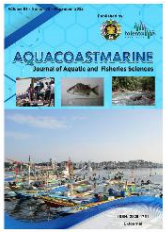
talenta PUBLISHER
AQUACOASTMARINE
Journal of Aquatic and Fisheries Sciences
Journal homepage: https://talenta.usu.ac.id/aquacoastmarine



Livelihood Imbalance Under Dual Marine Governance: Case Study from Aceh Besar Marine Protected Area

Ketimpangan Mata Pencaharian Pada Kerangka Tata Kelola Laut Ganda: Studi Kasus Kawasan Konservasi Perairan Aceh Besar

Rian Firdaus[*1,2], Fredinan Yulianda[1], Zairion[1,3], Gatot Yulianto[1]
[1]*Study Program of Coastal and Marine Resources Management, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor 16680, West Java, Indonesia*
[2]*Department of Fisheries, Politeknik Indonesia Venezuela, Aceh Besar 23371, Aceh, Indonesia*
[3]*Center for Coastal and Marine Resources Management Study, IPB University, Bogor 16127, West Java, Indonesia*

[*]Corresponding Author: rianfirdaus@apps.ipb.ac.id

ARTICLE INFO

Article history:
Received 12 January 2026
Revised 08 May 2026
Accepted 20 May 2026

Available online 11 November 2026

E-ISSN: 2829-1751

How to cite:
Firdaus, R., Yulianda, F., Zairion, Yulianto, G. (2026). Livelihood Imbalance Under Dual Marine Governance: Case Study from Aceh Besar Marine Protected Area. *AQUACOASTMARINE: J.Aquat.Fish.Sci*, 5(2), 172-182.

This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International.
10.32734/jafs.v5i2.25404

ABSTRACT

Small-scale fisheries in island regions are shaped not only by ecological conditions but also by culturally embedded governance systems. This study examines livelihood structure within the Aceh Besar Marine Protected Area (MPA), Indonesia, where formal conservation regulations coexist with the customary maritime institution of Panglima Laot. Using the Sustainable Livelihoods Approach, we assessed five livelihood capitals (human, natural, social, financial, physical) through a structured survey of 20 small-scale fishers. Structural balance was quantified using the Livelihood Balance Index (LBI), the coefficient of variation across capital means. The results show that physical, social and human capital are relatively strong (scores 3.74-3.88), whereas natural and financial capital are markedly weaker (3.13-3.20). The LBI value of 0.103 indicates a low-to-moderate structural imbalance among the five capitals. Consequently, although the average livelihood condition appears "good", the systematic deficit in natural and financial capital reveals a latent vulnerability that is not visible from mean scores alone. These findings imply that MPA management in dual-governance contexts must integrate ecological restoration with targeted financial inclusion programmes to strengthen household resilience. This study demonstrates that evaluating the configuration of livelihood assets, not only average welfare levels is essential for diagnosing hidden vulnerabilities in island communities.

Keyword: Livelihood Balance Index; Marine Protected Area; Panglima Laot; Small-scale fisheries; Sustainable Livelihoods Approach.

ABSTRAK

Perikanan skala kecil di wilayah kepulauan tidak hanya dipengaruhi oleh kondisi ekologi, tetapi juga oleh sistem tata kelola yang tertanam dalam budaya. Penelitian ini mengkaji struktur mata pencaharian di Kawasan Konservasi Perairan (KKP) Aceh Besar, Indonesia, di mana peraturan konservasi formal berdampingan dengan lembaga maritim adat Panglima Laot. Dengan menggunakan Pendekatan Mata Pencaharian Berkelanjutan, kami menilai lima modal mata pencaharian (manusia, alam, sosial, keuangan, fisik) melalui survei terstruktur terhadap 20 nelayan skala kecil. Keseimbangan struktural diukur dengan Indeks Keseimbangan Mata Pencaharian (LBI), koefisien variasi dari nilai tengah kelima modal. Hasil menunjukkan bahwa modal fisik, sosial, dan manusia relatif kuat (skor 3,74-3,88),

sedangkan modal alam dan keuangan jauh lebih lemah (3,13-3,20). Nilai LBI sebesar 0,103 menunjukkan ketidakseimbangan struktural tingkat rendah-hingga-sedang di antara kelima modal tersebut. Dengan demikian, meskipun kondisi mata pencaharian rata-rata tampak "baik", defisit sistematis pada modal alam dan keuangan mengungkapkan kerentanan tersembunyi yang tidak terlihat dari skor rata-rata saja. Temuan ini mengimplikasikan bahwa pengelolaan KKP dalam konteks tata kelola ganda harus mengintegrasikan restorasi ekologi dengan program inklusi keuangan yang terarah untuk memperkuat ketahanan rumah tangga. Studi ini menunjukkan bahwa mengevaluasi konfigurasi aset mata pencaharian bukan hanya tingkat kesejahteraan rata-rata, sangat penting untuk mendiagnosis kerentanan tersembunyi di komunitas pulau.

Kata kunci: Indeks Keseimbangan Mata Pencaharian; Kawasan Konservasi Perairan; Panglima Laot; Pendekatan Mata Pencaharian Berkelanjutan; Perikanan skala kecil.

1. Introduction

Small-scale fisheries (SSF) are fundamental to livelihoods, food security, and cultural identity in coastal and island regions worldwide (Béné et al., 2016; Weeratunge et al., 2014). However, the integration of SSF into broader marine governance frameworks, such as those associated with the 'blue economy,' remains contested and often marginalizes the interests of small-scale fishers (Cohen et al., 2019). In many developing countries, SSF constitute the majority of the fishing workforce and make substantial contributions to local nutrition and poverty reduction (Béné et al., 2016). Beyond their economic importance, small-scale fisheries are embedded in kinship networks, social norms, and place-based maritime practices that structure island societies (Weeratunge et al., 2014). In archipelagic settings, fishing represents not only a productive activity but also a culturally grounded system of governance and social organization.

Small-island communities are often characterized by spatial constraints, limited livelihood diversification, strong dependence on marine ecosystems, and exposure to climatic and environmental variability. Such vulnerability necessitates context-specific livelihood adaptation strategies, as demonstrated in small island communities in the Philippines where enhancing financial capacity and diversifying income streams are critical for building resilience (Hilvano, 2025). These structural conditions heighten vulnerability when resource productivity declines or when conservation policies restrict access to fishing grounds. Such vulnerability is often exacerbated by governance arrangements that prioritize resource stability over social equity, potentially reinforcing existing inequalities within fishing communities (Fabinyi et al., 2015). Climate-related reef degradation, for instance, can reduce fisheries productivity and weaken adaptive capacity in coastal communities (Cinner et al., 2012). Marine Protected Areas (MPAs) have therefore been widely adopted to restore ecosystem integrity and sustain fisheries. Global syntheses consistently show that well-enforced no-take reserves increase biomass, density, and species richness relative to unprotected areas (Halpern, 2003; Lester, 2009). Nevertheless, the social and economic effects of MPAs remain uneven and context-specific, with benefits and costs distributed differently across fishing communities (Mascia et al., 2010; Sowman & Sunde, 2018). Across Southeast Asia, ecological recovery within MPAs has in several cases been accompanied by social tension, particularly where restrictions constrain communities with few alternative income sources. Empirical studies demonstrate that perceptions of fairness, participation, and institutional trust are central to compliance and long-term governance legitimacy (Bennett & Dearden, 2014; Gurney et al., 2016). Such dynamics are especially salient in archipelagic contexts where customary institutions coexist with formal state regulatory frameworks (Jentoft et al., 2007).

Aceh provides a distinctive case of this dual governance structure. Coastal waters have long been regulated through the customary maritime institution of Panglima Laot, which oversees fishing zones, temporal restrictions, and conflict resolution among fishers (Wilson & Linkie, 2012). This customary authority operates alongside formal Marine Protected Area (MPA) regulations, producing a layered governance system in which state and traditional institutions function simultaneously. Within this arrangement, livelihood outcomes are shaped not only by ecological and market conditions but also by culturally embedded institutional norms. The Sustainable Livelihoods Approach (SLA) offers a multidimensional framework for examining how households mobilize human, natural, social, financial, and physical capital within broader policy and institutional environments (Allison, 2001). Its application in tropical coastal social-ecological systems has proven particularly valuable for understanding the complex interactions between resource-dependent communities and their environment (Ferrol-Schulte et al., 2013). Although widely applied in fisheries research, most SLA-based analyses emphasize average capital scores and give limited attention to the structural configuration of livelihood assets. As a result, imbalances among

capital dimensions and the latent vulnerabilities they generate are often overlooked. In small-island systems that depend heavily on marine resources, disproportional asset distribution can undermine resilience even when aggregate livelihood scores appear satisfactory (Cinner et al., 2012). Strong social cohesion and adequate physical infrastructure may coexist with declining natural capital or limited financial buffering capacity. Such structural asymmetry can weaken long-term livelihood sustainability and erode the social legitimacy of conservation governance (Mascia et al., 2010). Empirical assessments that quantitatively evaluate livelihood balance within culturally embedded marine governance systems remain scarce, particularly in Indonesia.

This study addresses this gap by introducing the Livelihood Balance Index (LBI) as a quantitative measure of structural asymmetry among livelihood capitals and applying it within a dual-governance island MPA where formal conservation policies intersect with the customary institution of Panglima Laot. By conceptualizing livelihood balance as a measurable structural property rather than relying solely on mean capital scores, this study offers a refined analytical lens for evaluating resilience in archipelagic conservation contexts. Because livelihood capitals in SLA are commonly operationalized as composite (formative) indices, the structural configuration approach aligns with index-based measurement rather than reflective psychometric scale development (Diamantopoulos & Winklhofer, 2001). This distinction is critical, as formative measurement models require different validation procedures than reflective models, particularly when constructing composite indices such as the Livelihood Balance Index (Coltman et al., 2008). Specifically, this study aims to: (i) assess the condition of the five livelihood capital dimensions among small-scale fishers; (ii) test statistical differences across capital categories; (iii) quantify structural imbalance using the Livelihood Balance Index; and (iv) examine the association between livelihood strategies and overall livelihood outcomes. Through integrating structural livelihood analysis with culturally grounded marine governance, this research advances understanding of conservation–livelihood dynamics in island systems.

2. Materials and Methods

2.1. Location and Characteristics of the Study Area

This study was conducted in the Aceh Besar Marine Protected Area (MPA), locally designated as Kawasan Konservasi Perairan (KKP), on the northern coast of Sumatra, Indonesia. The MPA was proposed by the Aceh Besar local government in 2018 and was formally designated by the central government through a ministerial decree issued by the Ministry of Marine Affairs and Fisheries (Decree No. 78/KEPMEN-KP/2020) establishing the Aceh Besar Marine Protected Area. This area encompasses coral reef, seagrass bed, and mangrove ecosystems that support small-scale fishing activities. Six coastal villages located within or directly adjacent to the conservation area were selected as survey locations, namely Lampageu, Lamteungoh, Lamtutui, Lam Awee, Lambadak, and Meunasah Tuha. This region is subject to dual marine governance, where formal conservation area regulations coexist with the traditional institution of Panglima Laot.

This region has a tropical monsoon climate with a rainy season lasting from September to March and a dry season from April to August. The majority of the population is Muslim and has a long-standing tradition of artisanal fishing. Institutionally, this region operates under a dual governance system, where formal conservation policies coexist with the traditional maritime authority of the Panglima Laot. The customary governance role of Panglima Laot in Aceh has been described in the literature as an adat-based institutional arrangement that interacts with formal marine management frameworks (Bustamam-Ahmad, 2017; Wilson & Linkie, 2012).

2.2. Survey Design and Data Collection

A cross-sectional survey was conducted from December 2024 to January 2025 via face-to-face interviews using a structured questionnaire. The study population comprised small-scale fishers operating in or around the Aceh Besar MPA. Twenty fishers were selected using convenience sampling (Babbie, 2016) based on the following criteria: (i) active fishing ≥4 days/week; (ii) aged ≥18 years; (iii) local residence ≥3 years; and (iv) informed consent. The sample size is justified by the exploratory, site-specific nature of the study, resource constraints, and representation of ~40% of the estimated fisher population (<50) (Lakens, 2022). Consequently, findings are exploratory and hypothesis-generating; statistical power is limited, and generalization beyond the study site is not warranted. All respondents shared similar characteristics (male, Muslim, vessels ≤5 GT, nearshore fishing) to reduce background variation. Sample distribution per village: Lampageu (n=4), Lamteungoh (n=3), Lamtutui (n=3), Lam Awee (n=4), Lambadak (n=3), Meunasah Tuha (n=3). The questionnaire was developed based on the Sustainable Livelihoods Approach (Allison, 2001;

Ferrol-Schulte et al., 2013) and adapted to the local context. Content validity was ensured by mapping items to the five SLA capitals. Three experts (marine fisheries, conservation, social-ecology) independently assessed item relevance, clarity, and cultural appropriateness; revisions preserved local context without altering core constructs. A pilot test with five fishers from a non-study village resulted in minor wording adjustments (e.g., insurance item examples). Because SLA capitals are formative composites (Coltman et al., 2008; Diamantopoulos & Winklhofer, 2001), the instrument captured heterogeneous attributes within each capital. The full questionnaire is provided in Supplementary Data 1.

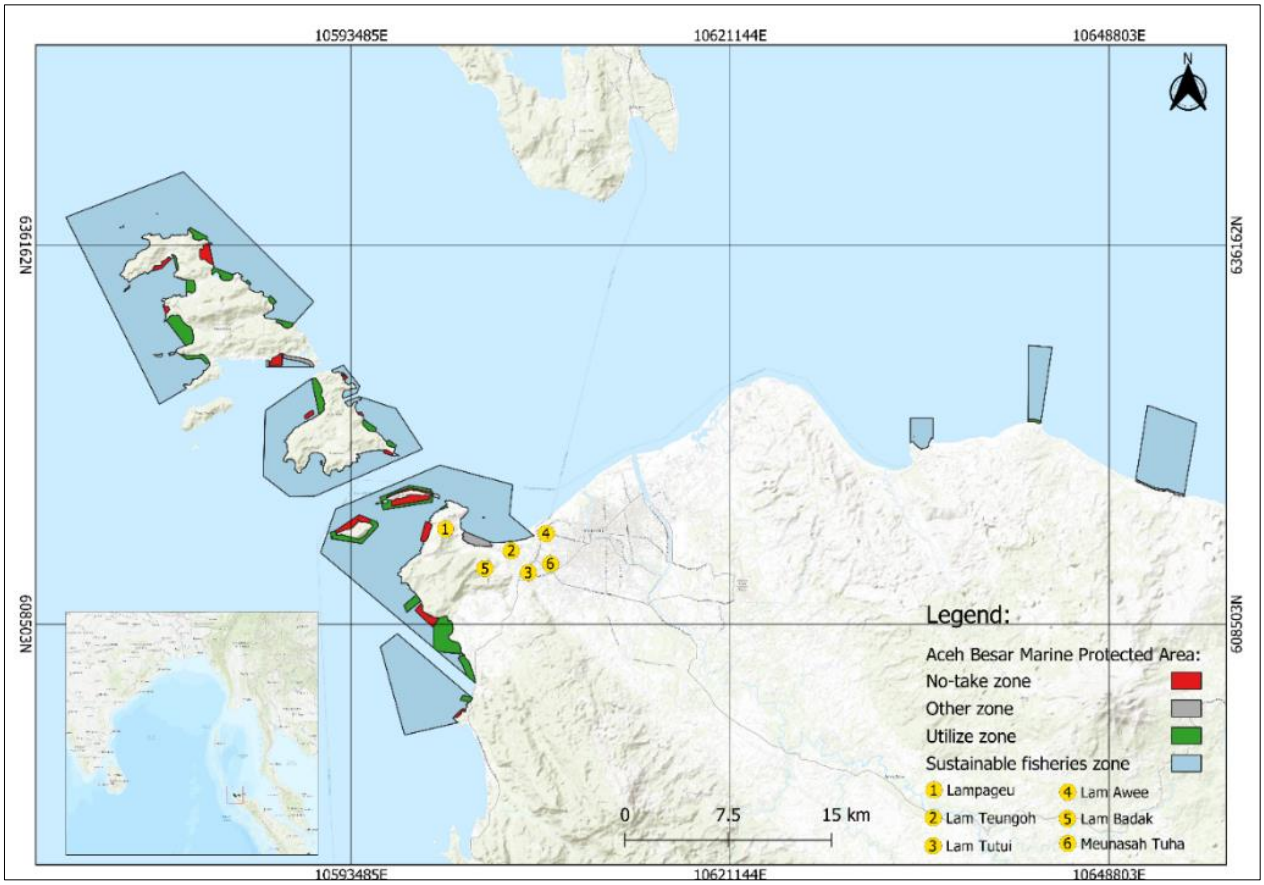


Figure 1. Study area map showing the Aceh Besar Marine Protected Area and survey villages in northern Sumatra, Indonesia. The map indicates the six coastal villages where small-scale fishers were surveyed (Lampageu, Lamteungoh, Lamtutui, Lam Awee, Lambadak, and Meunasah Tuha), the boundaries of marine protected areas, and the major coastal ecosystems (coral reefs, seagrass beds, and mangrove forests).

2.3. Data Analysis

The data were analyzed using IBM SPSS Statistics 22. Descriptive statistics (mean and standard deviation) were calculated for each dimension of capital. All livelihood capital values (human, natural, social, financial, and physical) were derived solely from information reported by the fisher respondents through the structured questionnaire. This approach is consistent with the Sustainable Livelihoods Approach when applied as a diagnostic tool to capture local users' experiential knowledge of resource availability and ecosystem condition (Allison, 2001; Ferrol-Schulte et al., 2013). For the natural capital component specifically, fishers were asked to rate perceived fish stock abundance, catch trends, coral reef condition, mangrove health, and access to non-fish resources on a 1-5 Likert scale.

The natural capital score therefore, reflects perceived ecosystem condition not objectively measured ecological indicators. Differences between the five dimensions of capital were tested using the Friedman test, given that the data were ordinal and the sample size was relatively small. If the results were significant, a paired Wilcoxon signed-rank test with Bonferroni correction was performed. The relationship between livelihood strategies (fishing only vs fishing and agriculture) and livelihood outcomes was analyzed using the Mann-Whitney U test. To assess the level of structural balance between capitals, the Livelihood Balance Index (LBI) was computed as the coefficient of variation across the five capital means (HC, NR, SC, FC, PC). A lower LBI value indicates a more balanced livelihood structure. To quantify structural balance among

the five livelihood capitals, the Livelihood Balance Index (LBI) was computed as the coefficient of variation across the capital means. Let Ci denote the mean score of each livelihood capital (i = 1,…,5), and let $\bar{C}$ represent the overall mean across capitals. The index is defined as:

$$LBI = \frac{SD\ (C_1, C_2, C_3, C_4, C_5)}{\bar{C}}$$

Where SD is the sample standard deviation across the five capital means and k=5 is the number of livelihood capitals. Lower LBI values indicate more balanced livelihood structures, whereas higher values reflect greater imbalance among livelihood assets.

3. Results and Discussion

3.1. Livelihood Capital Profile

The overall livelihood capital score averaged 3.56 (SD = 0.12; range = 3.08–3.79), indicating a generally good but uneven livelihood condition. Among the five dimensions, physical capital ranked highest (3.88 ± 0.28), followed by social capital (3.86 ± 0.21) and human capital (3.74 ± 0.23). Financial capital (3.19 ± 0.25) and natural capital (3.13 ± 0.22) recorded lower mean values (Table 1). Based on the predefined classification thresholds, human, social, and physical capitals were categorized as "good," whereas natural and financial capitals remained in the "moderate" category. The radar diagram (**Figure 2**) illustrates the livelihood asset configuration, showing an asymmetric profile in which the physical–social–human axes extend further outward compared to the natural-financial axes.

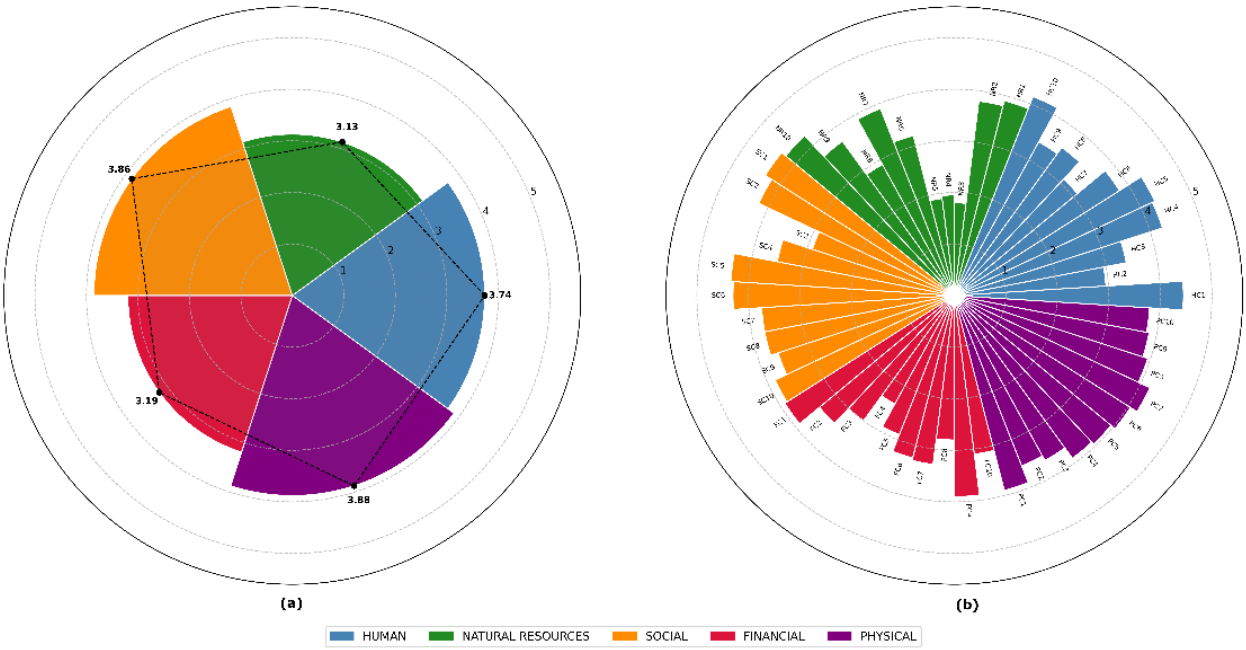


Figure 2. Livelihood asset profile of small-scale fishers in the Aceh Besar Marine Protected Area (n = 20). The five axes represent Human Capital (HC), Natural Resources (NR), Social Capital (SC), Financial Capital (FC), and Physical Capital (PC), scored on a 1–5 scale. The radar shape illustrates an asymmetric configuration, with higher scores on physical, social, and human capital relative to natural and financial capital.

Table 1. Descriptive statistics of livelihood capital dimensions

Capital	Mean	Median	SD	Variance	Min	Max	Range	Skewness	Kurtosis	CV (%)
HC	3.735	3.75	0.225	0.051	3.4	3.9	0.5	-0.101	-1.35	6.035
NR	3.13	3.15	0.223	0.05	2.7	3.4	0.7	0.13	-0.879	7.114
SC	3.855	3.9	0.206	0.043	3.4	4.1	0.7	-0.784	-0.748	5.354
FC	3.195	3.2	0.25	0.063	2.8	3.8	1	0.341	-0.297	7.831
PC	3.880	3.9	0.278	0.077	3.1	4.2	1.1	-1.14	0.985	7.174
Overall	3.559	3.53	0.122	0.015	3.08	3.79	0.71	0.305	-1.254	3.428

*HC: Human Capital; NR: Natural Resources; SC: Social Capital; FC: Financial Capital; PC: Physical Capital.

3.2. Capital Structure and Balance

Human capital (3.74) demonstrated strong competency in local ecological knowledge (4.4) and conservation awareness (4.2). However, lower scores were observed in formal education (3.3), health condition (3.1), and knowledge of MPA regulations (3.5), indicating uneven capacity within this dimension. In contrast, natural capital recorded one of the lowest mean scores (3.13). Fishers perceived insufficient fish stocks (2.95), declining catches (3.20), and limited availability of non-fish resources (2.85). Ecosystem conditions were rated as moderately stressed for coral reefs (3.05) and mangroves (3.15). Although regulatory awareness (3.75) and conservation access (3.80) were relatively high, this awareness did not correspond to stronger perceptions of resource availability. Climate concern also scored relatively high (4.15).

Social capital showed comparatively strong performance (3.86), particularly in communication (4.30), collaboration (4.25), and community acceptance (4.20). Nevertheless, indicators related to formal institutional integration were lower, including government relations (3.65), participation in decision-making (3.50), and NGO support (3.40). Financial capital remained comparatively weak (3.20). While daily income (3.25) and income diversification (3.65) suggested moderate stability, savings (2.70), credit access (2.95), and income stability (2.90) were constrained. Insurance coverage (1.85), the lowest score among all indicators, reflected limited risk protection. Physical capital ranked highest (3.88), with relatively strong boat condition (3.95), fishing gear (3.90), port infrastructure (3.85), and market access (3.80), although storage facilities (3.20) and technology adoption (2.45) remained limited.

Overall, the distribution of scores revealed a distinct clustering pattern. Natural and financial capital formed a lower-value cluster, whereas social and physical capital constituted a higher-value cluster; human capital showed statistically significant differences relative to both natural and financial capital and was closely aligned with the higher-value cluster. Human capital occupied an intermediate position within this configuration. Statistical testing supported this structural differentiation. The Friedman test confirmed significant differences among the five capital dimensions ($\chi^2 = 65.81$, df = 4, $p < 0.001$; Kendall's W = 0.823). Post-hoc Wilcoxon signed-rank tests with Bonferroni correction identified seven significant pairwise differences, primarily separating natural and financial capital from social and physical capital (**Table 2**).

Table 2. Pairwise comparisons of livelihood capital dimensions.

Comparison	Direction	p-value	Significance
HC vs NR	HC > NR	< 0.001	***
HC vs FC	HC > FC	< 0.001	***
NR vs SC	NR < SC	< 0.001	***
NR vs PC	NR < PC	< 0.001	***
SC vs FC	SC > FC	< 0.001	***
FC vs PC	FC < PC	< 0.001	***
HC vs SC	HC < SC	0.0017	**
HC vs PC	-	0.024	ns
NR vs FC	-	0.130	ns
SC vs PC	-	0.640	ns

*** $p < 0.001$; ** $p < 0.005$; ns = $p \geq 0.005$ (Bonferroni-adjusted)

To further quantify the structural configuration of livelihood assets, the Livelihood Balance Index (LBI) was calculated using the formula described in Section 2.3. The resulting LBI value is presented in **Table 3**.

Table 3. Livelihood Balance Index (LBI) calculation summary.

Livelihood Capital	Mean (Ci)
Human Capital (HC)	3.735
Natural Resources (NR)	3.130
Social Capital (SC)	3.855
Financial Capital (FC)	3.195
Physical Capital (PC)	3.880
Overall Mean $\bar{C}$	3.559
SD	0.367
LBI	0.103

As shown in Table 3, the standard deviation across the five livelihood capital means was 0.367. Dividing this value by the overall mean (3.559) produced a Livelihood Balance Index of 0.103, indicating a low-to-moderate level of structural asymmetry. Significant pairwise differences ($p < 0.001$) confirm a systematic: social/physical capital outrank natural/financial capital. Their equally weak condition ($p = 0.130$) forms a

joint bottleneck, implying single-domain interventions will fail. Mann-Whitney U tests indicated that fishers combining capture fisheries with agriculture exhibited significantly higher overall livelihood scores than fisheries-only households ($U = 5.0$, $p = 0.012$). However, this finding should be interpreted cautiously due to the very small size of the diversified subgroup ($n = 4$) and should therefore be considered exploratory rather than conclusive.

3.3. Structural Imbalance as Latent Vulnerability

This exploratory study provides initial insights suggesting that livelihood vulnerability in a small island MPA operating under dual governance may not necessarily arise from uniformly low welfare conditions, but rather from structural imbalance among livelihood capitals. Although the overall livelihood score was categorized as "good," the distribution of capital dimensions was uneven. Human, social, and physical capital were relatively strong, whereas natural and financial capital were comparatively weaker. This configuration indicates latent vulnerability that may not be visible when only average scores are considered, particularly in systems where climate and ecosystem change can reduce fisheries productivity and adaptive capacity (Cinner et al., 2012).

The Livelihood Balance Index (LBI = 0.103) confirms measurable, though not extreme, structural asymmetry among livelihood assets. In small-island systems characterized by high dependence on marine resources, weakened natural capital combined with limited financial buffering capacity can reduce adaptive flexibility. Even when communities possess strong social cohesion and adequate physical assets, declining resource availability and limited financial resilience may constrain long-term livelihood stability. Thus, balance among capital dimensions is a critical component of livelihood sustainability. These patterns are consistent with evidence that MPAs function as linked social-ecological systems in which ecological outcomes and livelihood dynamics interact (Pollnac, 2010). The relatively strong performance of social capital suggests cohesive community structures and effective local cooperation. This finding aligns with global evidence that social capital, particularly when combined with strong leadership, is one of the strongest predictors of successful fisheries management outcomes (Gutiérrez et al., 2011). However, lower scores related to formal participation and institutional support indicate a potential gap between internal solidarity and integration within broader governance systems. Participation in community-based MPA governance is shaped by multiscale socioeconomic and institutional factors rather than community cohesion alone, which can create uneven engagement across actors and levels (Gurney et al., 2016). Moreover, governance legitimacy in co-management contexts is influenced by pre-existing institutional structures and network relations (Bodin & Crona, 2009; Sandström et al., 2014).

In the Aceh context, where marine governance involves both formal conservation regulations and the customary authority of Panglima Laot, institutional alignment becomes particularly important (Wilson & Linkie, 2012). Similar dynamics have been observed elsewhere in Indonesia, such as the awig-awig customary system in Lombok, where the integration of traditional institutions with formal management has been critical for coral reef governance (Satria et al., 2006). Recent studies have further discussed Panglima Laot as an adat-based maritime institution and its relevance for fisheries governance and community-based management in Aceh and surrounding islands (Bustamam-Ahmad, 2017; Miswar, 2019; Rahmah, 2021). The institution has also been examined in relation to community surveillance and the integration of customary mechanisms into marine resource monitoring (Syahputra, 2018). Governance analyses emphasize that MPAs function as governance systems, and legitimacy and compliance depend on how rules are designed, communicated, and perceived as fair (Jentoft et al., 2007; Nielsen, 2003). Without coordination between customary and state-based management systems, conservation measures may unintentionally exacerbate economic pressure on small-scale fishers and undermine support for conservation (Bennett & Dearden, 2014; Sowman & Sunde, 2018). The exploratory finding that diversified households (fisheries combined with agriculture) achieved higher overall livelihood scores suggests that livelihood diversification may enhance resilience. This is consistent with broader research showing that diversification is a key strategy for building resilience in coastal communities, enabling households to spread risk and cope with environmental and economic shocks (Béné et al., 2012). However, given the small sample size, this result should be interpreted cautiously. Nonetheless, it underscores the broader implication that conservation strategies in small-island MPAs should integrate ecological recovery with financial strengthening and diversification pathways, consistent with calls to increase the role of local communities and social considerations in MPA implementation (Ferse et al., 2010; Mascia et al., 2010).

3.4. Consequences of Sustained Decline in Natural and Financial Capital

If natural capital and financial capital continue to decline simultaneously in the Aceh Besar MPA, the current structural imbalance (LBI = 0.103) is likely to escalate into a cascading system collapse. Natural capital already perceived as weak (mean score 3.13), with fishers reporting insufficient fish stocks (2.95) and declining catches (3.20) would deteriorate further. This decline would reduce catch per unit effort, forcing fishers to invest more time and fuel to obtain the same yield. Because financial capital is also limited (mean score 3.20), characterized by low savings (2.70), poor credit access (2.95), and minimal insurance coverage (1.85), households lack any buffer against rising operational costs. Consequently, fishers may fall into a poverty trap: they would be compelled to sell productive assets, reduce household consumption, and potentially adopt destructive fishing practices such as blast fishing or fine-mesh nets, despite relatively high conservation awareness (4.2). Such behavior would accelerate habitat degradation, further suppress fish stocks and close a negative feedback loop. As resources become scarcer, currently strong social capital (3.86) would erode. Trust and cooperation would give way to zero-sum competition, conflicts among fishers would increase, and the customary authority of Panglima Laot would lose its legitimacy as a conflict-resolution mechanism. Younger fishers would likely out-migrate, leaving behind an aging, more vulnerable population. At the governance level, the MPA would risk becoming a "paper park" legally designated but ecologically degraded and socially contested. State authorities might respond punitively, while customary leaders lose their mediating role, polarizing the dual governance system. In summary, sustained decline in natural and financial capitals does not merely reduce welfare, it triggers mutually reinforcing failures across ecological, economic, social, and institutional domains, leading to irreversible livelihood collapse.

3.5. Cycle of Livelihood Recovery under Improved Natural and Financial Capital

Conversely, if natural capital and financial capital are systematically strengthened through targeted interventions, the same causal structure can generate a virtuous cycle of livelihood recovery. Ecological restoration such as coral reef rehabilitation, mangrove replanting, and stock enhancement would increase fish biomass and biodiversity. Improved natural capital would raise catch per unit effort, reducing the time and fuel needed to achieve adequate catches. Lower operational costs would ease economic pressure on households. When financial capital is simultaneously strengthened for example, through microinsurance schemes, savings groups, credit for gear upgrades, and diversification loans households gain a buffer against temporary income shortfalls. With reduced economic desperation, fishers can afford to comply with MPA regulations, invest in selective and sustainable fishing gear, and practice long-term stewardship rather than short-term survival strategies. Reduced illegal fishing and habitat damage allow ecosystems to regenerate further, closing a positive feedback loop. As fish stocks recover, competition among fishers decreases, fostering trust, information sharing, and collective action. The Panglima Laot institution, now perceived as legitimate and effective, can mediate disputes and enforce customary rules without resistance. Younger fishers perceive viable futures in the community, reducing out migration and preserving intergenerational knowledge. At the governance level, formal MPA authorities and customary leaders operate synergistically: state agencies provide legal backing and technical support, while Panglima Laot ensures local compliance and social acceptance. The MPA would thus transform from a potential "paper park" into a functioning social-ecological system that delivers both conservation and livelihood benefits. Under this scenario, the Livelihood Balance Index would shift from 0.103 toward a more balanced configuration (target LBI < 0.07), where natural and financial capitals no longer lag behind social and physical assets. Proactively constructing this virtuous cycle is therefore essential to prevent the worst-case collapse and to build long-term resilience in dual-governance island MPAs.

3.6. Limitations and Future Research

This study is limited by its small sample size (n = 20) and cross-sectional design, which may constrain generalizability. Additionally, all livelihood capital values, particularly natural capital, are based solely on fishers' self-reported perceptions without independent biophysical or financial verification, which may introduce recall or desirability bias. Nevertheless, this study provides an initial quantitative assessment of livelihood structure within a culturally embedded dual-governance MPA context. Future research should employ larger, longitudinal samples, incorporate qualitative methods to explore causal mechanisms, and examine how different levels of institutional alignment between Panglima Laot and formal MPA authorities affect livelihood balance over time.

4. Conclusion

As an exploratory study, this research provides preliminary evidence that the livelihoods of small-scale fishers in the Aceh Besar Marine Protected Area are not uniformly weak but structurally imbalanced. While human, social, and physical capital appear relatively strong, limitations in natural and financial capital suggest a latent vulnerability that could undermine long-term resilience. In small-island settings characterized by dual governance systems where formal conservation policies intersect with customary institutions such as Panglima Laot, sustainable management therefore requires not only ecological protection but also concerted efforts to strengthen financial resilience and institutional coordination. Strengthening natural capital and enhancing economic buffering mechanisms are essential to ensure that existing social cohesion and community stability are not eroded by future ecological and economic pressures.

Acknowledgements

The authors would like to sincerely thank the Indonesian Education Scholarship (BPI), the Center for Higher Education Funding and Assessment, the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (PUSLAPDIK-KEMDIKTISAINTEK), and the Indonesia Endowment Fund for Education (LPDP) for their support in funding this doctoral research under contract No. (00581/J5.2.3/BPI.06/9/2022).

Conflict of Interest

No potential conflict of interest was reported by the authors.

References

Allison, E. H. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy*, *25*(5), 377–388. https://doi.org/10.1016/S0308-597X(01)00023-9

Babbie, E. (2016). *The practice of social research*. Cengage Learning.

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., Campling, L., Leschen, W., Little, D., Squires, D., Thilsted, S. H., Troell, M., & Williams, M. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: Assessing the current evidence. *World Development*, *79*, 177–196. https://doi.org/10.1016/j.worlddev.2015.11.007

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Not a retreat: The role of livelihood diversification in building resilience in coastal communities. In *Global Environmental Change* (Vol. 22, Issue 1). https://doi.org/10.1016/j.gloenvcha.2011.09.018

Bennett, N. J., & Dearden, P. (2014). Why local people do not support conservation: Community perceptions of marine protected area livelihood impacts, governance and management in Thailand. *Marine Policy*, *44*, 107–116. https://doi.org/10.1016/j.marpol.2013.08.017

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change*, *19*(3), 366–374. https://doi.org/10.1016/j.gloenvcha.2009.05.002

Bustamam-Ahmad, K. (2017). A study of Panglima La'Ōt: An 'Adat institution in Aceh. *Al Jami Ah*, *55*(1), 155–188. https://doi.org/10.14421/ajis.2017.551.155-188

Cinner, J. E., McClanahan, T. R., Graham, N. A. J., Daw, T. M., Maina, J., Stead, S. M., Wamukota, A., Brown, K., & Bodin, Ö. (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, *22*(1), 12–20. https://doi.org/10.1016/j.gloenvcha.2011.09.018

Cohen, P. J., Allison, E. H., Andrew, N. L., Cinner, J., Evans, L. S., Fabinyi, M., Garces, L. R., Hall, S. J., Hicks, C. C., Hughes, T. P., Jentoft, S., Mills, D. J., Masu, R., Mbaru, E. K., & Ratner, B. D. (2019). Securing a just space for small-scale fisheries in the blue economy. *Frontiers in Marine Science*, *6*, 171. https://doi.org/10.3389/fmars.2019.00171

Coltman, T., Devinney, T. M., Midgley, D. F., & Venaik, S. (2008). Formative versus reflective measurement models: Two applications of formative measurement. *Journal of Business Research*, *61*(12), 1250–1262. https://doi.org/10.1016/j.jbusres.2008.01.013

Diamantopoulos, A., & Winklhofer, H. M. (2001). Index construction with formative indicators: An alternative to scale development. *Journal of Marketing Research*, *38*(2), 269–277. https://doi.org/10.1509/jmkr.38.2.269.18845

Fabinyi, M., Foale, S., & Macintyre, M. (2015). Managing inequality or managing stocks? An ethnographic perspective on the governance of small-scale fisheries. *Fish and Fisheries*, *16*(3), 471–485. https://doi.org/10.1111/faf.12069

Ferrol-Schulte, D., Wolff, M., Ferse, S., & Glaser, M. (2013). Sustainable Livelihoods Approach in tropical coastal and marine social–ecological systems: A review. *Marine Policy*, *42*, 253–258. https://doi.org/10.1016/j.marpol.2013.03.007

Ferse, S. C. A., Máñez Costa, M., Máñez, K. S., Adhuri, D. S., & Glaser, M. (2010). Allies, not aliens: Increasing the role of local communities in marine protected area implementation. *Environmental Conservation*, *37*(1), 23–34. https://doi.org/10.1017/S0376892910000172

Gurney, G. G., Cinner, J. E., Sartin, J., Pressey, R. L., Ban, N. C., Marshall, N. A., & Prabuning, D. (2016). Participation in devolved commons management: Multiscale socioeconomic factors related to individuals' participation in community-based management of marine protected areas in Indonesia. *Environmental Science & Policy*, *61*, 212–220. https://doi.org/10.1016/j.envsci.2016.04.015

Gutiérrez, N. L., Hilborn, R., & Defeo, O. (2011). Leadership, social capital and incentives promote successful fisheries. *Nature*, *470*(7334), 386–389. https://doi.org/10.1038/nature09689

Halpern, B. S. (2003). THE IMPACT OF MARINE RESERVES: DO RESERVES WORK AND DOES RESERVE SIZE MATTER? In *Ecological Applications* (Vol. 13, Issue 1). http://www.wcmc.org.uk:80/marine/data/

Hilvano, N. (2025). *Small Island Livelihood Adaptation Strategies : e Case of Mina-anod Island , Llorente , Eastern Samar ,*. 54–72.

Jentoft, S., van Son, T. C., & Bjørkan, M. (2007). Marine protected areas: A governance system analysis. *Human Ecology*, *35*(5), 611–622. https://doi.org/10.1007/s10745-007-9125-6

Lester, S. E. (2009). Biological effects within no-take marine reserves: A global synthesis. *Marine Ecology Progress Series*, *384*, 33–46. https://doi.org/10.3354/meps08029

Mascia, M. B., Claus, C. A., & Naidoo, R. (2010). Impacts of marine protected areas on fishing communities. *Conservation Biology*, *24*(5), 1424–1429. https://doi.org/10.1111/j.1523-1739.2010.01523.x

Miswar, E. (2019). The effectivenes of Panglima Laot of Simeulue and its coherence with fisheries management industry based on EAFM (Ecosystem Approach to Fisheries Management). In *Iop Conference Series Earth and Environmental Science* (Vol. 348, Issue 1). https://doi.org/10.1088/1755-1315/348/1/012093

Nielsen, J. R. (2003). An analytical framework for studying: Compliance and legitimacy in fisheries management. *Marine Policy*, *27*(5), 425–432. https://doi.org/10.1016/S0308-597X(03)00022-8

Pollnac, R. (2010). Marine reserves as linked social-ecological systems. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(43), 18262–18265. https://doi.org/10.1073/pnas.0908266107

Rahmah, A. (2021). The role of panglima laot towards fisheries management based on ecosystem approach in Banda Aceh City. In *Iop Conference Series Earth and Environmental Science* (Vol. 674, Issue 1). https://doi.org/10.1088/1755-1315/674/1/012100

Sandström, A., Crona, B., & Bodin, Ö. (2014). Legitimacy in co-management: The impact of preexisting structures, social networks and governance strategies. *Environmental Policy and Governance*, *24*(1), 60–76. https://doi.org/10.1002/eet.1633

Satria, A., Matsuda, Y., & Sano, M. (2006). Questioning community based coral reef management systems: case study of awig-awig in Lombok, Indonesia. *Coastal Management*, *34*(1), 99–118. https://doi.org/10.1080/08920750500364879

Sowman, M., & Sunde, J. (2018). Social impacts of marine protected areas in South Africa on coastal fishing communities. *Ocean and Coastal Management*, *157*, 168–179. https://doi.org/10.1016/j.ocecoaman.2018.02.013

Syahputra, F. (2018). Community surveillance: How to incorporate customary community in monitoring marine area (study case Panglima Laot in Aceh). In *Iop Conference Series Earth and Environmental Science* (Vol. 216, Issue 1). https://doi.org/10.1088/1755-1315/216/1/012036

Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E. H., Nayak, P. K., & Badjeck, M. C. (2014). Small-scale fisheries through the wellbeing lens. *Fish and Fisheries*, *15*(2), 255–279. https://doi.org/10.1111/FAF.12016;CTYPE:STRING:JOURNAL

Wilson, C., & Linkie, M. (2012). The Panglima Laot of Aceh: A case study in large-scale community-based marine management after the 2004 Indian Ocean tsunami. *Oryx*, *46*(4), 495–500. https://doi.org/10.1017/S0030605312000191