford et al. (2014) further showed that many poor fishers in West Sumatra were non-boat-owning workers and argued that livelihood interventions should extend beyond physical fishing assets.

The Indonesian small-scale fisheries literature also shows that poverty, overfishing, market opportunities, and livelihood insecurity are interconnected (Adhuri et al., 2016). Stacey et al. (2021) emphasize the need for sustainable livelihood strategies that address both socioeconomic vulnerability and environmental pressures. These studies imply that fisheries sustainability cannot be separated from the broader economic structure of coastal communities.

Aquaculture provides an additional dimension because it can diversify fish production away from exclusive dependence on capture fisheries. However, aquaculture is not automatically sustainable. Sustainable seafood production requires attention to production efficiency, supply chains, environmental externalities, and appropriate regulation (Belton et al., 2020). Accordingly, this study does not treat aquaculture as synonymous with ecological sustainability.

Instead, the study constructs a Fishery Sustainability Indicator (FSI) as the share of aquaculture production in total fishery production. The FSI is interpreted as a proxy for the sustainability-oriented structure of local fishery production rather than a direct measure of ecosystem health. A direct ecological sustainability assessment would require indicators such as fish-stock biomass, fishing mortality, biodiversity, habitat condition, and ecosystem resilience.

Population pressure represents another potential determinant. Population growth can increase demand for fish, employment, land, and natural resources, potentially increasing pressure on fisheries. At the same time, population growth can enlarge markets and support diversification into aquaculture, processing, services, and other activities. Its net effect is therefore an empirical question.

These issues are particularly relevant to Sumatra Island, where coastal economies differ substantially in fishing dependence, poverty, population dynamics, infrastructure, market access, and aquaculture development. Such heterogeneity makes Sumatra an appropriate setting for examining how socioeconomic pressure relates to the structure of fishery production. Although previous studies have examined fisheries dependence, poverty, livelihood vulnerability, and fisheries governance in Indonesia, limited empirical research has simultaneously examined poverty, fishing activities, and population pressure as determinants of a sustainability-oriented fishery production structure across multiple regencies and cities on Sumatra Island. This study addresses that gap using a five-year panel of 65 regencies/cities.



The study asks: To what extent do poverty, fishing activities, and population pressure affect the sustainability-oriented structure of fishery production across regencies and cities on Sumatra Island? The objective is to estimate these relationships using panel-data methods and to derive policy implications for sustainable coastal economic development.

The contribution is threefold. First, it provides subnational evidence on socioeconomic determinants of fishery production structure. Second, it integrates poverty, fishing activities, and population pressure in one empirical framework. Third, it translates the results into policy implications concerning fishing-pressure management, livelihood diversification, sustainable aquaculture, and place-based fisheries governance.

METHODOLOGY

The study uses panel data covering 65 regencies/cities on Sumatra Island during 2020–2024. The final estimation contains 324 observations, forming an unbalanced panel. Fisheries data are obtained from the Ministry of Marine Affairs and Fisheries (KKP), while poverty and population data are obtained from Statistics Indonesia (BPS). The use of official government statistics ensures that the variables are based on standardized administrative and statistical sources

Table 1. Variables and data sources

Variable	Code	Measurement	Source
Fishery Sustainability Indicator	FSI	Aquaculture production / total fishery production × 100	KKP
Poverty	POV	Percentage of population living in poverty (%)	BPS
Fishing Activities	FA	Number of fishermen	KKP
Population Pressure	PP	Population growth (%)	BPS

Source: KKP and BPS (2020–2024); authors' calculations.

With FSI calculated as:

$$FSI_{it} = [Aquaculture_{it} / (Aquaculture_{it} + Capture_{it})] \times 100 \quad (1)$$



A higher FSI indicates a larger relative contribution of aquaculture to total fishery production. The indicator is deliberately interpreted as a production-structure proxy. It does not claim that aquaculture is inherently ecologically superior to capture fisheries, because both systems can generate environmental externalities depending on technology, intensity, location, and governance.

The empirical model is specified as:

$$FSI_{it} = \beta_0 + \beta_1 POVi_t + \beta_2 FA_{it} + \beta_3 PP_{it} + u_i + \varepsilon_{it} \quad (2)$$

where FSI is the Fishery Sustainability Indicator, POV is poverty, FA is fishing activities, PP is population pressure, u_i represents the individual-specific effect, and ε_{it} is the idiosyncratic error term. Common Effect, Fixed Effect, and Random Effects specifications are compared using the Chow, Hausman, and Breusch–Pagan Lagrange Multiplier tests. Pairwise correlations are examined to identify potentially severe multicollinearity among the explanatory variables. In addition, a residual-based absolute-error regression is used as a heteroskedasticity diagnostic. The reported residual regression indicates that the main significant coefficient remains associated with fishing activities, while the poverty and population terms are statistically insignificant. Because the residual-based diagnostic is not itself a formal correction for heteroskedasticity, it is treated as a diagnostic rather than as a substitute for a robust covariance estimator.

RESULT & DISCUSSION

1. Correlation and Multicollinearity

Table 2. Correlation matrix

	POV	FA	PP
POV	1.000000	-0.167961	0.121097
FA	-0.167961	1.000000	-0.093846
PP	0.121097	-0.093846	1.000000

Source: Authors' EViews output.

The pairwise correlations are low. The largest absolute correlation is 0.168 between poverty and fishing activities. The correlation matrix therefore provides no indication of severe pairwise multicollinearity.

2. Panel Model Selection

Table 3. Panel model selection tests

Test	Statistic	Prob.	Decision
Cross-section F	29.697869	0.0000	Reject CEM

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Cross-section Chi-square	690.489436	0.0000	Reject CEM
Hausman	4.298103	0.2310	Support REM
LM Cross-section	460.1220	0.0000	Support REM
LM Both	461.2621	0.0000	Support REM

Source: Authors' EViews output.

The Chow test rejects the Common Effect Model because both cross-section probabilities are 0.0000. The Hausman test has a probability of 0.2310, so the null hypothesis is not rejected and the Random Effects Model is preferred to the Fixed Effects Model. The Breusch–Pagan LM test also supports cross-sectional random effects. Accordingly, the Random Effects Model is used as the main specification.

3. Random Effects Estimation

Table 4. Random Effects Model estimation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	37.163460	5.425351	6.849964	0.0000***
POV	-0.210216	0.338438	-0.621135	0.5350
FA	-0.000909	0.000163	-5.571055	0.0000***
PP	0.197471	0.186675	1.057837	0.2909
R-squared	0.094437			
Adjusted R-squared	0.085948			
F-statistic	11.12383			
Prob. F-statistic	0.000001			
Durbin-Watson	1.490177			
Observations	324			

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Source: Authors' EViews output



The estimated equation is:

$$FSI_{it} = 37.163460 - 0.210216POV_{it} - 0.000909FA_{it} + 0.197471PP_{it} + u_i + \varepsilon_{it}$$

The F-statistic is 11.12383 with a probability of 0.000001, indicating that the explanatory variables are jointly significant. The adjusted R-squared is 0.085948, meaning that the model explains approximately 8.59% of the observed variation in FSI. The relatively modest explanatory power also indicates that fishery production structure is influenced by other ecological, technological, market, infrastructure, and institutional factors not included in the model.

4. Poverty and Fishery Sustainability

Poverty has a coefficient of -0.210216 , but its probability is 0.5350. Thus, poverty is not statistically significant at the 10%, 5%, or 1% level, and H1 is not supported. The negative sign is nevertheless consistent with the possibility that poorer communities may have fewer livelihood alternatives and therefore greater dependence on natural-resource-based activities.

The lack of statistical significance is consistent with the more nuanced fisheries-poverty literature. Béné (2003) argues that poverty is shaped by institutional access and exclusion as well as resource conditions. Stanford et al. (2013) similarly found no significant relationship between high fishing dependency and a high proportion of poverty among fishers in West Sumatra. These findings suggest that poverty alone does not determine the structure of fishery production. Livelihood diversification, assets, markets, and local institutions may mediate the relationship.

The policy implication is that poverty alleviation should not be equated with increasing fishing capacity. Instead, interventions should expand income opportunities and human and social capital while maintaining resource safeguards (Allison & Ellis, 2001; Stacey et al., 2021).

5. Fishing Activities and Fishery Sustainability

Fishing activities have a coefficient of -0.000909 and a probability of 0.0000. The effect is therefore negative and statistically significant at the 1% level, supporting H2. Holding other variables constant, an increase of 1,000 fishermen is associated with approximately a 0.909-point reduction in FSI.

The result is consistent with the resource-pressure mechanism in fisheries economics. Greater dependence on capture fishing can increase extraction pressure when the productive capacity of the resource is constrained. Anderson et al. (2019) identify fishing effort and fishing mortality as central management dimensions, while Hilborn et al. (2020) show that more intensive fisheries management is associated with better stock status. Recent bioeconomic evidence likewise emphasizes the need to reduce excessive fishing effort when it has become incompatible with sustainable catches and incomes (Gnanapragasam et al., 2026).



The coefficient should nevertheless be interpreted carefully because the number of fishermen is not identical to fishing effort. A proper effort measure would incorporate fishing days, trips, vessel characteristics, gear, and technology. The present result therefore indicates that a larger labour base in capture fisheries is associated with a less sustainability-oriented production structure; it does not imply that every additional fisherman mechanically causes ecological degradation.

6. Population Pressure and Fishery Sustainability

Population pressure has a positive coefficient of 0.197471 and a probability of 0.2909. The coefficient is statistically insignificant, so H3 is not supported. Population growth may increase demand for fish and coastal resources, but it can also enlarge markets and encourage diversification into aquaculture, processing, services, and other sectors. The absence of a significant effect suggests that demographic change alone does not sufficiently explain differences in fishery production structure across the study area.

7. Regional Heterogeneity and Governance

The Random Effects estimation reports a cross-section standard deviation of 24.95026 and an idiosyncratic standard deviation of 10.19191, with corresponding variance shares of 0.8570 and 0.1430. The relatively large cross-sectional component indicates that unobserved differences among regencies/cities matter.

These differences may reflect geography, resource availability, fishing infrastructure, aquaculture potential, market access, institutions, and local livelihood structures. This result supports place-based governance. Halim et al. (2020) show that territorial-based fisheries management rights can provide a framework for adapting management to local conditions in Indonesia. Such approaches are consistent with the broader sustainable-livelihoods perspective, which emphasizes locally grounded and adaptive governance (Ferrol-Schulte et al., 2013).

8. Policy Implications

First, fisheries policy should prioritize management of fishing pressure rather than focusing exclusively on increasing capture-fishing participation. Monitoring effort, improving landing data, supporting sustainable gear, strengthening spatial and seasonal management, and involving fishing communities can help align fishing activity with resource productivity.

Second, livelihood diversification should be strengthened. Potential activities include sustainable aquaculture, fish processing, marketing, coastal tourism, small enterprises, vocational training, and access to finance. This is consistent with evidence that fishing-community resilience depends on more than physical fishing assets (Stanford et al., 2014; Stacey et al., 2021).



Third, aquaculture development should be environmentally responsible. A larger aquaculture share should not be treated as automatically sustainable. Sustainable seafood systems require efficient production, appropriate supply chains, environmental safeguards, and effective regulation (Belton et al., 2020).

Fourth, governance should be place-based. The large cross-sectional component indicates that uniform policies may not produce uniform outcomes. Local fisheries management should therefore consider resource conditions, fishing dependence, poverty, population dynamics, infrastructure, market access, and institutional capacity.

CONCLUSION

This study examined the effects of poverty, fishing activities, and population pressure on the sustainability-oriented structure of fishery production across 65 regencies/cities on Sumatra Island during 2020–2024. The panel-model selection tests support the Random Effects Model.

The central finding is that fishing activities have a negative and statistically significant effect on FSI. Poverty has a negative but statistically insignificant coefficient, while population pressure has a positive but statistically insignificant coefficient. Thus, fishing activities are the only explanatory variable that exhibits a statistically robust partial relationship with the sustainability-oriented production structure.

The findings contribute to the fisheries-sustainability literature by showing that socioeconomic dependence on capture fishing is more strongly associated with the production structure than poverty or population growth in the observed panel. The results also support the view that fisheries policy must integrate resource management with livelihood considerations rather than pursuing production expansion alone.

The main policy message is that sustainable fisheries development on Sumatra should combine fishing-pressure management, livelihood diversification, responsible aquaculture development, and place-based governance. The FSI should nevertheless be interpreted as a production-structure proxy, not a direct ecological measure of ecosystem health.

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